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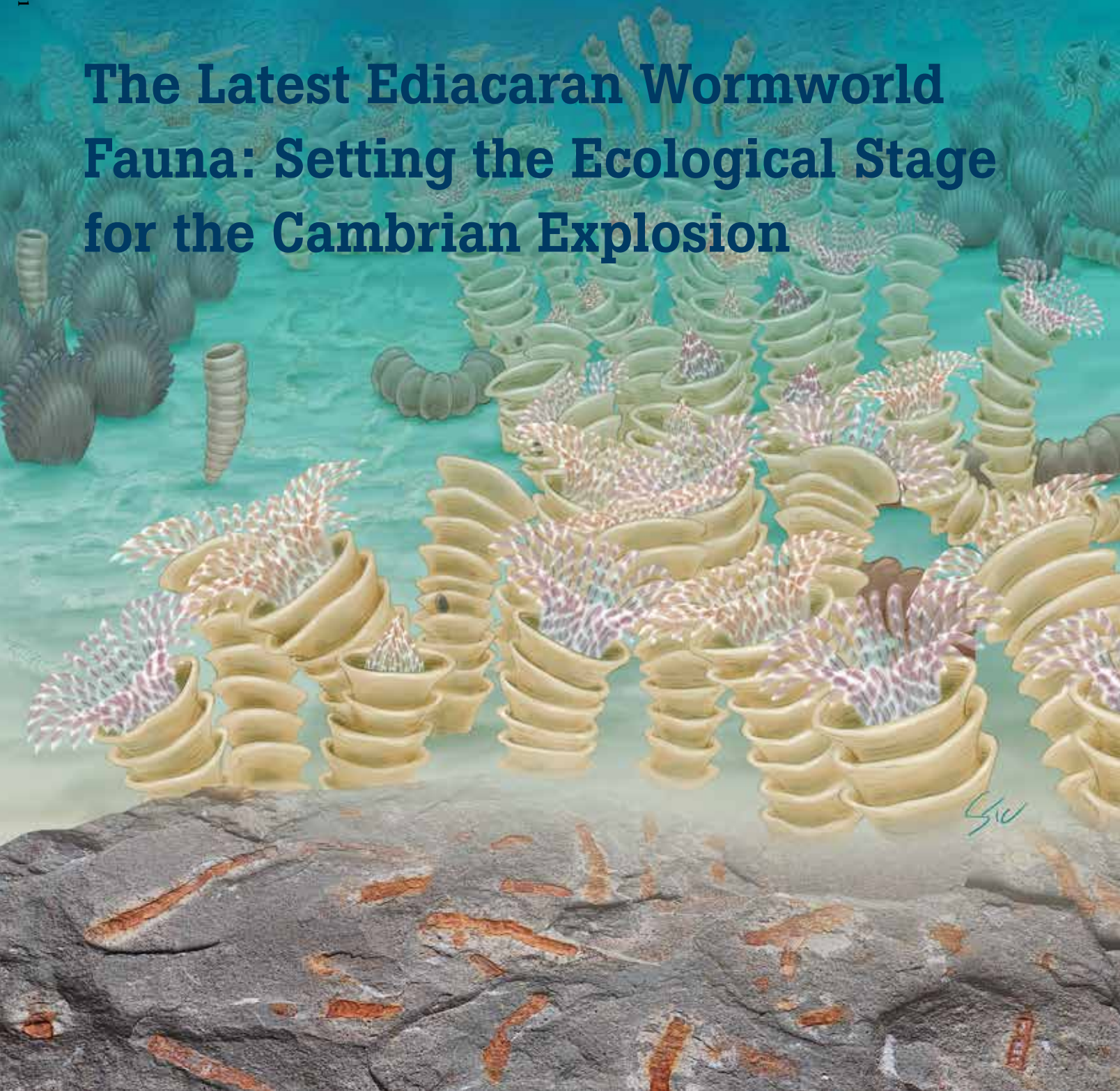

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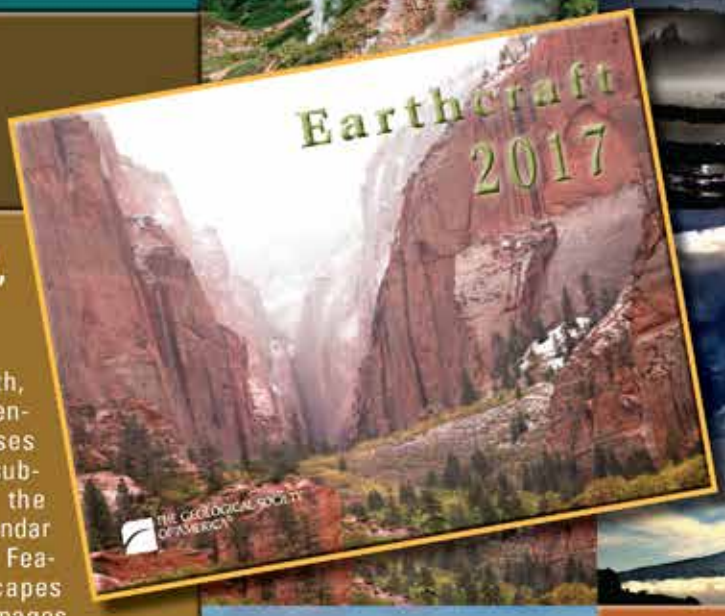

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NOVEMBER 2016 | VOLUME 26, NUMBER 11

Featured Article

SCIENCE

Cover: Illustration of shallow sea-floor ecosystem in the terminal Ediacaran period, dominated by vermiform taxa. Included here are conjectural reconstructions of *Cloudina, Gaojiashania, Wutubus, Corumbella, Namacalathus, Ernietta,* and horizontal/near-surface burrows, in addition to *Swartpuntia* and nondescript frondose Ediacarans in the distance. Slab photograph in the foreground from the Gaojiashan Lagerstätte with numerous pyritized (now oxidized) *Conotubus* tubes. Artwork kindly provided by Stacy Turpin Cheavens (Dept. of Orthopaedic Surgery, University of Missouri). See related article, p. 4–11.

GSA News

The Latest Ediacaran Wormworld Fauna: Setting the Ecological Stage for the Cambrian Explosion

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ABSTRACT

As signposted by the fossil record, the early Cambrian period chronicles the appearance and evolutionary diversification of most animal phyla in a geologically rapid event, traditionally termed the Cambrian Explosion. The uniqueness of this event pleads for a cause, and over the years, numerous biotic and abiotic factors have been offered as possible triggers. Many such explanations, however, either fail to correspond in time or do not provide a functional mechanism to explain the evolutionary pattern of animal diversification. We support the notion that a series of requisite biotic and abiotic events ushered in the Cambrian Explosion, wherein each event was necessary for the implementation of later events but did not guarantee their occurrence. The evolution of the terminal Ediacaran vermiform fauna was integral in the construction of the Eltonian pyramid, fostered an escalation of ecosystem engineering and macropredation, and represented a turning point in benthic ecosystems from those governed primarily by competition for space and resources to those also shaped by these novel pressures.

INTRODUCTION

Relative to its mass, the biosphere disproportionately impacts other components of the Earth system. It oxygenates the oceans and atmosphere, regulates global geochemical cycles, and influences rates and patterns of global change. Life leaves distinctive signals in the rock record, and few are more striking than those at the onset of the Phanerozoic—one of the most intensely studied intervals in the geologic record. The Cambrian Explosion—as famously revealed in the Burgess and Maotianshan shales—represents the geologically abrupt (~25 million years [m.y.]) appearance and diversification of nearly all major metazoan phyla. This proliferation of the roots of the animal phylogenetic tree and rapid expansion of morphological complexity was one of the more significant macroevolutionary events in life history and coincided with a variety of global-scale biotic and abiotic changes (Fig. 1; Briggs et al., 1992; Erwin, 2007)—some of which were brought about by metazoan activities, while others elicited a response by metazoans.

Molecular divergence time estimates (e.g., Erwin et al., 2011; Peterson et al., 2008) suggest that the last common ancestor of all animals evolved in the Cryogenian (ca. 800 Ma; although see dos Reis et al., 2015, for caveats). The earliest interpreted stem-group animals, however, are the ca. 600 Ma Doushantuo embryo-like microfossils (Chen et al., 2014a; Yin et al., 2016), leaving a 200-m.y. interlude between the fossil and molecular records. This hiatus between the estimated origin of Metazoa and their first appearance in the fossil record highlights the growing realization that the earliest stages of animal diversification were neither truly Cambrian nor explosive—with the phylogenetic origin of animals temporally removed from their morphological and ecological diversification by a long fuse (e.g., Conway Morris, 2000; Xiao, 2014). In this case, the significant lag between the establishment of the developmental toolkits necessary for the origin of novelty and their later implementation and ecological success can perhaps be attributed to the uniqueness of newly developing animal ecosystems. Between the ignition of the fuse and the subsequent evolutionary boom, three major eco-environmental feedbacks (see Erwin et al., 2011) arose that helped to pave the way for the Cambrian Explosion: (1) linkages between the pelagic and benthic ecosystems; (2) expansion of ecosystem engineering; and (3) metazoan macropredation. These feedbacks are explored herein in the context of the terminal Ediacaran fossil record of vermiform organisms. This "wormworld" biota—comprised of various tubicolous body fossils (Figs. 2A–2C), such as the cloudinids, and increasingly complex vermiform ichnofossils (Figs. 2D–2F)—critically occupied a fundamental phase shift from competition- to predation-governed marine benthic ecosystems.

BUILDING THE ELTONIAN PYRAMID

Competition and Nutrient Acquisition

The classic Ediacara biota were unheralded in life history, emerging ca. 578 Ma with new and complex multicellular morphologies unlike anything seen before (Narbonne, 2005). While some of these sessile and epibenthic curiosities have been posited as stem-group animals (e.g., Budd and Jensen, 2015), for the most part they lack convincing metazoan synapomorphies, leaving their positioning within the tree of life unresolved. These fossils, however, do provide clues as to how Ediacaran ecosystems

GSA Today, v. 26, no. 11, doi: 10.1130/GSATG265A.1.

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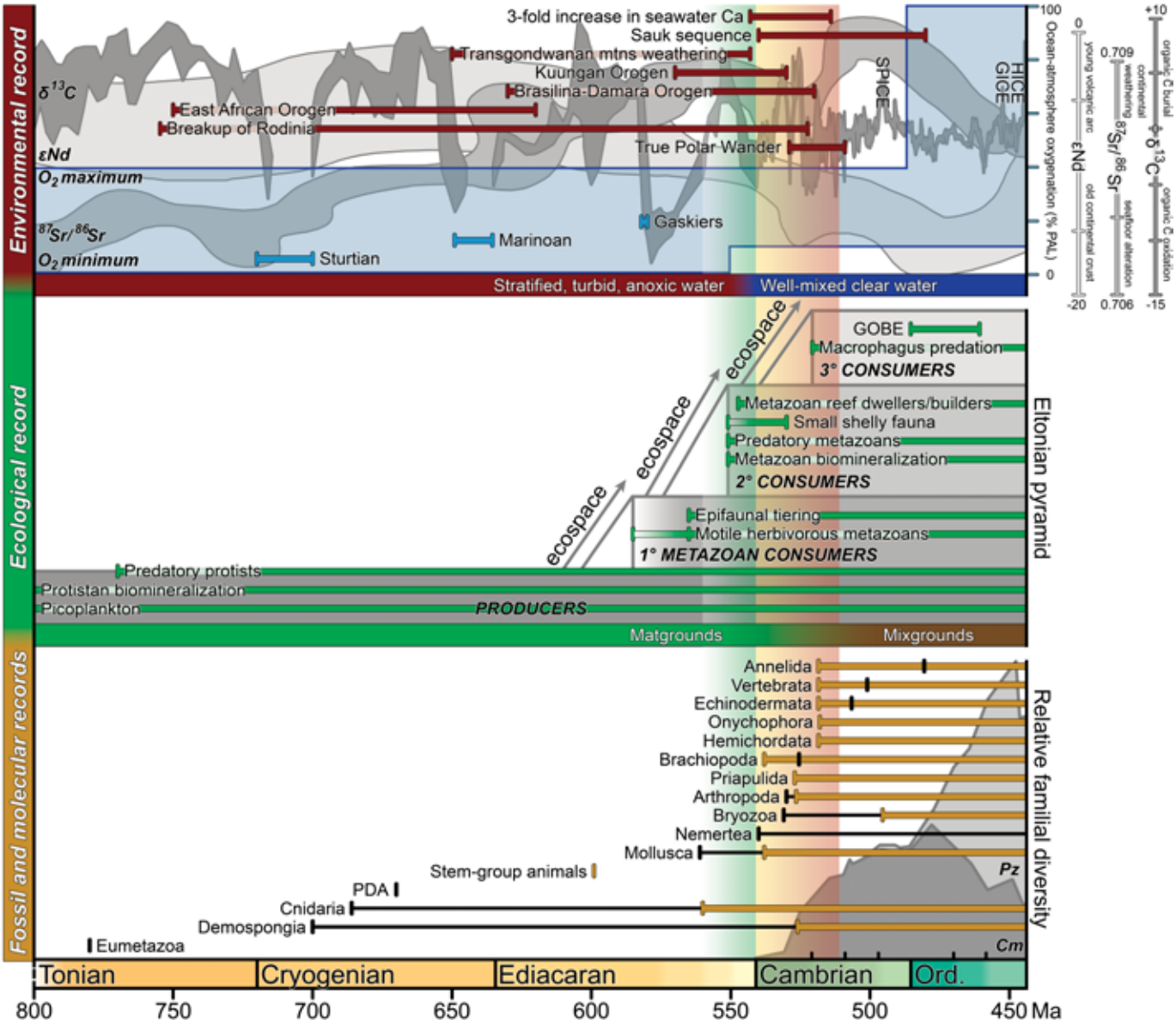

Figure 1. Compilation of temporally associated significant events and records during the Neoproterozoic–Paleozoic transition. From bottom to top: (i) fossil (yellow bars—first appearance) and molecular (black bars—reported divergence estimates; Erwin et al., 2011) records superimposed on the Cambrian and Paleozoic faunas of Sepkoski (1981); (ii) ecological record (green bars) indicating first appearances of important behaviors/events overlain on gray rectangles comprising the Eltonian pyramid and diagrammed after megatrajectories of Knoll and Bambach (2000); and (iii) environmental record of major Earth system events (light blue bars—Snowball Earth glaciations; maroon bars—orogenies and other events), with ocean-atmosphere oxygenation data (blue-gray, Sperling et al., 2015), εNd (light gray, Keto and Jacobson, 1988) and $^{87}Sr/^{86}Sr$ estimates (mid-gray, Maloof et al., 2010), and the $\delta^{13}C$ record (dark gray, Saltzman and Thomas, 2012). The Cambrian Explosion is indicated by the yellow-orange column, and the temporal expanse of the wormworld fauna by the green column. GICE—Guttenberg Carbon Isotope Excursion; GOBE—Great Ordovician Biodiversification Event; HICE—Hirnantian Carbon Isotope Excursion; PDA—protostome-deuterostome ancestor; SPICE—Steptoean Positive Carbon Isotope Excursion.

functioned. For instance, vertical tiering in fossil communities at Mistaken Point, Canada, highlights the importance of competitive nutrient acquisition from the seawater (Clapham and Narbonne, 2002; Ghisalberti et al., 2014). Filter feeding was likely well established, as evidenced by putative Cryogenian sponges (Maloof et al., 2010, though see Antcliffe et al., 2014) and less contested Ediacaran sponges (Yin et al., 2015)—which, along with the evolution of zooplankton (Butterfield, 1997), served to deliver waste organics to the substrate, providing a direct link between pelagic and benthic ecosystems. Nonetheless, while some Ediacaran taxa may have gained nutrients through suspension feeding (Rahman et al., 2015), osmotrophy (Laflamme et al., 2009), or saprotrophy (the latter two of which are rare to absent in extant Metazoa; Sperling and Vinther, 2010), the feeding strategies of most Ediacaran taxa remain indeterminate due to the abundance of non-analogue body plans. It is likely, though, that

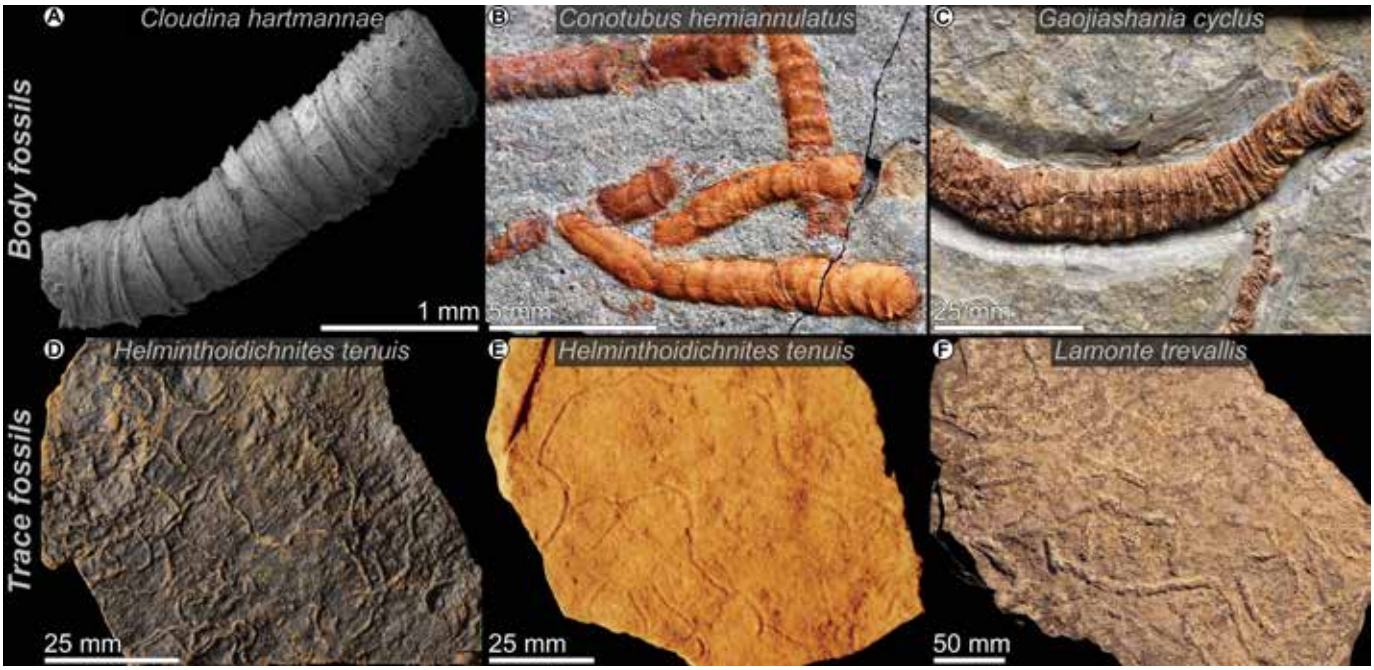

Figure 2. Representative wormworld body (A–C) and trace (D–F) fossils. (A–C) Tubular representatives from the Gaojiashan Lagerstätte, China; (D) surficial traces with micropustular elephant skin-like textures, Blueflower Formation, Canada (courtesy of C. Carbone); (E) surficial traces, Ediacara Member, Rawnsley Quartzite, South Australia (courtesy of L. Buatois); (F) complex undermat traces, Dengying Formation, China (courtesy of M. Meyer).

evolution in these sessile epibenthic ecosystems would have been driven by competition as reflected by niche partitioning and functional morphology in sessile communities (Bottjer and Ausich, 1986; Clapham and Narbonne, 2002).

Benthos Modification

Set against this competitive landscape, the first motile members of the second trophic tier (1° consumers) began to exploit widespread microbial mats, sedimentary organic carbon, and possibly the decaying material of fallen Ediacarans (Budd and Jensen, 2015). Metazoan trace fossils from the last ~25 m.y. of the Ediacaran period (ca. 565–541 Ma): (1) display behavioral evolution of the second trophic tier (Carbone and Narbonne, 2014; Chen et al., 2013; Meyer et al., 2014); (2) signify the development of sensory-muscular activity (Gehling et al., 2014; Jensen et al., 2005); (3) provide tangible evidence for both grazing and deposit feeding (Carbone and Narbonne, 2014); and (4) confirm a burgeoning and sophisticated motile component to benthic ecosystems, marking an important expansion of ecosystem engineering behaviors. Even with increasing species richness and ecosystem complexity through early Ediacaran assemblages (Shen et al., 2008; Xiao and Laflamme, 2009), the diversity of nascent bioturbating behaviors was restricted, possibly by benthic oxygen levels (Fike et al., 2006; Sperling et al., 2015) or by sharp sediment redox gradients maintained by the, at the time, still pervasive microbial blanketing of the shallow seafloor (Hagadorn and Bottjer, 1999). The complexity of traces in the ichnofossil record grew (Carbone and Narbonne, 2014), however, perhaps foreshadowing the coming revolution in the abiotic and biotic structure of the benthos (Bottjer et al., 2000). The redistribution of nutrients between the water column and the substrate in the latest Ediacaran, a significant consequence of bioturbation, could have resulted from many different shifts in biotic interactions. Notably, the expansion of the pelagic realm to accommodate larger mesozooplankton (Butterfield, 2009) would favor filter-feeding strategies over the passive diffusion of organics in osmotrophy. Furthermore, the innovation of metazoans with one-way guts (i.e., bilaterians) would have packaged nutrients in the form of fecal pellets, thus efficiently transporting nutrients from the water column to the substrate (Sperling et al., 2011) and benefiting detritivores at the cost of those reliant on dissolved nutrients. Nonetheless, there remains a delay between the emergence of surficial grazing behaviors and significant sediment mixing from vertical bioturbation (Tarhan et al., 2015). With an ostensibly limitless food source of microbial substrates (which persist into the Cambrian; Buatois et al., 2014) and the lack of macroscopic predation, there may not have been sufficient ecological stressors to drive metazoans into less hospitable or more physiologically challenging infaunal life modes. Nonetheless, the introduction of infaunalization and increasing intricacy of horizontal burrow networks at the Ediacaran-Cambrian transition (Hagadorn and Bottjer, 1999; Jensen, 2003) signaled a keystone development in ecosystem engineering, and began to propagate a shift—albeit protracted (Tarhan et al., 2015)—in the physical and chemical properties of the substrate.

Ecological Antagonism

The first occurrence of metazoan predation appears in the terminal Ediacaran (ca. 550–541 Ma), in concert with several other firsts, including metazoan biomineralization and the occupation of biohermal ecological niches (Cai et al., 2014; Penny et al., 2014; Wood and Curtis, 2015). The earliest mineralizing taxa appear in several contemporaneous units, such as the Nama Group, Namibia (Grotzinger et al., 2000); the Ara Group, Oman

(Amthor et al., 2003); the Gaojiashan Lagerstätte, China (Cai et al., 2010; Cortijo et al., 2015a); Estena River, Spain (Cortijo et al., 2010; Cortijo et al., 2015b); and elsewhere (Hagadorn and Waggoner, 2000; Hofmann and Mountjoy, 2001; Zhuravlev et al., 2012). The best known from this group is the terminal Ediacaran index fossil and one of the first biomineralizers, *Cloudina* (Fig. 2A). The cloudinids and similar taxa (Figs. 2B and 2C) remain phylogenetically enigmatic because of a lack of preserved soft-tissues (Schiffbauer et al., 2014); although, based on tube morphologies and growth patterns, these organisms have drawn comparisons with modern worms or anthozoan corals (Cai et al., 2014; Hua et al., 2005; Penny et al., 2014). While the presence of worm-like animals was previously established from the ichnofossil record, the cloudinids and similar taxa provide the first vermiform body fossils. Perhaps more importantly, the addition of 2° consumers of the third trophic tier is marked by site-/taxon-specific and size-selective predatory drillholes in the biocalcified tubes of *Cloudina* (Bengtson and Yue, 1992; Hua et al., 2003). This novel feeding strategy would have presented a severe ecological pressure; indeed, ~20% of individuals in some populations were drilled by predators (Hua et al., 2003). In addition to the added trophic level, the presence of these latest Ediacaran drillholes signifies three major evolutionary themes: (1) prey selectivity indicates the neural sophistication of the predator; (2) failed attempts (incomplete drillholes) demonstrate that mineralized exoskeletons impeded predators; and (3) predation pressure may have played a significant role in the proliferation of mineralized skeletons. With such a sophisticated predatory mechanism recorded in the tubes of *Cloudina*, it is likely that the origin of predation preceded this first occurrence. Given the similarities between drillholes in *Cloudina* and modern shelly prey, the organism responsible for Ediacaran drillholes was mechanically, if not phylogenetically, comparable to Phanerozoic drilling gastropods using a radula-like structure to rasp the prey skeleton. With *Kimberella* interpreted as a radula-bearing stem-group mollusk (Gehling et al., 2014), comparable physiological machinery for drilling predation may have already been in place ~10 m.y. before the first drillholes appear in the fossil record. However, from this fossil first occurrence and with improved preservation as a consequence of taphonomically robust biominerals, the record of macropredation is observed to increase in both frequency and predator/prey diversity well into the Phanerozoic (Huntley and Kowalewski, 2007).

THE IMPORTANCE OF THE WORMWORLD

While local facies and environmental controls have been shown to be of importance to understanding and appreciating the ecological contexts of classic Ediacaran communities (Gehling and Droser, 2013), currently available diversity data imply that the terminal Ediacaran is characterized by a considerably reduced Ediacara biota (Boag et al., 2016; Darroch et al., 2015; Shen et al., 2008; Xiao and Laflamme, 2009). Concurrently, eumetazoan vermiform body fossils and bilaterian trace fossils show an increase in diversity (Cai et al., 2014; Cai et al., 2011; Carbone and Narbonne, 2014; Wood and Curtis, 2015), offering glimpses into more modern ecosystem dynamics. The coupling of these records—the expansion of the wormworld fauna and diversity loss of classic Ediacarans (Laflamme et al., 2013; Xiao and Laflamme, 2009)—suggests that vermiform metazoans may have played a role in displacing preexisting biotic components in the terminal Ediacaran marine ecosystems (Darroch et al., 2015; Darroch et al., 2016). However, much work remains to (1) establish what (if any) biotic interactions occurred between these two broad groups; and (2) determine how many Ediacaran morphoclades actually represent metazoan lineages, such that further discussion does not become mired in artificial and polyphyletic groupings (MacGabhann, 2014).

Contrary to the influence of competition in shaping Ediacaran communities, vermiform organisms witnessed an expansion in ecological strategies through the onset of three new life modes: (1) macropredation (Bengtson and Yue, 1992; Hua et al., 2003); (2) reef-building (Penny et al., 2014); and (3) motile grazing (Carbone and Narbonne, 2014). While it can be difficult to quantify competition in fossil communities, evidence for niche partitioning can be indicated by over-dispersion of body size (e.g., Huntley et al., 2008) and spatial arrangement (Clapham and Narbonne, 2002; Ghisalberti et al., 2014). In a sessile epibenthic ecosystem relatively free of predation and with few motile organisms, the availability of space and nutrients on and above the matground must have been limiting factors shaping community structure. In contrast, nutrient acquisition was presumably non-limiting for those few mobile organisms feeding on the microbial substrate (Tarhan et al., 2015), at least early in the development of motility and herbivory. Thus, it is likely that the evolutionary importance of competition for resources was not equal across environments and trophic tiers, and that factors such as predation and disturbance were more influential in shaping wormworld communities. Escalation, organisms responding evolutionarily to their enemies (Vermeij, 1987), places an evolutionary premium on predators rather than competitors. Consequently, counter to the largely sessile guilds of the Ediacaran, the evolution of motility and bioturbation, grazing by 1° consumers, and predation by 2° consumers, marks the most significant difference between earlier Ediacaran and Cambrian ecosystems (Butterfield, 2007). The wormworld fauna thus captures an explicit tipping point where predation and disturbance became dominant ecological factors.

We suggest that the wormworld fauna and the ecological complexities that they ushered in led to the displacement and eventual biotic replacement (Darroch et al., 2015) of the classic Ediacara-type communities. These vermiform organisms were equipped with innovative adaptations of active feeding modes and sediment restructuring capabilities, biomineralized armament against predators, generalist and opportunist adaptability to varying substrates (Cai et al., 2014), sexual and asexual reproduction for enhanced dispersal (Cortijo et al., 2015a), resilience to environmental disturbance (Cai et al., 2010), and presumably high fecundity and rapid achievement of sexual maturity. The wormworld organisms were likely more adept at attaining ecological success over the comparatively ineffectual occupation of niches by the classic Ediacara biota. Indeed, while classic Ediacarans show an apparent decline approaching the Ediacaran -Cambrian transition (Darroch et al., 2015), several reports indicate that at least some terminal Ediacaran tubicolous organisms (including *Cambrotubulus, Platysolenites, Cloudina,* and *Sinotubulites*) may traverse this boundary (e.g., Kontorovich et al., 2008; McMenamin, 1985; Rogov et al., 2015; Yochelson and

Stump, 1977). In addition, the advent of predation added selective pressure to drive infaunalization (Dzik, 2007), expanding bioturbation vertically, reducing the availability of matground substrate upon which many Ediacara organisms grew, and advancing the ecosystem engineering feedback. The gregarious habit of some vermiform taxa may have additionally served as an antipredatory strategy and propagated ecosystem engineering via sediment baffling. It is important to note that the suggested mass extinction of the Ediacara biota in the context of our wormworld model is an ecologically driven event rather than an environmentally driven cataclysm akin to more recent (Phanerozoic) mass extinctions, and thus may have been comparatively protracted—as evidenced by Ediacara holdovers in the early Cambrian (Conway Morris, 1993; Hagadorn et al., 2000; Jensen et al., 1998). Nonetheless, whereas the static synecology and comparatively passive feeding modes of the classic Ediacarans had once emplaced a boundary on evolutionary possibility, the successful expansion of innovative traits of herbivory and carnivory, and their causal ties to infaunalization, reef-building, and biomineralization, permitted a new scaling of this bounding "right wall" (sensu Knoll and Bambach, 2000) as realized by the organisms of the wormworld fauna. Over time, the evolutionary breakthroughs conveyed by these neoteric organisms, including novel strategies, behaviors, and physiologies, increased the heterogeneity of benthic ecosystems, allowed for enhanced exploitation of resources, and established insurmountable increases in ecospace that ultimately signaled the curtain call for the Ediacara-type guilds.

THE SEARCH FOR A TRIGGER

The stark pattern of the Cambrian Explosion has steered many to identify a "trigger" (see reviews by Conway Morris, 2000; Erwin et al., 2011; Marshall, 2006; Xiao, 2014; Zhang et al., 2014). Previously proposed triggers can be categorized into three broad types (Erwin, 2015b): genetic, ecological, and environmental. For instance, a few examples include [genetic] the origin of the genetic toolkit for animal body plans; [ecological] bioturbation, predation, roughening of fitness landscapes, and adaptive radiation following an end-Ediacaran extinction; and [environmental] the Snowball Earth glaciations, increasing ocean oxygenation, and other dramatic seawater chemistry changes. While this is not the appropriate forum for an exhaustive discussion of triggers, we will briefly review three recent but distinct iterations of trigger hypotheses, centered on changing ocean chemistry, ties between oxygenation and carnivory, and nutritional incentive.

The Great Unconformity

Emphasizing the role of global environmental change, Peters and Gaines (2012) suggest that the Sauk transgression over the Great Unconformity flooded the continents and delivered excess ions to the ocean, necessitating a physiological response to intracellular calcium toxicity in the form of metazoan biomineralization. This evolutionary milestone, in conjunction with the expansion of shallow marine environments, promoted the explosive radiation of marine animals. The dominance of non-biomineralizing taxa in Burgess Shale–type biotas (Chen and Zhou, 1997; Conway Morris, 1986), however, implies that the Cambrian Explosion would have occurred with or without biomineralization (Butterfield, 2003). The temporal linkage of metazoan biomineralization and diversification begs the question as to whether they can be explained by the same trigger or are instead compounded causes and consequences of the immediately preceding and supervening events. Comparably, the initiation of the Mesozoic plankton radiation and contemporaneous expansion in planktic biomineralization (Knoll, 2003) proceeded without the presence of a global unconformity, echoing a disconnect between the oceanic influx of ions and evolutionary radiation.

The Hypoxia Hypothesis

Exploring the relationship between oxygen minimum zones and polychaete worm-feeding ecology in modern oceans as an analogue for terminal Ediacaran benthic communities, Sperling et al. (2013) propose an eco-environmental trigger. Their work emphasizes a series of requirements. First, an increase from suboxia to hypoxia (and stabilization of minimum oxygen content) removed a key limiting factor upon animal body size and permitted the establishment of more oxygen-demanding motile life modes. This resulted in increasing trophic complexity from expanding diversity and abundance of carnivorous taxa—and ultimately drove the evolutionary arms race resulting in the Cambrian Explosion.

The Savannah Hypothesis

While the former two hypotheses note the importance of predation and antipredatory (as presumed from the importance of biomineralization) strategies, the Savannah hypothesis of Budd and Jensen (2015) posits that the diversification of metazoan tracemakers was driven by resource heterogeneity from patches of post-burial Ediacara biota. Shallow burrowing behavior was the key evolutionary innovation that allowed exploitation of this resource. In conjunction with environmental heterogeneity and patch dynamics, such burrowing would have spurred the radiation of the bilateria—previously also tied to the advent of hard parts (e.g., Bengtson, 2004).

While there are broad similarities between the Savannah model and our proposed wormworld model, there are some key differences, which offer two testable hypotheses: (1) the majority of classic Ediacara-type organisms are interpreted by Budd and Jensen (2015) as stem metazoans and, thus, there would have been no biotic crisis among classic Ediacarans prior to the Cambrian (contra Laflamme et al., 2013); and (2) there should be clear positive spatial and temporal associations between Ediacara biota and trace fossils supporting the proposition that early bilaterians exploited decaying Ediacarans as a food source. Regarding the first prediction, on local-, regional-, and global-scales, latest Ediacaran fossil communities have been shown to be depauperate with respect to many iconic and readily preserved forms (Boag et al., 2016; Darroch et al., 2015; Xiao and Laflamme, 2009), supporting an extinction/biotic replacement scenario. With respect to the second prediction, available data suggest that direct associations between Ediacara-type organisms and bilaterian trace fossils are rare. Metazoan traces occur most frequently as isolated monospecific assemblages lacking Ediacara biota, suggestive of niche partitioning (Darroch et al., 2016). In China, vermiform trace fossils are found in the same stratigraphic sections as Ediacara biota, but only sometimes on the same beds, suggesting that their co-occurrence within communities was limited or that the classic Ediacara-type forms were relatively

intolerant to bioturbation (Chen et al., 2014b). This may indicate that direct interactions between Ediacara organisms and motile vermiform bilaterians became common only when forced by the diversification of motile animals and expansion into new ecospace. Possibly capturing a snapshot of this changeover, the Wood Canyon Formation in the southwestern Great Basin of the United States preserves traces, a diverse tubicolous fauna, and classic Ediacarans in the same stratigraphic section (Hagadorn and Waggoner, 2000).

SUMMARY—A SERIES OF SWITCHES?

These three trigger hypotheses, among many others, illustrate the complexity of the Cambrian Explosion and the many factors that must be considered in its explanation—exemplifying why the identification of a lone trigger has been a thorny process. Revisiting the three categories of triggers, the genetic toolkit for animal body plans is a requirement for the Cambrian Explosion, but its likely Cryogenian origin demonstrates that it was not an immediate trigger (Erwin, 2015a; Tweedt and Erwin, 2015). Purely environmental triggers correlate with the timing of the Explosion but cannot explain the evolutionary pattern, which is outwardly better explained by ecological triggers that create novel evolutionary opportunity (Butterfield, 2009; Sperling et al., 2013). With regard to the discussed hypotheses, it is important to note their overlap. Both the Great Unconformity and Hypoxia hypotheses involve predatory and antipredatory strategies, and both the Hypoxia and the Savannah hypotheses emphasize the role of vermiform organisms (or more broadly, bilaterians) in increasing predation, burrowing, and scavenging behaviors (with implications for neurological development; Budd and Jackson, 2016). The wormworld model underscores the role of the terminal Ediacaran vermiform fauna in significantly expanding the second trophic tier, intensifying ecosystem engineering behaviors, and establishing antipredatory mechanisms. In conjunction, these developments commenced a suite of antagonistic coevolutionary feedbacks between 1° and 2° consumers (i.e., the Red Queen hypothesis; Van Valen, 1973) amid the emerging Phanerozoic-style ecological landscape, ultimately setting the stage for the Cambrian Explosion.

In sum, the Cambrian Explosion appears to be but a part of an extended series of molecular, ecological, and environmental revolutions spanning the late Neoproterozoic to early Paleozoic. Therefore, the search for a lone trigger, by nature, does not account for this complexity; instead, integrated constructs accounting for taxonomic, morphological, and ecological expansion facilitated by environmental changes and genetic toolkit exaptations should provide more inclusive explanations for the Cambrian Explosion. As such, we view the events of this interval as a series of switches, wherein each switch served to fundamentally alter and increase the complexity and functionality of ecosystems. We view the step-wise building of the Eltonian pyramid, in large part owing to the ecological and evolutionary novelties conveyed by the rise of the wormworld fauna, as prime examples of these switches—but only a part of a series of interconnected switches. These other requisite steps must have included the genetic toolkits for bilaterianism, the linkage of the pelagic and benthic ecosystems, the increase of oxygen to support animal metabolisms, and the creation of new habitats through both biotic processes and those related to contemporaneous supercontinent breakup—which collectively enabled, but did not guarantee, the rise of animals yet to come.

ACKNOWLEDGMENTS

For D.L.S. We thank G. Dickens and three anonymous reviewers for constructive feedback, and we are grateful for the conversations with numerous colleagues that helped shape our thoughts on this topic.

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Manuscript received 24 Sept. 2015; accepted 16 May 2016.

2016–2017 Richard H. Jahns Distinguished Lecturer

Scott A. Anderson was named the Richard H. Jahns Distinguished Lecturer for 2016–2017. This lectureship was jointly established in 1988 by the Association of Environmental & Engineering Geologists (AEG) and the Environmental and Engineering Division of the Geological Society of America (GSA) to increase student awareness about applied geology.

Anderson is the Geotechnical Engineering Technical Services team manager for the Federal Highway Administration's (FHWA) Resource Center. He leads a national team of geotechnical engineers that assist state and local transportation agencies through technical assistance, training, and deployment of new technologies. Prior to joining FHWA, he worked in positions from staff geologist to senior consulting engineer and landslide technology leader for a major A/E design firm and spent four years as an assistant professor of civil engineering at the University of Hawaii. He earned bachelor's and master's degrees in engineering geology from the University of Colorado at Boulder and Colorado State University, and master's and doctorate degrees in civil engineering from the University of California at Berkeley. He is a licensed engineer and practicing engineering geologist with over 30 years of experience and approximately 100 publications and invited presentations. He has grown and lived in many places along a general path from Boston to Honolulu and now makes his home in Colorado, where he enjoys all of the outdoor time he can get.

Interested institutions can contact Anderson at scott.anderson@dot.gov to give one or more of the following lectures:

Natural Hazards, Risk, and the Resilience of Transportation Infrastructure

Natural hazards pose a risk to transportation infrastructure that's often tied to geology. Whether the hazard is from weather and climate, gravity and slopes, or seismic activity, for example, the expression of the hazard in terms of its potential consequence is a function of geologic setting. Not surprisingly, the practice of engineering geology has long had a focus on hazard characterization. This is good because hazard is an important input to risk, and risk is what needs to be measured and managed for the emerging need to optimize performance of transportation infrastructure. One way of managing risk is through building in resilience to natural hazards. How to do this, and to what extent it should be done, are important questions that open up newer areas of practice for the engineering geologist.

Solid as a Rock: How Engineering Geology Relates to Transportation Asset Management

Highway systems were built over a short period of time and to an envisioned design life that is expiring. Owners of transportation infrastructure are finding a pressing need to get the most of what they have and to build new inventory with this kind of thought in mind. This requires strategies for management but it also requires a clear look at what type of performance is expected, and what is actually needed. Settlement, heave, slope movements, longevity under the influence of scour, and corrosion are some of the ways this performance can be measured for structures of soil and rock. Change happens, and relatively few things are "solid as a rock."

Future Opportunities for Site and Event Characterization Using Remote Sensing and Social Media

The stereoscope and planimeter were once the office tools of the engineering geologist, just as the Brunton compass and hand level were in the field. The planimeter, Brunton, and hand level all allowed for measurements to be made, which was good, but the stereoscope allowed visualizing more than could be seen with the naked eye, and that was great. Today, remote sensing technologies help with all of this, and the engineering geologist needs to be as versed in them as they once were with stereoscopes and Bruntons. Platforms are well established and yet still have tremendous untapped potential. Skills for back-calculating what must have happened based on evidence left after an event will always be valuable, but so will skills for back-calculating based on comments, images, and videos posted by the public. Where once we could only imagine what happened, now we can often see it. Beyond the excitement of this, there is the potential to learn even more about earth processes.

Technical Observations from the 2014 Oso (SR 530) Landslide Reconnaissance

The Oso Landslide struck the community of Oso, Washington, USA, on Saturday, 22 March 2014, at approximately 10:37 a.m. on a clear, sunny day. It initiated within an approximately 200-m-high (650 ft) hillslope composed of unconsolidated glacial and colluvial deposits and transitioned to a catastrophic debris flow that rapidly inundated a neighborhood and, traveling more than a kilometer (0.6 mi), crossed a state highway (SR 530). Forty-three people in the neighborhood and on the highway lost their lives. There are lessons of all types to be learned from this disaster and these lessons will be explored—with special emphasis on the technical ones.

2017 Birdsall-Dreiss Distinguished Lecturer

Ed Harvey
is the supervisory hydrologist and chief of the U.S National Park Service (NPS) Water Resources Division (WRD) located in Fort Collins, Colorado. He received his B.S. in geology/geophysics from Olivet Nazarene University (1986), his M.S. in hydrogeochemistry from Purdue University (1990), and his Ph.D. from the University of Waterloo in Waterloo, Ontario, Canada (1996). Immediately after graduation, Harvey took a joint position at the University of Nebraska–Lincoln (UNL), where he was a research hydrogeologist with the Conservation and Survey Division (the state's geologic and water survey) and a professor of hydrologic sciences with the School of Natural Resources (SNR). At UNL, Harvey's research focused on groundwater-dependent ecosystems, groundwater–surface water interaction, and using geochemical and isotope applications methods to characterize regional groundwater flow systems.

More about Harvey and a list of his publications can be found at **https:/www.nps.gov/orgs/1439/forrest-ed-harvey.htm.**

In January 2013, Harvey left his academic position to assume his current role as NPS WRD chief. WRD provides Park Service –wide leadership for the preservation, protection, and management of water and aquatic resources; offers technical assistance to all 400+ national park units; leads and supports development of NPS water resource initiatives, guidelines, and policies; and provides disciplinary and policy support to the Washington, D.C., offices and Park Service leadership staff. More information about WRD can be found at **https://www.nps.gov/orgs/1439/index.htm.**

Harvey has served the broader geological and hydrogeological community in various capacities. He is a Fellow of the Geological Society of America (GSA), is presently a GSA Councilor, and served as a GSA books science editor from 2011 to 2014. Harvey chaired the GSA Hydrogeology Division from 2010 to 2011, having previously served as vice chair, newsletter editor, website administrator, and technical program chair for the 2009 meeting in Portland. In 2008, Harvey received the GSA Hydrogeology Division's George Burke Maxey Distinguished Service Award. Harvey has also been an associate editor for *Ground Water* and *Hydrogeology*.

Interested institutions can schedule a visit by contacting Ed Harvey at forrest_harvey@nps.gov, or by completing a request form at the GSA Hydrogeology Division Birdsall-Dreiss website (**community.geosociety.org/hydrodivision/aboutus/birdsall-lectures**). If emailing, please provide your institution name, a contact person's email and phone, and potential dates for when you would like to host the lecture. Harvey will present one lecture on the topic of National Park water resources described below.

GSA's Hydrogeology Division is particularly interested in including liberal arts colleges in the itinerary. The Division pays transportation expenses, and the host institution is expected to provide local accommodations.

Water Resource Management in the U.S. National Park Service

On 25 August 1916, President Woodrow Wilson signed the act creating the National Park Service, a new bureau in the Department of the Interior. This "Organic Act" directed the Park Service "to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." This conservation, enjoyment, and protection mandate also applies to water resources within parks.

Unlike most park resources that are located largely within park boundaries or are completely under the management control of the National Park Service, park water resource issues and management often involve greater challenges. These challenges arise from the fact that surface water and aquifer boundaries often extend beyond park boundaries and because the legal authority to allocate and manage water resources typically resides with the states. Thus, parks often need to consider resource issues at a larger landscape, or seascape, scale and manage collaboratively with neighbors and partners to protect, manage, and restore water resources. In addition, water resource expertise is not always available within a park, resulting in the need to partner with other agencies, universities, "friends" groups, or regional and national offices. Lastly, many park water resource issues have broader legal, political, socioeconomic, and cultural implications requiring park managers to consider more than just the science alone when making a water resource management decision.

The lecture, using a series of examples from various parks across the United States, will explore the process of how parks identify water resource needs, issues, and concerns, and how they develop and apply the necessary scientific information needed to make water resource management decisions. Specific challenges to decision making and park water resource management will be presented and explored (e.g., trans-boundary issues, partnership building, scientific uncertainty, funding and personnel/expertise, and making science-based decisions that also appropriately consider the legal, political, socioeconomic, and cultural impacts of the decision). As part of the visit, Harvey also will present future water resource research and management needs in parks and across the nation, present information about engaging in water resources research within parks and advise students on programs for seasonal and permanent employment as a water resource professional within the National Park Service.

2016 Honorary Fellow

GSA is pleased to announce the selection of the Society's 2016 Honorary Fellow: **Bor-ming Jahn,** whose lifetime of research has been devoted to the problems of continental evolution using the principles and techniques of isotope tracers (Sr-Nd-Hf-Pb-O), geochemistry, and geochronology. His studies extend to all continents, but his most significant contribution is in Asia.

Honorary Fellowship is presented to an international geoscientist who has distinguished him or herself in geoscience investigations, promoting environmental awareness, linking science and society, providing notable service to implementing public policy in natural resource managements, or otherwise making outstanding contributions to science. This award was presented at the GSA Awards Ceremony during the 2016 GSA Annual Meeting in September.

Trained as a geochemist, Bor-ming Jahn employs the principles and techniques of elemental and isotope (Sr-Nd-Hf-Pb-O) geochemistry to tackle important issues like the evolution of the upper mantle, continental crust growth, genesis of magmatic rocks (komatiite, basalt, and granitoids), geochemistry of sedimentary rocks, composition of the upper crust, evolution of Archean craton, continental subduction, ultrahigh-pressure metamorphism, geochemistry of loess, and paleoclimate change.

Jahn has made important contributions to the research on the Central Asian Orogenic Belt across China, Russia, and Central Asia. By presenting solid evidence for massive generation of juvenile crust in northern China, Mongolia, Kazakhstan, and southern Siberia (collectively termed the Central Asian Orogenic Belt), he established the region as the world's most important site of juvenile crustal accretion in the Phanerozoic era and challenged traditional ideas about Earth's rate of continental growth. His impressive work in this area has undoubtedly promoted a new field of study and inspired numerous research activities on this subject. In fact, since 1999, published papers related to this new field have grown twentyfold.

Jahn's research on ultrahigh-pressure metamorphic rock has modified the traditional theory of plate tectonics, which held that the continental crust could not subduct. Instead, he has proven that it could subduct to a depth of 100–200 km. His analysis of the chemical composition of loess has provided a greater understanding of research on ancient crust and paleoclimate changes. Jahn's five articles published on this topic have been cited more than 700 times. He also used Sr-Nd isotope data to argue for the continental origin of ultrahigh-pressure eclogites from the Dabie Mountains of China. This work has profound implications for subduction of the continental crust.

Jahn has independently or jointly published more than 200 peer-reviewed academic articles and been cited more than 14,800 times. He was the chief editor of the *Journal of Asian Earth Science*s from 2006 to 2016. And, he was elected as an academician of Academia Sinica for his academic achievements in 2012. He is also a fellow of the Mineralogical Society of America, Geochemical Society, and European Association of Geochemistry.

A preeminent scientist, Jahn received the Chevalier dans l'ordre des Palmes Académiques. He was also awarded the Prestwich Prize by the Geological Society of France in 2013, and the International Prize by the Geological Society of Japan in 2014. Most recently, he was honored with the V.K. Ting Award by the Geological Society of China (Taiwan).

Upcoming Award Deadlines

For details, see the October *GSA Today* or go to **www.geosociety.org/awards/aboutAwards.htm.**

Award nominations: Go to **www.geosociety.org/awards/nominations.htm.**

Fellowship nominations: **www.geosociety.org/members/fellow.htm.**

You can also email GSA Grants and Awards at **awards@geosociety.org.**

2017 GSA Medals and Awards

Nomination deadline: 1 Feb. 2017

- Penrose Medal
- Day Medal
- Young Scientist Award (Donath Medal)
- GSA Public Service Award
- Randolph W. "Bill" and Cecile T. Bromery Award for Minorities
- GSA Distinguished Service Award
- Doris M. Curtis Outstanding Woman in Science Award
- Geologic Mapping Award in Honor of Florence Bascom
- Honorary Fellow

GSA Fellowship

Nomination deadline: 1 Feb. 2017

Elevation to GSA Fellowship is an honor bestowed on the best of our profession at each spring GSA Council meeting. **GSA Fellows** may support two nominees each year but only **one** as a primary nominator, and **GSA members** who are not Fellows may be secondary nominators for up to **two** nominees.

For a listing of other national awards and nomination forms, visit **www.geosociety.org/awards/national.htm**. If you know of an award not listed, please send the details to gsatoday@geosociety.org.

John C. Frye Environmental Geology Award

Nomination deadline: 31 Mar. 2017

In cooperation with the Association of American State Geologists and supported by endowment income from the GSA Foundation's John C. Frye Memorial Fund, GSA makes an annual award for the best paper on environmental geology published either by GSA or by a state geological survey.

2017 Post-Doctoral Research Awards

Application deadline: 1 Feb. 2017

- The **Gladys W. Cole Memorial Research Award** for research on the geomorphology of semiarid and arid terrains in the United States and Mexico is awarded annually to a GSA member or Fellow between 30 and 65 years of age who has published one or more significant papers on geomorphology.
- The **W. Storrs Cole Memorial Research Award** for research on invertebrate micropaleontology is awarded annually to a GSA member or Fellow between 30 and 65 years of age who has published one or more significant papers on micropaleontology.

Learn more about these post-doc research awards at **www.geosociety.org/grants/postdoc.htm.**

OTHER AWARDS

Nomination deadline: 1 Feb. 2017

Submit nominations for the following awards at **www.agiweb.org/direct/awards.html.**

- **AGI Medal in Memory of Ian Campbell for Superlative Service to the Geosciences** recognizes singular performance in and contribution to the profession of geology.
- **The AGI Marcus Milling Legendary Geoscientist Medal** is given to a recipient with consistent contributions of high-quality scientific achievements and service to the Earth sciences having lasting, historic value; who has been recognized for accomplishments in field(s) of expertise by professional societies, universities, or other organizations; and is a senior scientist nearing completion or has completed full-time regular employment.

Congratulations to All the 2016 GSA Division Award Recipients

GSA's primary Division awards were announced in the July 2016 issue of *GSA Today*; they are included again below along with other Division awards presented at this year's annual meeting. Learn more about GSA's specialty Divisions at **www.geosociety.org/divisions.** Read the citations and responses (named awards only) at www.geosociety.org/awards/divisions.htm.

ARCHAEOLOGICAL GEOLOGY DIVISION

Rip Rapp Archaeological Geology Award
Daniel H. Sandweiss, University of Maine

Claude C. Albritton, Jr., Memorial Student Research Award
Justin A. Holcomb, Boston University

Richard Hay Student Paper/Poster Award
Michael Aiuvalasit, Southern Methodist University

ENERGY GEOLOGY DIVISION

Gilbert H. Cady Award
Robert A. Gastaldo, Colby College

Antoinette Lierman Medlin Research Award
Qiang Wei, China University of Mining and Technology

Best Paper Award (for papers presented at the 2015 GSA Annual Meeting)
Christina L. Lopano, U.S. Dept. of Energy
John M. Hill, The University of Texas at Austin

ENGINEERING AND ENVIRONMENTAL GEOLOGY DIVISION

E.B. Burwell, Jr., Award
Keaton, J.R., Wartman, J., Anderson, S., Benoît, J., deLaChapelle, J., Gilbert, R., and Montgomery, D.R., 2014, The 22 March 2014 Oso Landslide, Snohomish County, Washington: Geotechnical Extreme Events Reconnaissance Sponsored by the National Science Foundation, July 22, 2014, 186 p.

Distinguished Practice Award
Lynn Highland, U.S. Geological Survey

Meritorious Service Award
William J. Burns, Oregon Dept. of Geology and Mineral Industries

Richard H. Jahns Distinguished Lecturer (2015–2016)
Jerome V. De Graff, California State University Fresno

Roy J. Shlemon Scholarship Awards
Julia Howe, University of Utah
Rachael Delaney, Kent State University
Marzieh (Mari) Foroutan, University of Calgary

GEOBIOLOGY & GEOMICROBIOLOGY DIVISION

Outstanding Contributions in Geobiosciences Award—Pre-Tenure
Erik A. Sperling, Stanford University

Outstanding Contributions in Geobiosciences Award—Post-Tenure
Tanja Bosak, Massachusetts Institute of Technology

Outstanding Contributions in Geobiosciences Award—Distinguished Career
Dawn Y. Sumner, University of California Davis

GEOINFORMATICS DIVISION

Outstanding Contributions Award
Betty M. Adrian, U.S. Geological Survey

GEOLOGY AND SOCIETY DIVISION

Best Student Paper Award
Hayley Joyell Smith, North Carolina State University
Alyssa Apryasz, William Paterson University
Randall Sanders, William Paterson University

GEOPHYSICS DIVISION

George P. Woollard Award
William J. Hinze, Professor Emeritus, Purdue University

Allan V. Cox Student Research Award
Rebekah F. Lee, Boise State University

Geophysics Division Student Research Award
Samuel Johnson, The University of Texas at Dallas

GEOSCIENCE EDUCATION DIVISION

Biggs Award for Excellence in Earth Science Teaching
Joshua I. Villalobos, El Paso Community College

HISTORY AND PHILOSOPHY OF GEOLOGY DIVISION

Mary C. Rabbitt History of Geology Award
Mott T. Greene, University of Washington

Gerry and Sue Friedman Award for Distinguished Service
Gary D. Rosenberg, Indiana University–Purdue University Indianapolis

HYDROGEOLOGY DIVISION

O.E. Meinzer Award
Andrew T. Fisher, University of California Santa Cruz

Birdsall-Dreiss Distinguished Lecturer (2015–2016)
Shemin Ge, University of Colorado Boulder

George Burke Maxey Distinguished Service Award
John W. Hess, Geological Society of America Foundation

Kohout Early Career Award
Audrey H. Sawyer, The Ohio State University

Hydrogeology Student Research Award
DeAnna Laurel, Colorado State University
Dorothea Lundberg, University of Maryland
Ravindra Dwivedi, The University of Arizona
Daniel Wilusz, Johns Hopkins University
Nathan Young, Iowa State University

LIMNOGEOLOGY DIVISION

Israel C. Russell Award
Alan R. Carroll, University of Wisconsin–Madison

Kerry Kelts Student Research Awards
Danielle R. Haskett, University of Georgia

MINERALOGY, GEOCHEMISTRY, PETROLOGY, AND VOLCANOLOGY DIVISION

Distinguished Geologic Career Award
Donald A. Swanson, Hawaiian Volcano Observatory

Early Career Award
John M. Cottle, University of California Santa Barbara

MGPV Student Research Grant Award
George Reo, Northern Illinois University
Nikki Seymour, Colorado State University
Rebecca Paisley, McGill University
Andrew Harp, University at Buffalo
Jacob Anderson, Boise State University
David Hernandez-Uribe, Central Washington University

PLANETARY GEOLOGY DIVISION

G.K. Gilbert Award
M. Darby Dyar, Mount Holyoke College

Ronald Greeley Award for Distinguished Service
Tracy K.P. Gregg, State University of New York at Buffalo

Stephen E. Dwornik Research Awards
Best Graduate Oral: **Michelle S. Thompson,** University of Arizona
Honorable Mention Graduate Oral: **Mathieu G.A. LaPotre,** Cal Tech
Best Graduate Poster: **Cameron M. Mercer,** Arizona State University
Honorable Mention Graduate Poster: **Lauren M. Jozwiak,** Brown University
Best Undergraduate Oral: **Danielle G. Neighbour,** University of Arkansas
Best Undergraduate Poster: **Julianne Sweeney,** SUNY at Geneseo
Honorable Mention Undergraduate Poster: **Michael J. O'Shea,** SUNY at Geneseo

Pellas-Ryder Award
Romy Hanna, University of Texas at Austin
Tanya Harrison, University of Western Ontario

QUATERNARY GEOLOGY AND GEOMORPHOLOGY DIVISION

Kirk Bryan Award for Research Excellence
Goldfinger, C., Nelson, C.H., Morey, A.E., Johnson, J.E., Patton, J.R., Karabanov, E., Gutiérrez-Pastor, J., Eriksson, A.T., Gràcia, E., Dunhill, G., Enkin, R.J., Dallimore, A., and Vallier, T., 2012, Turbidite event history—Methods and implications for Holocene paleoseismicity of the Cascadia subduction zone: U.S. Geological Survey Professional Paper 1661-F, U.S. Geological Survey, Reston, 170 p.

Distinguished Career Award
William F. Ruddiman, University of Virginia

Farouk El-Baz Award for Desert Research
Bernhard Eitel, Universität Heidelberg

Arthur D. Howard Student Research Grant
Adam Hawkins, University of Northern British Columbia

J. Hoover Mackin Student Research Grant
Helen Beeson, University of Nevada–Reno

continued on p. 18

continued from p. 17

Marie Morisawa Student Research Award
Joanmarie Del Vecchio, Pennsylvania State University

Robert K. Fahnestock Memorial Award
Lauren Colliver, Purdue University

John A. Black Award
Lauren Brown, University of California Los Angeles

John Montagne Research Award
Ny Riavo Voarintsoa, University of Georgia

Gladys W. Cole Research Award
Sara Rathburn, Colorado State University

SEDIMENTARY GEOLOGY DIVISION

Laurence L. Sloss Award
Tim K. Lowenstein, State University of New York at Binghamton

Sedimentary Geology Division Student Research Award
Lauren Colliver, Purdue University

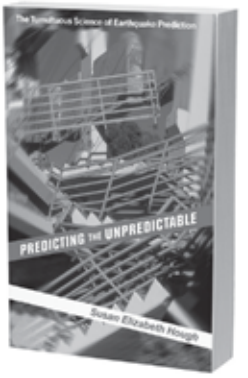
Stephen E. Laubach Structural Diagenesis Research Award (Joint with SG&T Division)
Sebastian Cardona, Colorado School of Mines

STRUCTURAL GEOLOGY AND TECTONICS DIVISION

Career Contribution Award
David D. Pollard, Stanford University

Outstanding Publication Award
Christie D. Rowe and **W. Ashley Griffith,** 2015, Do faults preserve a record of seismic slip: A second opinion: Journal of Structural Geology, v. 78, p. 1–26, doi: 10.1016/j.jsg.2015.06.006.

Structural Geology & Tectonics Student Research Award
Zoe Braden, Queen's University
Zachariah Fleming, The University of Texas at El Paso
Yiduo Liu, University of Houston
Camille Mayberry, Central Washington University
Danielle Shulaker, Stanford University



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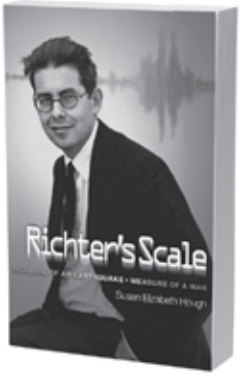

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The GSA student research grant application process is available online only; no paper applications or letters will be accepted. Apply online at **www.geosociety.org/grants/gradgrants.htm** starting in December. Online submissions must be completed by Wednesday, 1 Feb. 2017, at 5 p.m. MST.

For further information on the 2017 Research Grants Program, go to www.geosociety.org/grants/gradgrants.htm, call +1-303-357-1025, or e-mail awards@geosociety.org.

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Exploring Career Paths through Published Materials Webinar

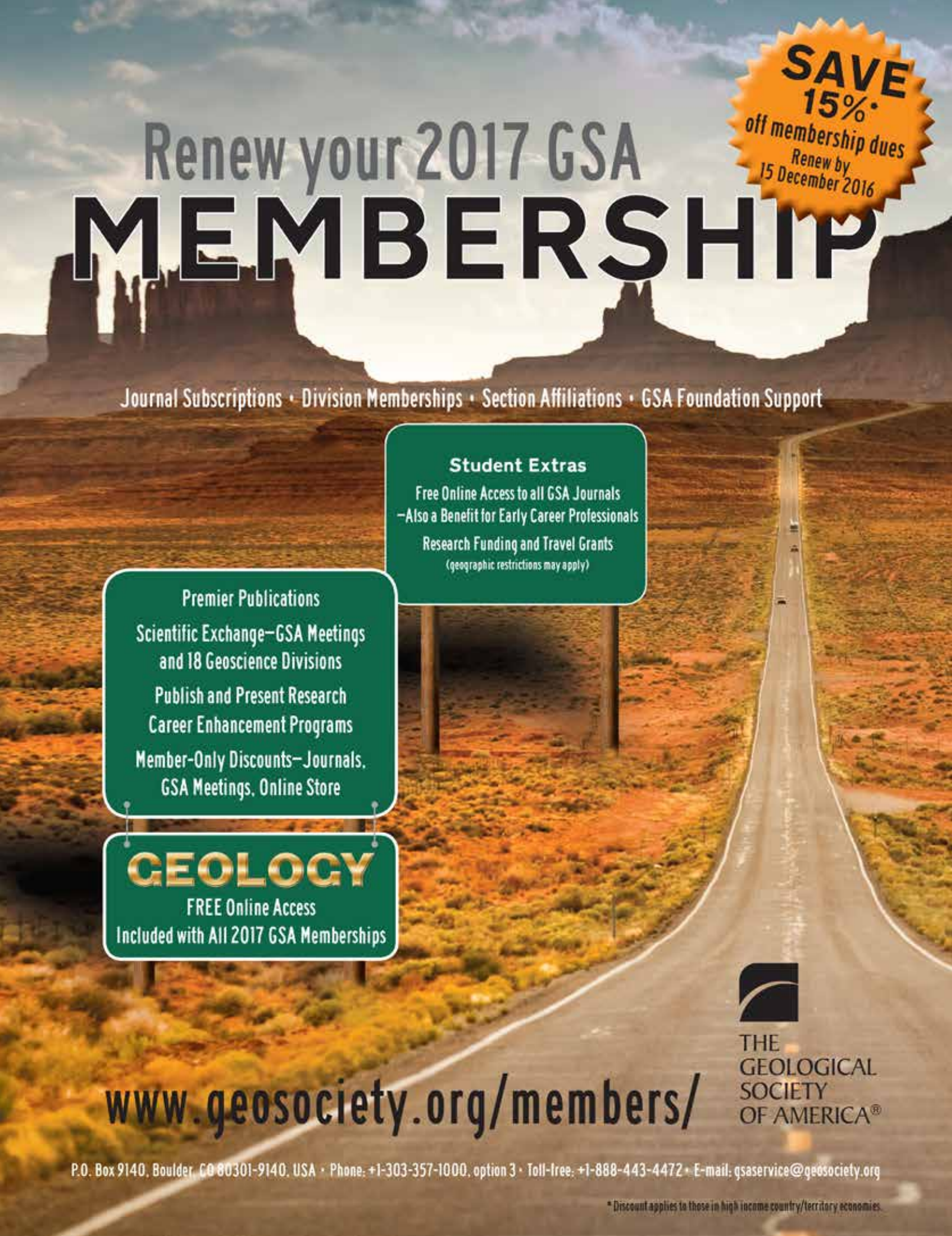
Wed., 9 Nov., 11 a.m.–noon MST

Learn about the types of career paths by exploring the published materials, subject classification scheme, historical aspects of geoscience careers and research, and other hidden information gems within the USGS Library. Presenter: **Emily Wild,** U.S. Geological Survey. Read the abstract and register at **https://attendee.gotowebinar.com/register/4927315501987503105.**

Why GSA Membership is Important to Me

GSA membership is important to me because of the Society's long-standing support of effective practice and rigorous research in geoscience education. I'm part of a cohort who trained initially as geoscientists, and who came by our subsequent scholarly interest in geoscience teaching and learning after first accruing some experience as college or high school educators and having engaged with challenges of student interest and retention, access and inclusion, authentic assessment, and public geoscience literacy. We became interested in applying scientific methods to address these and other problems of teaching and learning. We gathered at GSA annual and sectional meetings to share ideas and present our work, in part because of the Society's affiliation with the National Association of Geoscience Teachers (NAGT) and the co-convening of NAGT events with these meetings. I initially became a Society member for the geology, and that is still an important reason for my continued active membership. But as my research interests in place-based and cross-cultural geoscience teaching and learning grew out of my work in Native American communities, the professional value of my GSA membership increased proportionately. I am a past-president of NAGT and have served on GSA's education and diversity committees—and I am truly proud to have witnessed and collaborated in the great expansion of co-sponsored Geo-Ed sessions and short courses at GSA meetings, the genesis and growth of the Geoscience Education Division (GED), and the publication of a number of GSA Special Papers focused on geoscience teaching and learning. We've gained two more generations of geoscience-education researchers, now including scholars who've identified as such from the inception of their careers. GSA is a professional home to them too. An increasing number of geoscience-education researchers are being recognized as GSA Fellows; this reflects both the maturity of the field and the Society's profound support of it. At each year's Annual Meeting, GSA, GED, and NAGT together offer the broadest, deepest, and most current program in geoscience education research and practice. I encourage all geoscientists to sample some of that bounty! GSA membership has been indispensable to my career—and now, it is providing the same kinds of benefits to my students.

Steven Semken
Arizona State University
GSA Member since 1988
GSA Fellow since 2014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Catastrophic Mega-Scale Landslide Failure of Large Volcanic Fields

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www.geosociety.org/fieldforums/

CONVENERS

Robert F. Biek, Utah Geological Survey, Salt Lake City, Utah, USA, bobbiek@utah.gov

David B. Hacker, Department of Geology, Kent State University, Kent, Ohio, USA, dhacker@kent.edu

Peter D. Rowley, Geologic Mapping Inc., New Harmony, Utah, USA, pdrowley@rushisp.com

DESCRIPTION AND OBJECTIVES

This six-day field forum is designed to investigate the concept of exceptionally large catastrophic collapse of volcanic fields using the distinguishing characteristics and geologic implications of the gigantic Markagunt gravity slide and Marysvale volcanic field, southwest Utah, USA.

Growing evidence of large landslides on volcanic edifices during the past few decades has led to their identification and study at hundreds of volcanoes around the world. Such flank failures and sector collapses are a common form of volcano instability and a significant part of a volcano's development. However, mega-scale failure of volcanic fields, producing gravity slide structures so large that they blur the boundary between gravitational and tectonic processes, has not been widely recognized.

The newly discovered Miocene Markagunt gravity slide (MGS) in southwestern Utah, USA, provides an ideal setting for investigating the structure and evolution of mega-scale collapse features of volcanic fields. Superb exposures of internal deformation, from source-area breakaway faults to distal debris-avalanche deposits, show that the MGS exhibits the full range of structural features commonly seen in modern landslides, but on a mega-scale. The MGS remained undiscovered for so long precisely because of its gigantic size (>5000 km^2, >95 km long, >35 km runout, estimated volume 3000 km^3; dimensions revised from *Geology*, v. 42, no. 11, p. 943–946) and initially confusing mix of extensional, translational, and compressional structures overprinted by post-MGS basin-range tectonism. That features as large as the MGS can remain undetected despite decades of geologic mapping and research in the area suggests to us that other volcanic fields around the world may hold evidence of as-yet-undiscovered, exceptionally large gravity slides. Furthermore, some modern volcanic fields may possess the conditions capable of generating similar large slides. Only the Eocene Heart Mountain gravity slide (HMGS) in Wyoming, USA, is a terrestrial slide of comparable size; it was considered unique until discovery of the MGS.

The MGS represents southward catastrophic failure ca. 22–21 Ma of the southwestern sector of the Oligocene to Miocene Marysvale volcanic field. Recent geologic mapping indicates that the MGS is a large contiguous volcanic sheet of allochthonous andesitic mudflow breccias and lava flows, volcaniclastic rocks, source intrusions, and intertonguing regional ignimbrites. The presence of basal cataclastic breccias, clastic dikes, and pseudotachylyte, the uniformity of kinematic indicators, and the overall geometry of the MGS show that it represents a single catastrophic emplacement event. The MGS preserves the first reported occurrence of landslide-generated pseudotachylyte in North America, among only a handful known throughout the world. Catastrophic failure was preceded by gravitational spreading of the volcanic field, well displayed along the Rubys Inn thrust fault zone in and near Bryce Canyon National Park. Continued late-stage growth of the Marysvale volcanic field, which loaded ever more volcanic rocks on a structurally weak basement of ash-rich volcaniclastic strata, created conditions necessary for gravity sliding. Inflation of the volcanic pile by intrusions above the batholith beneath the heart of the field may have tilted strata on the southern flank gently southward, providing tilted planes for sliding on the underlying weak volcaniclastic strata.

The MGS is significant because it provides a stunning example of gravity-slide structures so large that they may be mistaken for tectonic features. Some low-angle normal faults, including some interpreted as detachment faults, may need reassessment in light of the implications of the MGS. For example, gravitationally driven, unrooted low-angle normal faults that emplace younger rocks on older rocks, called attenuation or denudation faults, are common in the Great Basin. They represent failure of upper parts of ranges along regional shale units following uplift along range-front normal faults and are similar in many respects to the MGS.

This Thompson Field Forum will Emphasize:

- Different lines of evidence diagnostic of large to small catastrophic gravity slides, using the MGS as an example;
- Cross-disciplinary assessment of extreme deformation processes recorded by basal and lateral breccias and associated clastic dikes, ultracataclasite shear zones, jigsaw-puzzle fracturing of clasts, striations and grooves, riedel shears, breakaway and internal faults, and pseudotachylyte;
- Factors contributing to volcanic landslide initiation and transport;

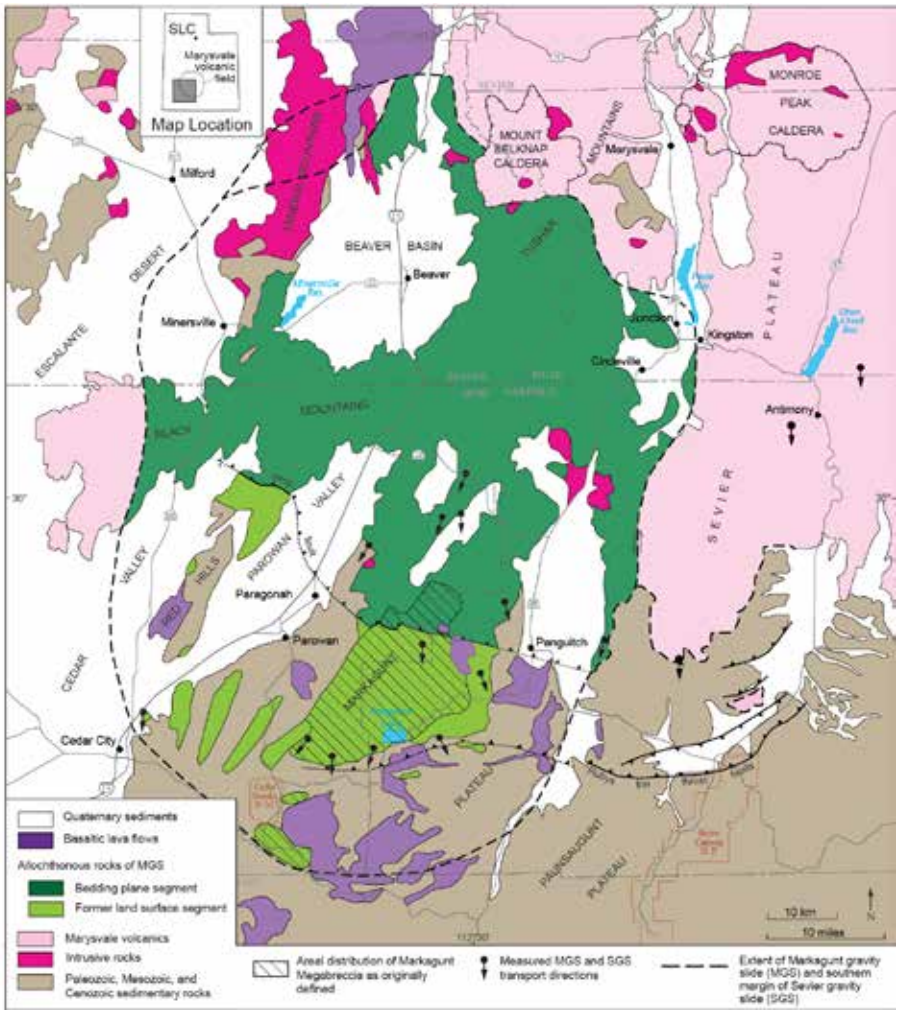


Figure 1. Extent of the Markagunt gravity slide (MGS), which moved as a single, gigantic, catastrophic slide, despite being larger than Rhode Island. The ramp fault is where the slide mass moved southward up and over the former land surface at least 35 km. The Rubys Inn thrust faults resulted from gravitational spreading of the volcanic field prior to MGS emplacement. The southern margin of the newly discovered Sevier gravity slide (SGS, which forms much of the Sevier Plateau), possibly triggered by inflation of the 23 Ma Monroe Peak caldera, is also shown. SLC—Salt lake City.

- The role of magmatic intrusions in inflation of volcanic fields and slope destabilization;
- Gravitational basement spreading of volcanic fields prior to catastrophic failure;
- Comparison of structural features of the MGS with those of low-angle normal faults;
- The use of analog and numerical modeling techniques in simulating the growth of volcanic fields and sector collapse; and
- The possible importance of monitoring radial spreading of modern volcanic fields to aid hazard assessment of potentially catastrophic collapse, not just of individual volcanic cones, but of entire sectors of active volcanic fields.

The subject of large-scale catastrophic failure of volcanic fields will bring together researchers and students—specialists in structural geology, rock mechanics, landslides, volcanology, petrography, tectonics, geochronology, geophysics, sedimentology, and modeling—using different approaches that collectively may yield a better understanding of these rare but complex catastrophic events. The field-based format of this forum will allow for lively discussions, integration of ideas, and development of future research and collaborations. Our goal is to assemble a diverse group willing to look at the MGS from multiple angles. We see significant opportunities for collaborative, cross-disciplinary research not only in our effort to characterize the MGS, but to understand how it relates to other large terrestrial landslides and volcanic provinces throughout the world.

PRELIMINARY AGENDA

The Field Forum will be based out of hotels in Cedar City and Bryce Canyon City, Utah. Some critical outcrops will require off-trail hiking of 1 or 2 km over locally steep slopes. Elevations are between 1800 and 3400 m.

16 Sept.: Evening ice breaker.

17 Sept., Day 1: Half day of invited and volunteered presentations, then a field introduction to local volcanic stratigraphy.

18 Sept., Day 2: Former land surface segment; age constraints; mechanics of basal breccia formation.

19 Sept., Day 3: MGS breakaway area and western slide margin; ramp fault; catastrophic versus tectonic mechanisms.

20 Sept., Day 4: Bedding-plane segment and features diagnostic of slide margins and catastrophic emplacement.

continued on p. 24

continued from p. 23

21 Sept., Day 5: Gravitational spreading of volcanic fields; newly discovered Sevier gravity slide.

22 Sept., Day 6: Wrap-up discussions and plans for future research and collaboration.

ATTENDEES AND ESTIMATED COSTS

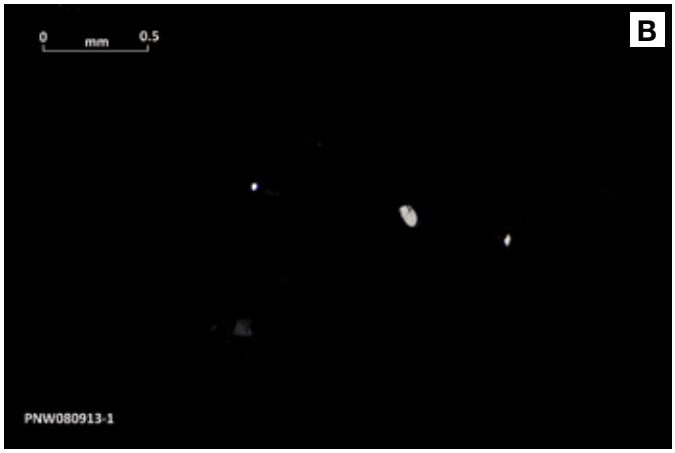
The registration fee will cover hotel lodging for six nights (double occupancy), breakfast, lunch, and snacks for six days, handouts, and transportation for the field trip. Airfare is not included and participants must make their own travel arrangements. Registration fees have not been finalized. Please check the GSA website for updates at **www.geosociety.org/fieldforums.**

APPLICATION & REGISTRATION

Application deadline: 31 Jan. 2017

Registration deadline: 31 March 2017

Participants will have to commit to attending the full six days of the field conference. Group size will be limited to 40 participants. **To apply,** please contact the conveners through bobbiek@utah.gov with a letter of intent that includes a statement of interests, the relevance of your recent work to the themes of the field conference, the subject of a proposed presentation, and contact information. Interested graduate students and early career faculty are strongly encouraged to apply. Once you have been selected to participate, you will be sent registration information. Please check the conference website for updates.



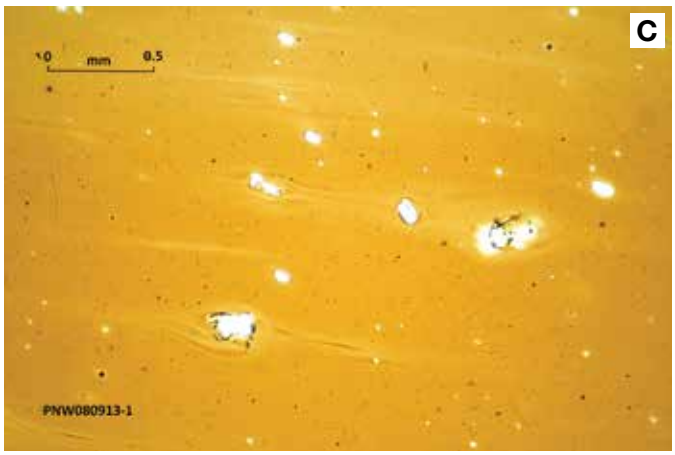
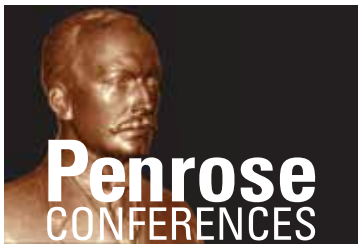


Figure 2. Pseudotachylyte dike sourced from an internal MGS shear surface (A). Photomicrographs of two different samples show (B) isotropic nature of glass with few remaining partially melted plagioclase phenocrysts (crossed-polarized light) and (C) attendant flow structures visible in plain-polarized light. Photos by Bob Biek.

Propose a Thompson Field Forum

These forums are designed to capture the essence of discoveries or controversial topics via on-the-spot discussion of a particular geologic feature via an exchange of current knowledge and exciting ideas. Forums stimulate individual and collaborative research and are field-trip oriented.

Go to **www.geosociety.org/fieldforums/** to learn more.



THE GEOLOGICAL SOCIETY OF AMERICA

Penrose Conference Report

Layered Mafic Intrusions and Associated Economic Deposits

Red Lodge, Montana, USA, 8–12 August 2016

CONVENERS

Alan E. Boudreau, School of the Environment, Duke University, Durham, North Carolina, USA

Eric C. Ferré, Dept. of Geology, Southern Illinois University, Carbondale, Illinois, USA

Brian O'Driscoll, School of Earth and Environmental Sciences, University of Manchester, Manchester, UK

Edward M. Ripley, Dept. of Geological Sciences, Indiana University, Bloomington, Indiana, USA

ORGANIZING COMMITTEE

S. Barnes, J. Day, M. Cheadle, J. Gee, A. Glazner, T. Kalakay, C. Lundstrom, B. Meurer, M. Koski, W. Maier, L. Meinert, P. Moffitt, J. Scoates, and B. Stewart

INTRODUCTION

Layered mafic intrusions (LMI) play a central role in our understanding of magmatic systems. They also represent one of the fundamental modes of magma transfer from the upper mantle to the crust. These magmatic systems formed throughout geologic time from the Archean (e.g., Stillwater Complex) to the Paleogene (e.g., Skaergaard Complex) on all five continents. As many of the best-studied layered intrusions are associated with Large Igneous Provinces, they are largely independent from tectonic processes at plate boundaries. Layered intrusions have generated significant historic interest from the igneous petrology and geochemistry communities because they lie at the heart of some of the most fundamental petrologic precepts, such as fractional crystallization and Bowen's reaction series. These intrusions also host first-class economic deposits of platinum group elements (PGE), chrome, nickel titanium, and vanadium around the world. As an illustration of how unique and important these environments are, it is worth highlighting that the Bushveld Complex (South Africa) hosts >75% of the world's exploited platinum. The Stillwater Complex also hosts significant economic quantities of these precious metals, at even higher grades (i.e., 18 ppm Pt+Pd) than the Bushveld, so it is an important location for understanding ore-forming processes. In general, it is the combination of the industrial and scientific relevance of layered intrusions that has ensured support for research on these intrusions for the past six decades. Despite the large volume of literature dedicated to layered intrusions, advances in various subdisciplines are somewhat scattered, and there is a need for synthesis of the past 20 years of research as well as an urgent need to define the new scientific challenges that the broad community and graduate students should focus on. The Stillwater Complex is an ideal setting in which to consider these challenges, as it combines a rich tradition of petrological research with active economic interests in a relatively easily accessible location. More simply, it is one of the most important layered intrusions on Earth, in terms of historical study and quality of exposure.

The Geological Society of America Foundation, the National Science Foundation Petrology and Geochemistry Program, the U.S. Geological Survey Mineral Resources Program, the Rocky Mountain Association of Geologists Foundation, and the Stillwater Mining Company Foundation jointly sponsored this Penrose Conference.

The conference, held at the Rock Creek Resort in Red Lodge, Montana, USA, from 8 August through 12 August 2016, gathered an impressive array of 58 experts and six industry delegates from Taiwan, Germany, the UK, Canada, South Africa, and the U.S.

PRESENTATIONS AND FIELD TRIP

Participants met in session, exchanged new results, discussed critical scientific questions, and engaged with one another on the outcrops of the Stillwater Complex during two days of geological excursions led by Alan Boudreau and Mike Zientek on the Stillwater Complex.

The major aims of the conference were to define the critical scientific questions that the community will need to address in the next decade, to foster collaboration with industrial partners, and to promote exchange between the generation of senior scientists and younger academics. Thirteen graduate students (nine of whom were women) and seven early-career scientists (four of whom were women) were supported through the generous donations of our sponsors. The format of the discussions actively promoted the intellectual contribution of younger scientists.

The scientific party collectively defined the following key questions:

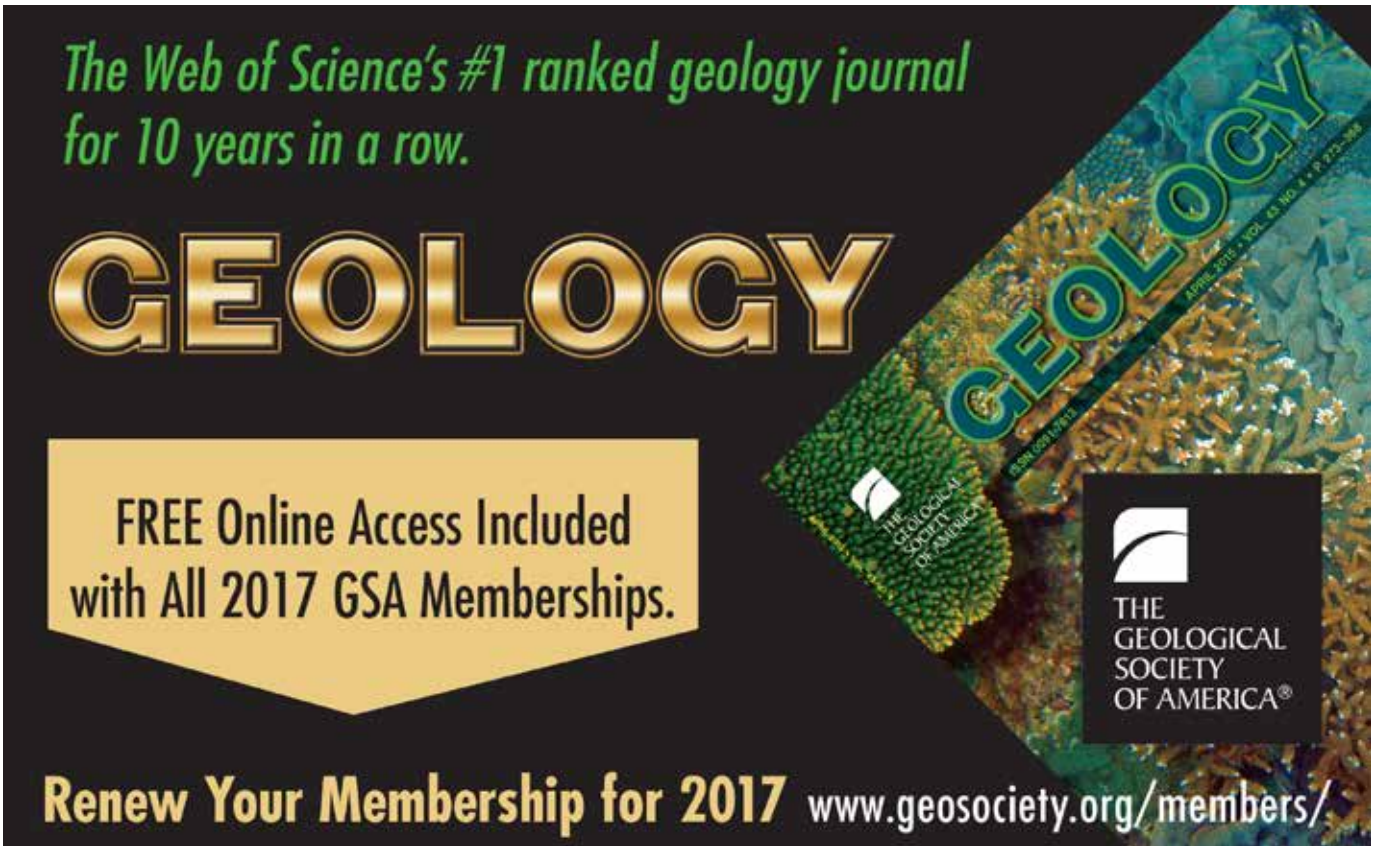
- What are the timescales of emplacement and cooling of LMI?
- What is the physical nature of a magma chamber?
- Have large volume mafic magma chambers ever existed?
- How do monomineralic layers form in LMI?
- How much crustal contamination occurs in LMI magmatism?
- In what tectonic settings are LMI likely to form?

- What can we learn from the material sciences about the cooling and solidification of layered cumulates?

The participants also agreed on a number of collaborative initiatives, including a Facebook page (https://www.facebook.com/layeredmaficintrusions/photos?ref=page_internal); an International LMI working group, including several national correspondents; a forthcoming Wager Symposium in 2018; and a large-scale collaborative research proposal focusing on graduate research to be submitted to the National Science Foundation in 2017.

The abstracts of presentations are available at **www.geosociety.org/penrose/16montana.htm.**

Participants: Raquel Alonso-Perez, Lew Ashwal, Jean Bédard, Alan Boudreau, John Boyd, Kevin Butak, Jeff Chaumba, Mike Cheadle, Gilbert Ching, June Cho, Konrad Chrzastowski, Tiffany Cummings, Jim Dahy, James Day, Mat Dunlop, Sabastien Dyer, Eric Ferré, Caroll Finn, Anais Fourny, Jeff Gee, Ennis Geragthy, Allen Glazner, Alex Hammerstrom, Adriana Heimann Rios, Luke Hepworth, Paul Holick, Marian Holness, Victoria Honour, Jeff Hughes, Emma Hunt, Chris Jenkins, Kate Jillings, Felix Kaufmann, Mike Koski, Rais Latypov, Nivea Magalhaes, Rick Marquard, Nichole Moerhuis, Ria Mukherjee, James Mungall, Brian O'Driscoll, Amy Parker, Heather Parks, Mike Pasecznyk, Steven Prevec, Ed Ripley, Jake Setera, Greg Shellnutt, Josh Smith, LeeAnn Srogi, Ilya Veksler, Tom Ver Hoeve, Zoja Vukmanovic, Corey Wall, Laurene-Marie Wavrant, Sue Webb, Ben Wermette, Lauretta Yantis, and Mike Zientek.



Preliminary Announcement and Call for Papers

SOUTHEASTERN SECTION

66th Annual Meeting of the Southeastern Section, GSA
Richmond, Virginia, USA
30–31 March 2017

www.geosociety.org/Sections/se/2017mtg

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Rockin' the Fall Zone

Strategically located on the Fall Zone, Richmond sits where the James River dramatically cascades over the Petersburg Granite at the eastern edge of the Piedmont to the sedimentary strata of the Coastal Plain. The Class IV rapids running through the city's downtown area, and visible from walking trails along Belle Isle, are recognized as the best urban whitewater in America. Richmond also has a vibrant arts and music scene, a growing microbrewery industry, and is home to Lewis Ginter Botanical Garden, named one of the best botanical gardens in the country. With either a stroll around town, or a short drive to the mountains or coast, Richmond is ideally located to explore the geologic diversity of the southeast.

CALL FOR PAPERS

Abstract deadline: 3 Jan. 2017

Submit abstracts online at **www.geosociety.org/Sections/se/2017mtg/.** The submission fee is 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.

In addition to the following Symposia and Theme Sessions, we are also soliciting abstracts for general discipline sessions.

Symposia

S1. **From Mountains to Coast: Biogeochemical Processes Affecting the Water Quality of the Bay in Our Backyard.** Karen C. Rice, USGS, kcrice@usgs.gov; Janet S. Herman, Univ. of Virginia, jherman@virginia.edu.

S2. **Tectonics of Blue Ridge and Piedmont Terranes: Insight from Integrated Studies (Posters).** Arthur J. Merschat, USGS, amerschat@usgs.gov; Elizabeth McClellan, Radford Univ., emccellan@radford.edu; Mitchell Scharman, Marshall Univ., scharman@marshall.edu.

S3. **Geologic Maps and Map Derivatives: The Legacy of Mike Higgins (Posters).** Darcy McPhee, USGS, dmcphee@usgs.gov; Mark Carter, USGS, mcarter@usgs.gov.

S4. **Geology and the Civil War.** Robert C. Whisonant, Radford Univ., rwhisona@radford.edu; Stephen W. Henderson, Oxford College of Emory Univ., shender@emory.edu.

Theme Sessions

T1. **New Insights in Linking Mid-Atlantic Terranes to the Northern and Southern Appalachians.** Christopher M. Bailey, College of William and Mary, cmbail@wm.edu; Steven J. Whitmeyer, James Madison Univ., whitmesj@jmu.edu.

T2. **Cenozoic Paleontology of the Mid-Atlantic.** Emily S. Stafford, Western Carolina Univ., esstafford@email.wcu.edu.

T3. **Geoscience Careers for New Geoscience Graduates.** Ronald J. Wallace, Georgia Department of Natural Resources, ronald.wallace@dnr.state.ga.us; Michael D. Lawless, Draper Aden Associates, mlawless@daa.com.

T4. **Digital Imaging Techniques for Enhancing Student Learning and Research.** Parvinder Sethi, Radford Univ., psethi@radford.edu; Chester (Skip) Watts, Radford Univ., cwatts@radford.edu.

T5. **Beaches, Barriers, and Marshes of the Southeast Coast: Dynamic Systems in a Changing Climate.** Christopher Hein, Virginia Institute of Marine Science, hein@vims.edu; Michael Fenster, Randolph-Macon College, mfenster@rmc.edu.

T6. **Karst Geology and Hazards in the Southeastern U.S.** Randall Orndorff, USGS, rorndorf@usgs.gov.

T7. **Transforming Geoscience Teaching and Learning at 2Y and 4Y Colleges.** Callan Bentley, Northern Virginia Community College, cbentley@nvcc.edu; Jason P. Jones, North Carolina State Univ., jpjones7@ncsu.edu;Rachel Atkins, North Carolina State Univ., ratkins@ncsu.edu; Pete Berquist, Thomas Nelson Community College, berquistp@tncc.edu; LeeAnna Chapman, North Carolina State Univ., ltyoung@ncsu.edu; Charles Doug Czajka, North Carolina State Univ., cdczajka@ncsu.edu; Jennifer Dixon, North Carolina State Univ., jldicks2@ncsu.edu.

T8. **Economic Geology and the Atlantic Continental Shelf: Marine Aggregate, Heavy Minerals, Energy Resources, and Carbon Storage.** William Lassetter, Virginia Division of Geology and Mineral Resources, william.lassetter@dmme.virginia.gov; Rick Berquist, Virginia Division of Geology and Mineral Resources, rick.berquist@dmme.virginia.gov.

T9. **Seismic Zones, Paleoseismology, and Neotectonics in the Southeastern United States.** J. Wright Horton, Jr., USGS, whorton@usgs.gov; Ronald Counts, USGS, rcounts@usgs.gov.

T10. **Deciphering Metamorphic Histories in Multiply-Deformed Terranes in the Piedmont and Blue Ridge.** William C. Burton, USGS, bburton@usgs.gov; Willis E. Hames, Auburn Univ., hameswe@auburn.edu.

T11. **Hydrology and Hydrogeology in the Southeast: Processes, Problems, and Geologic Controls.** J.P. Gannon, Western Carolina Univ., jpgannon@wcu.edu; David L. Nelms, USGS, dlnelms@usgs.gov; David Kinner, Western Carolina Univ., dkinner@wcu.edu; Mark Lord, Western Carolina Univ., mlord@wcu.edu; Jerry Miller, Western Carolina Univ., jmiller@wcu.edu; E. Randolph McFarland, USGS, ermcfarl@usgs.gov.

T12. **Methods for Assessing Knowledge and Understanding among K–16 Students and the General Public.** Frank L. Forcino, Western Carolina Univ., flforcino@email.wcu.edu; Rachel Salter, North Dakota State Univ., rachel.salter@ndsu.edu.

T13. **Topics in Paleozoic Paleontology and Stratigraphy.** Stephen A. Leslie, James Madison Univ., lesliesa@jmu.edu; Bradley Deline, Univ. of West Georgia, bdeline@westga.edu; John Haynes, James Madison Univ., haynesjx@jmu.edu.

T14. **Brittle Deformation in the Piedmont and Coastal Plain Provinces: Understanding the Tectonics along the Eastern North American Margin.** Mervin J. Bartholomew, Univ. of Memphis, jbrthlm1@memphis.edu; Christopher M. Bailey, College of William and Mary, cmbail@wm.edu.

T15. **Plutonism and Volcanism in the Southern Appalachians.** Brent E. Owens, College of William and Mary, beowen@wm.edu; Elizabeth Johnson, James Madison Univ., johns2ea@jmu.edu.

T16. **Stormwater Control Measures: Runoff Quantity and Pollution Science and Management in the Southeastern U.S.** Vijay M. Vulava, Univ. of Charleston, vulavav@cofc.edu; Barbara Beckingham, Univ. of Charleston, beckinghamba@cofc.edu; Timothy Callahan, Univ. of Charleston, callahant@cofc.edu.

T17. **Geologic Studies of the U.S. Atlantic Coastal Plain Province.** Christopher Swezey, USGS, cswezey@usgs.gov; Rick Berquist, Virginia Division of Geology and Mineral Resources, rick.berquist@dmme.virginia.gov.

T18. **2YC Student Research and Teaching Methods (Posters).** Pete Berquist, Thomas Nelson Community College, berquistp@tncc.edu; Callan Bentley, Northern Virginia Community College, cbentley@nvcc.edu.

T19. **Undergraduate Research (Posters).** Lee Phillips, Univ. of North Carolina at Greensboro, plphilli@uncg.edu; Elizabeth Johnson, James Madison Univ., johns2ea@jmu.edu.

T20. **Paleozoic Clastics and Carbonates of the Southeast (Posters).** Jeannette M. Wolak, Tennessee Technological Univ., jwolak@tntech.edu.

FIELD TRIPS

Pre-Meeting Trips

Fossil-Collecting from the Middle Miocene Carmel Church Quarry Marine Ecosystem. Alexander K. Hastings, Virginia Museum of Natural History, alexander.hastings@vmnh.virginia.gov; Ray Vodden, Virginia Museum of Natural History, raymond.vodden@vmnh.virginia.gov; Christina Byrd, Virginia Museum of Natural History, christina.byrd@vmnh.virginia.gov.

From Laurentia to Iapetus: Traversing the Blue Ridge–Piedmont Terrane Boundary in Central Virginia. Anna V. Spears, College of William and Mary, avspears@email.wm.edu; Christopher M. Bailey, College of William and Mary, cmbail@wm.edu; Aaron Marshall, College of William and Mary.

Geology along the Blue Ridge Parkway in Virginia. Mark Carter, USGS, mcarter@usgs.gov; Scott Southworth, USGS, ssouthw@usgs.gov; Richard Tollo, George Washington Univ., rtollo@gwu.edu; Arthur Merschat, USGS; Sara Wagner, George Washington Univ.; Ava Lazor, George Washington Univ.; John Aleinikoff, USGS.

Geology of Belle Isle, Richmond. Karen M. Layou, Reynolds Community College, klayou@reynolds.edu; Brent Owens, College of William and Mary, beowen@wm.edu.

Post-Meeting Trips

Geologic Controls on Cave Development in the Burnsville Cove Area, Bath and Highland Counties, Virginia. Christopher Swezey, USGS, cswezey@usgs.gov; John Haynes, James Madison Univ., haynesjx@jmu.edu; Phil Lucas, Virginia Speleological Survey; Rick Lambert, Virginia Speleological Survey.

Geologic Evolution, Modern Processes, and Mangement Strategies of Virginia's Mainland Beaches and Barrier Island. Michael Fenster, Randolph Macon College, mfenster@rmc.edu; Christopher Hein, Virginia Institute of Marine Science, hein@vims.edu.

Geology and Paleontology at Stratford Hall, Northern Neck, Virginia. Rob Weems, USGS, rweems4@gmail.com; Lucy Edwards, USGS, leedward@usgs.gov; Bryan Landacre, USGS.

Geology of the Civil War Battlefields at Petersburg, Virginia. Aaron Cross, Virginia Division of Geology and Mineral Resources (VDGMR), aaron.cross@dmme.virginia.gov; C.R. Berquist, VDGMR, crberq@wm.edu; Marcie Occhi, VDGMR, marcie.occhi@dmme.virginia.gov; Jessica Strand, VDGMR.

Geology of the Petersburg Batholith, Eastern Piedmont, Virginia. Brent Owens, William & Mary, beowen@wm.edu; Mark Carter, USGS, mcarter@usgs.gov; Christopher M. Bailey, William & Mary, cmbail@wm.edu.

Industrial Minerals and Mines in the Arvonia Formation of the Chopawamsic Terrane, Buckingham County, Virginia. Chee Saunders, Cardno Inc., chee.saunders@cardno.com.

Tertiary Strata and Paleontology of the James River Region, Virginia. Lauck W. Ward, Virginia Museum of Natural History, lauck.ward@vmnh.virginia.gov; Harry Dowsett, USGS.

OPPORTUNITIES FOR STUDENTS AND EARLY CAREER PROFESSIONALS

Roy J. Shlemon Mentor Program in Applied Geoscience. Students and early career professionals will have the opportunity to discuss career prospects and challenges with applied geoscientists from various sectors over a FREE lunch.

John Mann Mentors in Applied Hydrogeology Program. Students and early career professionals interested in applied hydrogeology or hydrology as a career will have the opportunity to network with professionals in these fields over a FREE lunch.

GEOSCIENCE CAREER WORKSHOPS

Part 1: Career Planning and Informational Interviewing. Your job-hunting process should begin with career planning, not when you apply for jobs. This workshop will help you begin this process and will introduce you to informational interviewing.

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

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

REGISTRATION

Early registration deadline: 27 February 2017
Cancellation deadline: 6 March 2017

Online registration begins January 2017. For further information, or if you have special requirements, please contact the local committee chairs, David Spears, david.spears@dmme.virginia.gov, or Karen Layou, klayou@reynolds.edu.

ACCOMMODATIONS

Hotel registration deadline: 7 March 2017

Blocks of rooms have been reserved at the Omni Richmond Hotel, located at 100 South 12th Street, Richmond, VA 23219, USA, +1-804-344-7000. The meeting will take place within the Omni Richmond's convention facilities. The meeting rate is US$165 per night plus tax for single and double occupancy. To make your reservations, please call Omni Reservations at 1-800-THE-OMNI and be sure to refer to the code: 17SEGSA.

LOCAL COMMITTEE

General Co-Chairs: David Spears, david.spears@dmme.virginia.gov; Karen Layou, klayou@reynolds.edu

Technical Program Co-Chairs: Beth McClellan, emcclellan@radford.edu; Mark Carter, mcarter@usgs.gov

Field Trip Co-Chairs: Chuck Bailey, cmbail@wm.edu; Shelley Jaye, sjaye@nvcc.edu

Sponsorships Co-Chairs: Steve Leslie, lesliea@jmu.edu; Matt Heller, matthew.heller@dmme.virginia.gov

Exhibits Chair: Chee Saunders, chee.saunders@cardno.com

Student Volunteer Chair: Lynsey Lemay, lemayl@tncc.edu

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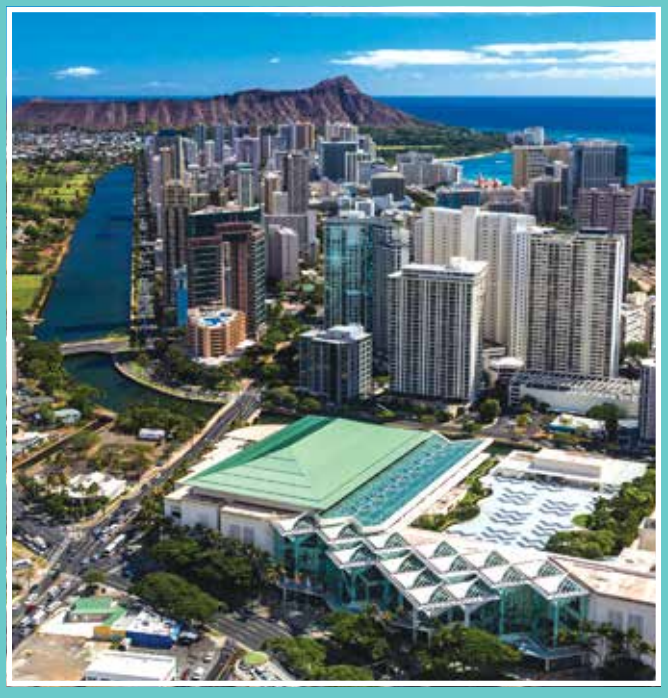
THE GEOLOGICAL SOCIETY OF AMERICA®

Preliminary Announcement and Call for Papers

CORDILLERAN SECTION

113th Annual Meeting of the Cordilleran Section, GSA
Hawai'i Convention Center
Honolulu, Hawai'i, USA
23–25 May 2017

www.geosociety.org/Sections/cord/2017mtg/



Convention Center. Hawai'i Tourism Authority. Photo by Tor Johnson.

The Geoscience Hotspot

We are excited to announce that the 2017 Cordilleran GSA meeting will be held at the beautiful Hawai'i Convention Center in Honolulu. The technical program currently consists of 34 Topical Sessions and Symposia, complemented by six Science and Education Short Courses and Workshops, and 12 Field Trips on the islands of Hawai'i, Maui, O'ahu, and Kaua'i. Short courses, workshops, and field trips will occur both before and after the technical sessions. Other special events include student mentoring programs and career workshops that will offer exceptional opportunities for networking. The meeting venue is steps away from Waikīkī and your gateway to national monuments and the stunning mountains, gardens, parks, and warm waters of the tropical Pacific. *E komo mai* (Welcome!) to you and your family to our tropical paradise (www.gohawaii.com/oahu).

CALL FOR PAPERS

Abstract deadline: 14 Feb. 2017

Submit abstracts online at **www.geosociety.org/Sections/cord/2017mtg/.** The submission fee is 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.

In addition to the following Theme Sessions, we are soliciting abstracts for general discipline sessions. Please direct questions on these sessions to technical program co-chairs Henrietta Dulai hdulaiov@hawaii.edu, Greg Moore, gmoore@hawaii.edu, and Brian Popp, popp@hawaii.edu.

Symposium

S1. **Biogeochemistry of Sedimentary Carbonates: A Symposium Dedicated to Bob Berner and John Morse.** Fred T. Mackenzie, Univ. of Hawai'i, fredm@soest.hawaii.edu; Jane Schoonmaker, Univ. of Hawai'i, jane@soest.hawaii.edu.

Theme Sessions

T1. **Cordilleran Magmatic Forensics—Insights from the Igneous, Metamorphic, and Sedimentary Record.** Shanaka de Silva, Oregon State Univ., desilvas@geo.oregonstate.edu; Rita Economos, Southern Methodist Univ., rita.economos@gmail.com; Nancy Riggs, Northern Arizona Univ., nancy.riggs@nau.edu; Andy Barth, Indiana Univ.–Purdue Univ. Indianapolis, ibsz100@iupui.edu.

T2. **Structural Geology and Tectonics of the Western United States.** Stephen Martel, Univ. of Hawai'i, smartel@hawaii.edu; Ann Egger, Central Washington Univ., annegger@geology.cwu.edu.

T3. **Magmatism and Orogenesis in the Sedimentary Record.** Matthew McKay, Missouri State Univ., matthewmckay@missouristate.edu; William Jackson, Univ. of Alabama/Geological Survey of Alabama, wjackson@gsa.state.al.us; Keith Gray, Wichita State Univ., k.gray@wichita.edu.

T4. **The Pacific Plate through Geologic Time.** Paul Wessel, Univ. of Hawai'i, pwessel@hawaii.edu; Simon E. Williams, EarthByte, Univ. of Sydney, Australia, simon.williams@sydney.edu.au.

T5. **Internal Structure, Active Deformation, and Mechanics of Accretionary Prisms and Orogenic Wedges.** Garrett Ito, Univ. of Hawai'i, gito@hawaii.edu; Gregory F. Moore, Univ. of Hawai'i, gmoore@hawaii.edu; James Foster, Univ. of Hawai'i, jfoster@soest.hawaii.edu.

T6. **Magmatic Processes and Sources for Hotspot Volcanoes.** Michael Garcia, Univ. of Hawai'i, mogarcia@hawaii.edu; Jasper Konter, Univ. of Hawai'i, jkonter@hawaii.edu.

T7. **Origin and Evolution of Continental and Oceanic-Arc Magmas.** Michael Garcia, Univ. of Hawai'i, mogarcia@hawaii.edu.

T8. **Explosive Volcanism.** Bruce. F. Houghton, Univ. of Hawai'i, bhought@soest.hawaii.edu; Don Swanson, USGS, Hawaiian Volcano Observatory, donswan@usgs.gov; Sarah Fagents, Univ. of Hawai'i, fagents@hawaii.edu.

T9. **Volcanic Impacts.** Costanza Bonadonna, Univ. of Geneva, bonadonna@unige.ch; Sebastien Biasse, Univ. of Hawai'i, sbiasse@hawaii.edu; Susanna Jenkins, Earth Observatory of

Singapore, susanna.jenkins@gmail.com; Thomas Wilson, Univ. of Canterbury, New Zealand, thomas.wilson@canterbury.ac.nz; Christina Neal, USGS, Hawaiian Volcano Observatory, tneal@usgs.gov.

T10. **Hazards and Hazard Communication Related to the Active Volcanoes of Hawai'i.** Christina Neal, USGS, Hawaiian Volcano Observatory, tneal@usgs.gov; Janet Babb, USGS, Hawaiian Volcano Observatory, jbabb@usgs.gov.

T11. **Submarine Volcanism in Hawai'i and Elsewhere.** Ken Rubin, Univ. of Hawai'i, krubin@hawai.edu; Sam Mitchell, Univ. of Hawai'i, samjm@hawaii.edu.

T12. **Fluid Flow, Submarine Seeps, and Gas Hydrate Systems: Implications for the Global Carbon Cycle and Seafloor Stability.** Katie Taladay, Univ. of Hawai'i, taladay@hawaii.edu; Hitoshi Tomaru, Chiba Univ., tomaru@chiba-u.jp.

T13. **Marine Minerals, Key Resources for the Twenty-First Century.** James R. Hein, USGS, jhein@usgs.gov; Kira Mizell, USGS, kmizell@usgs.gov; Amy Gartman, USGS, agartman@usgs.gov.

T14. **Advances in Geothermal Resource Investigation.** Pete Stelling, Western Washington Univ., pete.stelling@wwu.edu; Nick Hinz, Univ. of Nevada–Reno, nhinz@unr.edu; Nicole Lautze, Univ. of Hawai'i, nlautze@soest.hawaii.edu; Garrett Ito, Univ. of Hawai'i, gito@hawaii.edu.

T15. **Mineral Physics Research Aspects Related to Deep Earth's Interior and Phenomena.** Murli Manghnani, Univ. of Hawai'i, murli@soest.hawaii.edu; Bin Chen, Univ. of Hawai'i, binchen@hawaii.edu.

T16. **New Developments in the Geology and Geochemistry of Mars.** Jim Bell, Arizona State Univ., jim.bell@asu.edu; Scott Rowland, Univ. of Hawai'i, scott@soest.hawaii.edu.

T17. **Volcanism across the Solar System.** Sarah A. Fagents, Univ. of Hawai'i, fagents@hawaii.edu; Rosaly Lopes, Jet Propulsion Laboratory, rosaly.m.lopes-gautier@jpl.nasa.gov.

T18. **Deposition and Diagenesis of Volcaniclastic Sediments on Earth and Mars.** Juergen Schieber, Indiana Univ., jschiebe@indiana.edu; Ken Edgett, Malin Space Science Systems, edgett@msss.com; David Bish, Indiana Univ., bish@indiana.edu.

T19. **Mars on Earth: Understanding Mars through Earth Surface Processes.** Robert A. Craddock, Center for Earth and Planetary Studies, Smithsonian Institution, craddockb@si.edu; Jacob E. Bleacher, Planetary Geodynamics Lab, NASA Goddard Space Flight Center, jacob.e.bleacher@nasa.gov; Christopher Hamilton, Univ. of Arizona, hamilton@lpl.arizona.edu.

T20. **Paleomagnetism, Rock Magnetism, and Archaeomagnetism.** Emilio Herrero-Bervera, Univ. of Hawai'i, herrero@soest.hawaii.edu; Evdokia Tema, Univ. degli Studi di Torino, Italy, evdokia.tema@unito.it.

T21. **Geoarchaeology in Hawai'i and Oceania.** Floyd W. McCoy, Univ. of Hawai'i–Windward, fmccoy@hawaii.edu; Alex Morrison, International Archaeology LLC, alexmorr@hawaii.edu; Alex Parisky, Univ. of Hawai'i–Windward, parisky@hawaii.edu.

T22. **Cenozoic Paleoecology, Paleogeography, and Evolutionary History of Pacific Marine Life.** Steven M. Stanley, Univ. of Hawai'i, stevenst@hawaii.edu; Sonia J. Rowley, Univ. of Hawai'i, srowley@hawaii.edu.

T23. **Ocean Acidification: Past, Present, and Future: A Session to Honor the Work and Career of Fred T. Mackenzie.** Michael Guidry, Univ. of Hawai'i, guidry@hawaii.edu; Eric De Carlo, Univ. of Hawai'i, edecarlo@soest.hawaii.edu.

T24. **Modeling Past Climates.** Axel Timmermann, IPRC, SOEST, Univ. of Hawai'i, axel@hawaii.edu; Tobias Friedrich, Univ. of Hawai'i, tobiasf@hawaii.edu; Fabian Schloesser, Univ. of Hawai'i, schloess@gmail.com.

T25. **Interpreting Holocene Climate from the Geologic Record.** Basil Gomez, Univ. of Hawai'i, basilg@hawaii.edu.

T26. **Sedimentary Records of Sea Level, Extreme Events, and Coastal Evolution.** Charles Fletcher, Univ. of Hawai'i, fletcher@soest.hawaii.edu; Bruce Richmond, USGS, brichmond@usgs.gov; Ken Rubin, Univ. of Hawai'i, krubin@hawaii.edu.

T27. **Impacts of Climate Change on Pacific Shores.** Charles Fletcher, Univ. of Hawai'i, fletcher@soest.hawaii.edu; Patrick Barnard, USGS, pbarnard@usgs.gov.

T28. **Pacific Coastal Processes.** Charles Fletcher, Univ. of Hawai'i, fletcher@soest.hawaii.edu; Patrick Barnard, USGS, pbarnard@usgs.gov.

T29. **Coastal Hydrology: Impacts of Natural and Anthropogenic Change.** Henrietta Dulai, Univ. of Hawai'i, hdulaiov@hawaii.edu; Craig R. Glenn, Univ. of Hawai'i, glenn@soest.hawaii.edu; Peter Swarzenski, International Atomic Energy Agency (Monaco) and USGS, Santa Cruz, pswarzen@usgs.gov.

T30. **Integrated Approaches for Assessing Water Resources.** Aly El-Kadi, Univ. of Hawai'i, elkadi@hawaii.edu; Stephen S. Anthony, USGS, Pacific Islands Water Science Center, santhony@usgs.gov.

T31. **Engineering Geology of the Western United States.** Stephen Martel, Univ. of Hawai'i, smartel@hawaii.edu; Scott Burns, Portland State Univ., burnss@pdx.edu; Jerome De Graff, California State Univ. Fresno, jdegraff@csufresno.edu.

T32. **Applications of Unmanned Aerial Vehicles (UAVs) in the Earth, Ocean, Planetary, and Life Sciences.** Matthew Barbee, Univ. of Hawai'i, mbarbee@hawaii.edu; Craig R. Glenn, Univ. of Hawai'i, glenn@soest.hawaii.edu; Nicolas Turner, Univ. of Hawai'i, nrturner@hawaii.edu; Charles Devaney, International Building Solutions Group, devaneycharles@gmail.com.

T33. **Undergraduate Research Session (Posters).** *Cosponsored by Council on Undergraduate Research, Geosciences Division.* Lydia K. Fox, Univ. of the Pacific, lkfox@pacific.edu; Jeff Marshall, Cal Poly Pomona Univ., marshall@cpp.edu.

FIELD TRIPS

Trip registration opens in February 2017. For additional information, please contact field co-chair Scott Rowland, scott@soest.hawaii.edu.

Coastal Erosion on Maui. Tara Owens, Univ. of Hawai'i Sea Grant, taram@hawaii.edu, Jim Biurka, Maui County Planning Dept., James.Buika@co.maui.hi.us.

Coastal Geology of O'ahu. Brad Romine, Univ. of Hawai'i Sea Grant, romine@hawaii.edu; Dolan Eversole, Univ. of Hawai'i Sea Grant, eversole@hawaii.edu.

Eruptions and Faulting at Kīlauea Summit, Upper East Rift Zone, and Koa'e Fault System. Don Swanson, USGS, Hawaiian Volcano Observatory, donswan@usgs.gov; Tina Neal, USGS, Hawaiian Volcano Observatory, tneal@usgs.gov.

The Geology of East and West Maui. John Sinton, Univ. of Hawai'i, sinton@hawaii.edu; Emily First, Univ. of Hawai'i, efirst@hawaii.edu.

The Geology and Soils of Kohala Volcano. Oliver Chadwick, Univ. of California, Santa Barbara, oac@geog.ucsb.edu; Ken Hon, Univ. of Hawai'i–Hilo, kenhon@hawaii.edu.

Ko'olau Geology. Jasper Konter, Univ. of Hawai'i, jkonter@hawaii.edu; Val Finlayson, Univ. of Hawai'i, vfinlays@hawaii.edu.

Mauna Loa. Frank Trusdell, USGS, Hawaiian Volcano Observatory, trusdell@usgs.gov; Steve Schilling, USGS, Hawaiian Volcano Observatory, sschilli@usgs.gov.

O'ahu Hydrology. Aly El-Kadi, Univ. of Hawai'i, elkadi@hawaii.edu; Arthur Aiu, Honolulu Board of Water Supply, aaiu@hbws.org.

Past and Present Geologic Processes on Kaua'i. Chuck Blay, The Edge of Kauai, teok@aloha.net; Mike Garcia, Univ. of Hawai'i, mogarcia@hawaii.edu.

Structural Geology and Geothermal Energy at Kīlauea Volcano. Stephen Martel, Univ. of Hawai'i, smartel@hawaii.edu; Nicole Lautze, Univ. of Hawai'i, nlautze@higp.hawaii.edu.

Summit and Flank Features of Hualālai Volcano. Scott Rowland, Univ. of Hawai'i, scott@hawaii.edu; Julia Hammer, Univ. of Hawai'i, jhammer@hawaii.edu.

Wai'anae Geology. Scott Rowland, Univ. of Hawai'i, scott@hawaii.edu.

OPPORTUNITIES FOR STUDENTS AND EARLY CAREER PROFESSIONALS

Roy J. Shlemon Mentor Program in Applied Geoscience. Students and early career professionals will have the opportunity to discuss career prospects and challenges with applied geoscientists from various sectors over a FREE lunch.

John Mann Mentors in Applied Hydrogeology Program. Students and early career professionals interested in applied hydrogeology or hydrology as a career will have the opportunity to network with professionals in these fields over a FREE lunch.

Geoscience Career Workshops

Part 1: Career Planning and Informational Interviewing. Your job-hunting process should begin with career planning, not when you apply for jobs. This workshop will help you begin this process and will introduce you to informational interviewing.

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

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

REGISTRATION

Early registration deadline: 17 April 2017
Cancellation deadline: 24 April 2017

Registration opens in February 2017. For further information or if you need special accommodations please contact Conference Chair Craig Glenn, glenn@soest.hawaii.edu.

ACCOMMODATIONS

Hotel reservation deadline: 1 May 2017

A limited amount of rooms are available within a two-minute walk from the Convention Center. This block of rooms has been reserved at the Ala Moana Hotel, 410 Atkinson Drive, Honolulu, HI 96814, USA. GSA meeting rate: US$165 single or double (Kona Tower, queen bed only) and US$185 single or double with balcony (Waikiki Tower, one king bed or two double beds). Triple (US$235) and quad (US$285) rooms are available in the Waikiki Tower utilizing existing bedding, but no rollaway beds. Rates are per night plus 13.962% tax. Amenities include restaurants, outdoor pool, fitness center, Starbucks, business center, and free Wi-Fi. Parking: US$20/night for self-parking; $25/night valet. Make your reservations online at https://aws.passkey.com/event/16033051/owner/11602/home, or call +1-800-367-6025 and reference the **2017 Annual Meeting of the Cordilleran Section of GSA.** Neighbor islands: Call +1-800-446-8990.

LOCAL COMMITTEE

Department of Geology and Geophysics, Univ. of Hawai'i at Mānoa
School of Ocean and Earth Science and Technology
1680 East-West Rd., Honolulu, HI 96922, USA

Conference Chair: Craig R. Glenn, glenn@soest.hawaii.edu

Conference Vice-Chairs: Stephen Martel, smartel@hawaii.edu; Ralph Moberly, ralph@sost.hawaii.edu

Technical Program Co-Chairs: Henrietta Dulai, hdulaiov@hawaii.edu; Greg Moore, gmoore@hawaii.edu; Brian Popp, popp@hawaii.edu

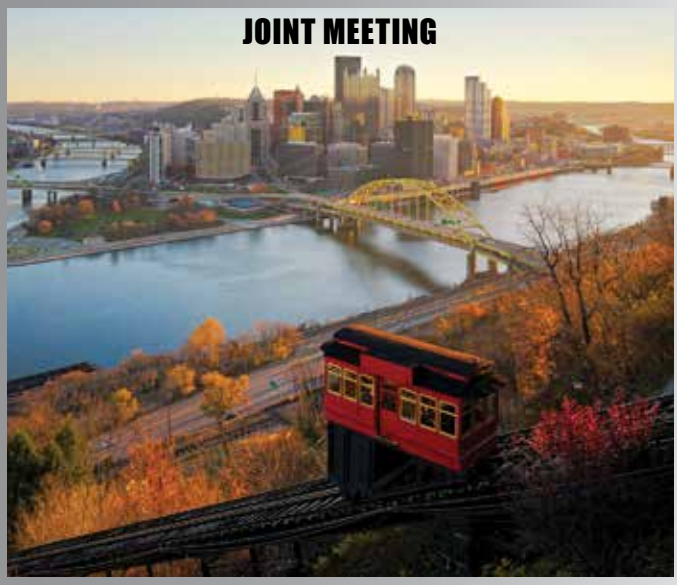
Field Trip Co-Chairs: Scott Rowland, scott@soest.hawaii.edu; Bruce Houghton, bhought@soest.hawaii.edu

Volcano on the Big Island. Halema'uma'u Crater. Photo by Ethan Tweedie.

2017 GSA Section Meetings

Aerial overview of the Canyon Lake spillway of south-central Texas. Photo by Larry Walther.

South-Central Section
Location: San Antonio, Texas, USA
Dates: 13–14 March
Meeting Chair: Benjamin Surpless, bsurples@trinity.edu
www.geosociety.org/Sections/sc/2017mtg/



Downtown Pittsburgh from Duquesne Incline.

Northeastern Section
(Joint with North-Central Section)
Location: Pittsburgh, Pennsylvania, USA
Dates: 19–21 March
Meeting Chair: Patrick Burkhart, patrick.burkhart@sru.edu
www.geosociety.org/Sections/ne/2017mtg/

North-Central Section
(Joint with Northeastern Section)
Location: Pittsburgh, Pennsylvania, USA
Dates: 19–21 March
Meeting Chair: Timothy G. Fisher,
timothy.fisher@utoledo.edu
www.geosociety.org/Sections/ne/2017mtg/

Midlothian Mines. Photo used with permission from Richmond Region Tourism.

Southeastern Section
Location: Richmond, Virginia, USA
Dates: 30–31 March
Meeting Co-Chairs: David Spears, david.spears@dmme
.virginia.gov; Karen Layou, klayou@reynolds.edu
www.geosociety.org/Sections/se/2017mtg/

Used with permission from Hawai'i Tourism Authority. Photo by Tor Johnson.

Cordilleran Section
Location: Honolulu, Hawaii, USA
Dates: 23–25 May
Meeting Chair: Craig R. Glenn, glenn@soest.hawaii.edu
www.geosociety.org/Sections/cord/2017mtg/

Dinosaur Provincial Park. Photo by Jenni Scott.

Rocky Mountain Section
Location: Calgary, Alberta, Canada
Dates: 9–10 June
Meeting Chair: Katherine Boggs, kboggs@mtroyal.ca
www.geosociety.org/Sections/rm/2017mtg/

www.geosociety.org/sections

Thank You

2016 GeoCorps™ America Participants, Partners, and Donors

GeoCorps provides paid geoscience opportunities in partnership with government agencies and other organizations committed to science and stewardship, including the Bureau of Land Management (BLM), and the USDA Forest Service. All levels of geoscientists—students, educators, professionals, retirees, and others—are encouraged to apply. Opportunities for spring/summer 2017 will be posted online and open for applications beginning next month.

Julia Franceschi

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Thank You

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The National Park Service (NPS) Geoscientists-in-the-Parks (GIP) program places college students and early career professionals (18–35 years old) in NPS units for three months to one year to assist with geology and integrated science projects. This program is a partnership between the NPS, GSA, and Environmental Stewards. Opportunities for spring/summer 2017 will be posted online and open for applications next month.

Matt Dieterich

Elliott Smith and colleagues

Anne Miller

Partners and Major Donors to the Geoscientists-in-the-Parks

Partners include

National Park Service

Environmental Stewards

Major donors include

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Sally and Robert Newcomb

Other Funding Sources Include

Badlands Natural History Association
Bryce Canyon Natural History Association
Devils Tower Natural History Association
Eastern National
The Friends of the Florissant Fossil Beds
Grand Canyon Association
Rocky Mountain Conservancy
The Madrona Institute
Western National Parks Association
Zion Natural History Association

2016 PARTICIPANTS

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Bandelier National Monument
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Carl Sandburg Home National Historic Site
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Stephanie Uriostegui

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Madison Armstrong
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Elizabeth Haddon

Geoscience Jobs & Opportunities

Positions Open

TENURE-TRACK, ASSISTANT PROFESSOR PETROLOGY/MINERALOGY UNIVERSITY OF GEORGIA

The Dept. of Geology at the University of Georgia seeks to fill a position for a tenure-track assistant professor in the field of petrology/mineralogy, welcoming applications from scientists in both the Earth and Planetary sciences to complement the department's growing focus in planetary sciences. We encourage applications from petrologists/mineralogists with strong backgrounds in chemistry and physics who may employ unconventional and interdisciplinary approaches to address big-picture questions including but not limited to petrologic and/or mineralogical aspects of planetary evolution involving core, mantle, and/or crustal processes. A Ph.D. in Geology, Earth or Planetary Science or other related discipline is required by August 1, 2017. The successful candidate must be comfortable teaching our undergraduate core curriculum classes in mineralogy and/or petrology, a graduate course in their specialty, as well as introductory courses in geology. The successful candidate will be expected to establish an externally funded research program to attract outstanding graduate students in their field, and our core electron microprobe facility with dedicated, long-standing technical support may be critical to that effort. Applicants should submit a cover letter, curriculum vitae, a statement of research and teaching interests and contact information for 3 references. Application materials should be uploaded to facultyjobs.uga.edu. Review of applications will begin January 16, 2017. The position will remain open until filled, but to ensure full consideration, all application materials should be submitted by 5 PM January 16, 2017.

The Franklin College of Arts and Sciences, its many units, and the University of Georgia are committed to increasing the diversity of its faculty and students, and sustaining a work and learning environment that is inclusive. The University is an Equal Opportunity/Affirmative Action employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability, gender identity, sexual orientation or protected veteran status. Georgia is well known for its quality of life in regard to both outdoor and urban activities (exploregeorgia.org). UGA is a land and sea grant institution located in Athens, 90 miles northeast of Atlanta, the state capital (www.visitathensga.com; www.uga.edu).

ASSISTANT PROFESSOR OF PLANETARY MATERIALS PURDUE UNIVERSITY

The Dept. of Earth, Atmospheric, and Planetary Sciences (EAPS), within the College of Science, Purdue University, invites applications for a tenure-track faculty position at the rank of Assistant Professor in the area of Planetary Materials. The Planetary Science Group within EAPS has an international reputation, extensive involvement in spacecraft missions, and newly developed undergraduate and graduate programs. We seek to grow and are looking for someone who conducts laboratory analysis of planetary materials or their terrestrial analogues. Candidates must have completed their PhD in an appropriate field. The appointee is expected to develop and maintain a vigorous, externally funded, internationally recognized research program and to teach and mentor students at the undergraduate and graduate levels.

Applications should be submitted electronically at https://hiring.science.purdue.edu. Applications should include a curriculum vitae, a statement of research, a teaching statement, and contact information of three individuals who can provide letters of reference. Questions related to this position should be addressed to Dr. Chris Andronicos (candroni@purdue.edu), Chair of the Search Committee. Review of applications will begin on December 1, 2016, and continue until the position is filled.

Purdue University is an EOE/AA employer. All individuals, including minorities, women, individuals with disabilities, and veterans are encouraged to apply.

ENDOWED CHAIR (ASSOCIATE/FULL PROFESSOR) OF UNCONVENTIONAL ENERGY PURDUE UNIVERSITY

The Dept. of Earth, Atmospheric, and Planetary Sciences at Purdue University invite applications for the Stephen and Karen Brand Chair in unconventional energy resources. Candidates with a core expertise in unconventional energy with a strong and consistent track record of applying this expertise to unconventional petroleum resources will be considered. Candidates with expertise including, but not limited to, unconventional exploration and production, tight reservoir characterization, geophysics and seismic data analysis, subsurface integration, hydraulic fracture mechanics, pore/fluid interactions, water and environmental issues, and enhanced oil and gas recovery are encouraged to apply. Excellence in and/or commitment to multidisciplinary research and teaching is a requirement. It is expected that the candidate hired would significantly enhance Purdue's visibility and impact in this key area; increase opportunities for industry collaboration and grant funding; and inspire and train the next generation of leaders in the field.

This is an open-rank search; senior or mid-career scientists with academic, national laboratory, and industry background are all encouraged to apply. Applicant must hold a doctorate in an appropriate field; salary and rank are commensurate with qualifications and experience. The Dept. of Earth, Atmospheric, and Planetary Sciences, and the College of Science at Purdue embrace diversity and seek candidates who will have experience working with diverse groups.

The department, in collaboration with other departments, has expertise in solid earth geophysics and crustal seismology, fracture mechanics, fluid flow in porous media, hydrogeology, clay mineralogy and surface chemistry, and basin analysis. The department has a long tradition of training students for careers in the petroleum industry and is part of a new multidisciplinary initiative at Purdue University aimed at addressing the energy needs of the country and is affiliated with the newly established Enhanced Oil Recovery Laboratory located in Discovery Park. Faculty members have a long history of working closely with and providing leadership to various Purdue University Discovery Park Centers (www.purdue.edu/DP). The successful applicant will conduct research, will advise graduate students, will teach undergraduate and graduate level courses, and will perform service. The successful applicant will be expected to work across these existing areas of Purdue expertise and build on them with a focus on unconventional resources. Applicants should have a vision for the design and execution of a cross-functional program that achieves the intended mission as described above.

Interested applicants should visit https://hiring.science.purdue.edu; submit a curriculum vitae, a research statement, a vision statement, a teaching statement, and complete contact information for at least 3 references. Review of applications will begin October 31, 2016, and continue until the position is filled. Questions related to this position should be sent to Ken Ridgway, Chair of the Search Committee, email ridge@purdue.edu. Applications will be accepted until the position is filled.

Purdue University is a dynamic, growing university and a great place to work. Our inclusive community of scholars, students and staff impart an uncommon sense of larger purpose and contribute creative ideas to further the university's mission of teaching, discovery and engagement.

Purdue University is an EOE/AA employer. Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. All qualified applicants for employment will receive consideration without regard to race, religion, color, sex, national origin or ancestry, genetic information, marital status, parental status, sexual orientation, gender identity and expression, disability or status as a veteran.

TENURE TRACK ASSISTANT PROFESSOR POSITION IN GEOMORPHOLOGY AND/OR COASTAL PHYSICAL OCEANOGRAPHY, DEPT. OF EARTH, OCEAN AND ATMOSPHERIC SCIENCE THE FLORIDA STATE UNIVERSITY

The Dept. of Earth, Ocean and Atmospheric Science (EOAS) at the Florida State University (FSU) announces a search for a tenure track Assistant Professor in coastal/land-sea processes, specifically Geomorphology and/or Coastal Physical Oceanography. Candidates must hold a Ph.D. or its equivalent in an Earth Science or closely related field. The successful applicant will be expected to develop an internationally visible research program, mentor students and postdocs and teach at the graduate and undergraduate levels. Interested parties should submit a cover letter, curriculum vita, statement of teaching and research and contact information for three references using FSU's electronic submission system at http://jobs.fsu.edu, job title# 40820.

EOAS has over 40 faculty members, approxi-

mately 160 graduate students, a diverse undergraduate population and grants graduate degrees in Meteorology, Oceanography, Geology and Aquatic Environmental Sciences. FSU resources include the Center for Ocean-Atmosphere Prediction Studies, the Geophysical Fluid Dynamics Institute and the National High Magnetic Field Laboratory. A recent research initiative at FSU emphasized Coastal and Marine Science by adding eight faculty members within the Departments of EOAS, Biological Science and Geography. This position continues to build on this initiative. Tallahassee is the capital city of Florida, home to three institutions of higher learning and was recently named an All-American City by the National Civic League.

Applications will be considered until the position is filled; those received by December 1, 2016 are assured of full consideration. Women and members of minority groups are especially encouraged to apply. Please direct questions to Profs. William K Dewar (wdewar@fsu.edu) and Vincent Salters (vsalters@fsu.edu).

An Equal Opportunity/Access/Affirmative Action Employer. Florida State University subscribes to Equal Opportunity and complies with the Americans with Disabilities Act. All eligible candidates are invited to apply for position vacancies as appropriate. Florida State University is a public records agency pursuant to Chapter 119, Florida Statues.

GEOCHEMISTRY RESEARCH ASSOCIATE 2, WESTERN WASHINGTON UNIVERSITY

Geochemistry Research Associate 2 (LA-ICP-MS). Western Washington University invites applications for a professional staff position, with the primary role being to train, supervise, and assist students, faculty and visitors in the operation of the LA-ICP-MS for geoscience applications. We expect the person we hire to collaborate with faculty and students on research projects, to develop and pursue projects and proposals for external funding, and to refine and develop laboratory methods and procedures for geoscience applications of geochemistry. Required qualifications for the position are 1) M.S. in geoscience or physical science 2) Minimum 1 year of experience maintaining LA-ICP-MS instrumentation and performing data reduction for geological samples 3) Computer skills (e.g. Glitter, or other LA-ICP-MS data reduction software) 4) Demonstrated commitment to work effectively with a diverse student body 5) Good oral and written communication skills. For full position announcement, including all required and preferred qualifications, and to apply, see https://jobs.wwu.edu/JobPosting.aspx?JPID=7163. Review of applications begins Oct 19, 2016; position is open until filled. To apply, submit a letter of application that specifically addresses the listed job qualifications, a current vita, and three professional references to WWU's Electronic Application System for Employment (linked to electronic job posting). Questions regarding this position should be directed to Bernard Housen (Bernard.housen@wwu.edu) or Susan DeBari (susan.debari@wwu.edu). position is open until filled. WWU is an EO/AA employer and encourages applications from women, minorities, persons with disabilities, and veterans.

WIESS VISITING PROFESSOR DEPT. OF EARTH SCIENCE RICE UNIVERSITY

We are soliciting applications for the Wiess Visiting Professor in the Dept. of Earth Science at Rice University. Our department has lively research programs in

1. Carbonate and Clastic Sedimentology and Coastal Processes
2. Paleoclimatology
3. Atmospheric Chemistry
4. Biogeochemistry
5. Geobiology
6. Low and High Temperature Geochemistry
7. Petrology
8. Rock Physics and Geomechanics
9. Environmental, Exploration, Solid Earth and Theoretical Seismology
10. Crustal and Mantle Structure and Geodynamics,
11. Planetary Science

We invite applications from established scientists whose research falls in any of these areas, and request that you identify one or more of our faculty whose research interests overlap yours. The department is characterized by collegiality and interdisciplinary research. Our faculty have ties to the Rice Departments of Biosciences, Chemistry, Computational and Applied Mathematics, Mechanical Engineering, and Physics and Astronomy. We also have strong ties to the local petroleum industry, the NASA Johnson Space Center, and the Lunar Planetary Institute.

The Wiess Visiting Professorship provides travel expenses to and from Rice, and living expenses while in residence, details are negotiable. Visiting Professors are typically in residence from a few months to a full academic year. Ideally Wiess Visiting Professors interact at a high level with members of our department, often through topical seminars. We particularly encourage women and minority geoscientists to apply.

See: http://earthscience.rice.edu for more details about our Department, and http://earthscience.rice.edu/directory/wiess-visiting-professor/ for a list of previous Wiess Visiting Professors.

Please provide a curriculum vita, research statement, and indication of availability. Applications and inquiries can be sent to: Chair, Wiess Visiting Professor Committee, Dept. of Earth Environmental and Planetary Science, Rice University, MS-126, 6100 Main Street, Houston, TX 77005; or esci-search@rice.edu. Please put Wiess Visiting Professor on the subject line.

Rice University, located in Houston, Texas, is a private, coeducational, nonsectarian university that aspires to path-breaking research, unsurpassed teaching, and contributions to the betterment of our world. Rice fulfills this mission by cultivating a diverse community of learning and discovery that produces leaders across the spectrum of human endeavor. From its beginning in 1912, Rice has been dedicated to excellence in all regards.

Rice University is an Equal Opportunity Employer with commitment to diversity at all levels, and considers qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national or ethnic origin, genetic information, disability or protected veteran status.

ASSISTANT/ASSOCIATE PROFESSOR OF INVERTEBRATE PALEONTOLOGY, DREXEL UNIVERSITY

The Dept. of Biodiversity, Earth & Environmental Science at Drexel University seeks applicants for a tenure-track assistant or associate professor appointment in invertebrate paleontology. Areas of interest include, but are not limited to, Systematic and Evolutionary Biology, Paleoecology, Climatology and Conservation Paleobiology, with the aim of deploying paleontological data to understand patterns of global change. The successful candidate will develop a research program in their subject area; will teach courses in Invertebrate Paleontology and Stratigraphy, and other potential courses; and will be Curator of the Invertebrate Paleontology collection at Drexel's Academy of Natural Sciences. The ability to collaborate with other research groups at the university, such as Environmental Biogeochemistry and Environmental Engineering, is a plus. Drexel University emphasizes experiential learning and field-oriented candidates are encouraged to apply.

Candidates must have a Ph.D. in Geology, Invertebrate Paleontology or a related field, a record of scientific achievement, a strong interest in undergraduate and graduate teaching, and must be able to develop a high-quality, externally-funded research program. For the Associate level, the candidate must demonstrate extramural funding.

Qualified candidates should submit a cover letter, CV, a summary of research experience, a statement of teaching philosophy, and a list of three or more references with postal address, email address, and telephone number.

Applicants should apply online at drexeljobs.com (Position # 7849). Review of applications will begin December 1st, 2016 and will continue until the position is filled. Inquires may be sent to Dr. Gary Rosenberg, Search Committee Chair at gr347@drexel.edu.

Drexel University is an Equal Opportunity/Affirmative Action Employer and is proactively committed to diversity and inclusion in all of its policies, practices and services. We are especially interested in qualified candidates who can contribute to the varied diversity and excellence of the academic community, and all of its complements.

ASSISTANT PROFESSOR GISCIENCE, 9-MONTH, FULL-TIME UNIVERSITY OF SOUTH FLORIDA

The School of Geosciences at the University of South Florida seeks to fill a 9-month, full-time and tenure-earning, Assistant Professor position in the field of GIScience with an emphasis on spatial analysis, statistics, and modelling. The successful candidate could have any research specialty, though preference may be given to candidates with strengths in medical geography, transportation, or human security. The successful candidate will be expected to develop an externally funded research program, mentor graduate students, and teach undergraduate and/or graduate courses. Salary is negotiable.

Additional information is available at the School of Geosciences website: http://hennarot.forest.usf.edu/main/depts/geosci/ or by emailing the search committee chair, Dr. Joni Downs (downs@usf.edu).

Minimum Qualifications: Ph.D. in Geography

or related field is required and must be conferred by appointment start date.

This position is subject to a criminal background check. USF is an Equal Opportunity/Equal Access Institution that embraces diversity in the workplace

First review of applications begins on November 15, 2016. This position is open until filled.

Apply online at USF Careers www.usf.edu/administrative-services/human-resources/careers/.

JOINT APPOINTMENT GEOLOGY & GEOPHYSICS DEPT. AND THE ENERGY & GEOSCIENCE INSTITUTE, UNIVERSITY OF UTAH

The Dept. of Geology and Geophysics (GG) and the Energy & Geoscience Institute (EGI) at the University of Utah invite applications for a position equally split between GG and EGI, to begin Fall Semester 2017. The position in GG will be at the Associate Professor or Professor level with the possibility of tenure at appointment; the position at EGI will be at the level of Senior Research Scientist. The successful candidate will bring expertise in energy geoscience, and will develop a strong, externally funded, and internationally recognized research program involving students and supported by industry and government resources. We seek experts with skill sets that can be broadly applied to current and future energy systems, including hydrocarbon and renewable energies, as well as allied fields in carbon science measurement and mitigation such as carbon capture and storage or other geo-engineered solutions. Candidates must have a completed Ph.D. at the time of appointment and a strong record of research and publication. The appointee will participate in collaborative, bridge-building efforts between GG and EGI and will have offices at both locations. More information can be found online at www.earth.utah.edu and www.egi.utah.edu.

To apply, upload a letter of application, curriculum vitae, names and contact information for three references, and statements of research and teaching interests to http://utah.peopleadmin.com/postings/52704. Review of applications will begin July 15, 2016, but applications may be considered until the position is filled. Questions should be addressed to Cari Johnson (Cari.Johnson@utah.edu) and Ray Levey (RLevey@egi.utah.edu).

The University of Utah is an Equal Opportunity/Affirmative Action employer and educator. Minorities, women, and persons with disabilities are strongly encouraged to apply. Veterans preference. Reasonable accommodations provided. For additional information, see www.regulations.utah.edu/humanResources/5-106.html. The University of Utah values candidates who have experience working in settings with students from diverse backgrounds, and possess a strong commitment to improving access to higher education for students from historically underrepresented groups.

ASSISTANT PROFESSOR OF EARTH AND ATMOSPHERIC SCIENCES (VERTEBRATE PALEONTOLOGY) UNIVERSITY OF NEBRASKA–LINCOLN

Applications are invited for a tenure track position as Assistant Professor with specialization in vertebrate paleontology in the Dept. of Earth and Atmospheric Sciences at the University of Nebraska-Lincoln. The main duties of the successful candidate will be to develop an active and rigorous research program that is supported by external funding and to teach undergraduate and graduate courses. In addition, the candidate will co-supervise curation of the internationally significant mammal collections within the Vertebrate Paleontology Division of the University of Nebraska State Museum (UNSM). We seek applicants with research and teaching interests that complement departmental strengths in the related fields of paleontology, sedimentary geology, and paleoclimatology. The candidate should demonstrate strong potential for research and teaching and must hold a Ph.D. in a related field at the time of appointment. Female and ethnic minority candidates are strongly encouraged to apply.

The Sedimentary Geology and Paleontology program is one of the primary components of the Dept. of Earth and Atmospheric Sciences. The department offers B.S. degrees in Geology and Meteorology/Climatology, as well as M.S. and Ph.D. degrees in Earth & Atmospheric Sciences. Find out more about our department at http://eas.unl.edu/. The UNSM fossil vertebrate collection contains some 1.5 million specimens, over 90% of which are mammals ranging in age from late Eocene to Holocene, and provides outstanding opportunities for research. For more about the museum see: http://museum.unl.edu/research/index.html.

To apply, go to http://employment.unl.edu/postings/51184 and complete the "faculty/administrative form." Applicants must attach a cover letter, curriculum vitae, statement of research, teaching, and curatorial interests, and names of at least three references via the above website. We will begin to review applications on November 15, 2016, but the position will remain open for applications until it is filled.

The University of Nebraska-Lincoln is committed to a pluralistic campus community through affirmative action, equal opportunity, work-life balance, and dual careers. Please see www.unl.edu/equity/notice-nondiscrimination.

For further information contact, Dr. David K. Watkins, Search Committee Chair by email, phone, or mail at: dwatkins1@unl.edu; 1-402-472-2177; Dept. of Earth and Atmospheric Sciences, University of Nebraska-Lincoln, 214 Bessey Hall, Lincoln, NE 68588-0340.

TENURE-TRACK FACULTY POSITION INTEGRATED HYDROCLIMATE MODELER, DEPT. OF GEOLOGICAL SCIENCES, UNIVERSITY OF ALABAMA

The University of Alabama (UA) Dept. of Geological Sciences invites applications for a tenure-track faculty position in integrated hydroclimate modeling, beginning August 2017. The position will be filled at the Assistant Professor level. Candidates must have a strong record of research and a Ph.D. by the time of appointment in hydro-climate systems science, water-atmospheric science, and/or a closely related field, preferably with specialization in integrated modeling of atmospheric processes and hydrologic response, as they impact water management, availability, distribution, and sustainability. The candidate's research would ideally aim to understand and model the movement of water between the atmosphere, land surface, soil, and/or subsurface reservoirs, and how changes in future climate affect water resources and/or environment from regional to global scales. The successful candidate will be expected to establish a strong, externally-funded research program and to attract high-quality Ph.D. and M.S. graduate students. The candidate will also be expected to teach introductory courses related to their field and undergraduate and graduate courses in hydroclimate sciences and modeling, water resources, and water-atmosphere interactions, advise graduate students, and contribute to the Department's research program in water resources and environmental geology. Existing working relationships and collaboration with entities such as NOAA, NASA, USGS, NCAR, DOE, and/or NSF is seen as positive. Opportunities for research collaboration also exist with the NOAA National Water Center, the Environmental Institute, the Geological Survey of Alabama, the Center for Sedimentary Basin Studies, the Center for Freshwater Studies, and the Water Policy and Law Institute, all located on The University of Alabama campus. The Department has a broad range of resources and existing facilities, including modeling and computational resources, field and laboratory equipment, and chemical and stable isotope analytical facilities. Questions should be directed to Dr. Geoff Tick (gtick@ua.edu), Chair of the Integrated Hydroclimate Modeler Search Committee. Applicants should submit a cover letter, curriculum vitae, research statement, teaching statement, and names and contact information for at least three referees through the UA Jobs Website at: https://facultyjobs.ua.edu/postings/39236. Review of applications will begin December 1, 2016, and continue until the position is filled. The University of Alabama is an equal opportunity/affirmative action employer and actively seeks diversity in its employees. Minority and women candidates are especially encouraged to apply.

ASSISTANT PROFESSOR STABLE ISOTOPE GEOCHEMISTRY WESTERN WASHINGTON UNIVERSITY

About the Position: Applications are invited for a tenure track Assistant Professor position in Stable Isotope Geochemistry in the Geology Dept. at WWU in Bellingham, WA, with an expected start date of September 2017. We encourage applications from candidates from underrepresented backgrounds who are interested in this faculty position.

Position Responsibilities: The ideal candidate will enhance our existing strengths in geoscience teaching and research by developing new courses and research avenues in stable isotope geochemistry applied to any of a diverse range of geoscience problems. Areas of interest include, but are not limited to paleoclimatology/paleolimnology/paleoceanography/paleoecology, fluid flow and fluid-rock interactions, applications of stable isotopes to (bio) geochemical processes and (bio)mineralization. The applicant will be expected to successfully contribute to the department's course and curricular offerings, establish a successful research program that includes BS and MS students and securing external funding for support of major research instrumentation, work with department faculty and staff to develop

connections to WWU departments and programs in marine and environmental sciences and allied fields. The faculty member will be expected to participate in service activities, including departmental committees and student advising.

Required Qualifications: Earned doctorate by hire date in the geosciences with an emphasis and experience in stable isotope geochemistry; Record of or potential for high quality undergraduate teaching; Commitment to establishing a vigorous research program involving graduate and/or undergraduate students; Ability to establish an externally-supported research program; Demonstrated commitment to working effectively with a diverse student body.

Preferred Qualifications: Post-doctoral research experience in the geosciences; Experience teaching in a BS and/or graduate program; Ability and interest to work with other interdisciplinary programs in materials science, marine and environmental science; Experience or demonstrated ability managing geochemistry research lab.

Application Instructions: Applications must include (1) a detailed cover letter that addresses the required and preferred qualifications and describes the applicant's background and interest in joining the department, (2) a statement outlining the candidate's plans and approaches for teaching and course development at WWU, including a statement on how the applicant's background and experiences (academic and non-academic) have prepared them to effectively teach increasingly diverse students and work effectively with diverse colleagues, (3) a detailed research statement including plans for laboratory development and undergraduate/graduate student involvement in future research projects, (4) a full curriculum vitae including the names, addresses, e-mail addresses, and telephone numbers of three professional references, and (5) undergraduate and graduate transcripts. Submit all application material to the WWU Electronic Application System for Employment (https://jobs.wwu.edu/JobPosting.aspx?JPID=7158). Inquiries may be addressed to Prof. Brady Foreman at (360) 650-2546 or Brady.Foreman@wwu.edu. WWU is an AA/EO employer. For disability accommodation call (360) 650-3774. Review of applications begins December 19, 2016; position open until filled.

FACULTY POSITION IN PLANETARY MINERALOGY/PETROLOGY/ GEOCHEMISTRY, UNIVERSITY OF TENNESSEE, KNOXVILLE

The Dept. of Earth & Planetary Sciences at The University of Tennessee seeks to fill a faculty position in mineralogy/ petrology/geochemistry with emphasis in planetary geoscience at the rank of Assistant Professor. The position begins August 1, 2017. The University of Tennessee, Knoxville, is a Research I University and the flagship campus of the UT system. The Dept. (http://eps.utk.edu) focuses on geology and has an active emphasis on planetary research, including the study of terrestrial analogs, through its Planetary Geosciences Institute (http://web.utk.edu/~pgi). Requirements for the position are: Ph.D. in geology or a related field, and demonstrated research experience in planetary/ terrestrial geoscience.

The successful candidate is expected to conduct a robust, funded program of planetary/terrestrial research, mentor graduate students, effectively teach courses in mineralogy and/or petrology at the undergraduate and graduate levels, and collaborate in department research dealing with mineralogy, petrology, geochemistry, and solar system exploration. Salary and benefits are competitive and commensurate with experience. The Knoxville campus of the University of Tennessee is seeking candidates who have the ability to contribute in meaningful ways to the diversity and intercultural goals of the University.

To apply, please email the following to jmoersch@utk.edu, with the subject line "Planetary faculty application": C.V., cover letter describing research and teaching experience and plans, and names of 4 references with contact information. Applications received by November 15, 2016, are ensured review, but earlier submission is encouraged. The position will remain open until filled. Questions about the position should be directed to J. Moersch.

The University of Tennessee is an EEO/AA/Title VI/Section 504/ADA/ADEA institution in the provision of its education and employment programs and services. All qualified applicants will receive equal consideration for employment without regard to race, color, national origin, religion, sex, pregnancy, marital status, sexual orientation, gender identity, age, physical or mental disability, or covered veteran status.

ASSISTANT PROFESSOR MARINE/COASTAL GEOLOGY/ GEOCHEMISTRY, COLBY COLLEGE, WATERVILLE, MAINE

The Colby College Dept. of Geology invites applications for a tenure-track position in marine geology/geochemistry at the level of Assistant Professor to begin September 1, 2017. This position is part of a cluster hire in support of Colby's new Environmental Science initiative. Colby requires strong, innovative teaching at all levels of the undergraduate curriculum and an active research program involving undergraduate collaborators. Ideal candidates for this position also will (1) teach a 200-level, low-temperature-geochemistry or biogeochemistry course in addition to other courses in the Geology Department; (2) present ambitious research plans focusing on the marine/coastal record of environmental change over 100–1,000,000-year timescales; and (3) strengthen collaborations between Colby College and the Bigelow Laboratory for Ocean Sciences on the coast of Maine (www.bigelow.org). There also are opportunities for collaborations with scientists at Colby and other nearby institutions including the University of Maine Climate Change Institute, Bowdoin College, and Bates College. A Ph.D. is required at the time of appointment. The search committee is especially interested in candidates with diverse perspectives and backgrounds, and candidates who have a record of success advising and mentoring individuals from groups underrepresented in higher education.

Tenure-track faculty at Colby receive competitive startup packages and are eligible for a pretenure sabbatical. Female U.S. citizens are eligible for a Clare Booth Luce Endowed Chair that provides additional research funding throughout their pretenure probationary period. Colby faculty are afforded professional travel funding, and can apply for divisional research grants and summer research-assistant funding on a competitive basis. More information about the resources and instrumentation available at Colby and collaborating institutions can be found at www.colby.edu/geologydept and www.colby.edu/environmentalstudies.

Complete applications will include a brief cover letter, curriculum vitae, statements of teaching philosophy and research interests, three letters of recommendation, and reprints of recent journal articles. Please submit all materials via Interfolio at: apply.interfolio.com/37632. Applications received by November 30, 2016 will receive full consideration, but applications will be reviewed until the position is filled. Inquiries may also be directed to Marinegeo@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 discrimination 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.

FULL-TIME, TENURE-TRACK ASSISTANT PROFESSOR AUGUSTANA COLLEGE

Geology: Augustana College, Rock Island, Illinois, invites applications for a full-time, tenure-track assistant professor in geology beginning August 2017. We seek a colleague, committed to excellence in teaching, advising, mentoring, and research involving our diverse undergraduates, who is a broadly trained geoscientist with expertise in paleontology, stratigraphy and/or sedimentology, and who should be able to capitalize on and help oversee the extensive collections of the Augustana's Fryxell Geology Museum. The successful candidate will teach a range of undergraduate courses and will advise students on directed research projects. In addition, the successful candidate must contribute to field trips and seek ways to collaborate with other programs on campus. The application deadline is December 16, 2016. Application instructions and more information can be found at https://academicjobsonline.org/ajo/jobs/7825 . Augustana College is an equal opportunity employer and actively encourages applications from women and persons of diverse ethnic backgrounds. We do not discriminate based on age, race, color, ethnic origin, gender, sexual orientation, disability or creed.

TENURE-TRACK POSITION IN SEDIMENTARY GEOLOGY AND PALEOCLIMATOLOGY, UNIVERSITY OF MARY WASHINGTON

The Dept. of Earth and Environmental Sciences at the University of Mary Washington seeks applications for a full-time, tenure-track position at the rank of Assistant Professor to begin Fall 2017. Candidates must have expertise in sedimentary geology and paleoclimatology. Additional expertise in estuarine/coastal processes, paleontology, or closely related fields is desirable. The successful candidate will teach classes in introductory geology and oceanography, upper-level undergraduate classes in sedimentation/stratigraphy and Earth's climate history, and other classes in their area of expertise. The successful candidate must also be able to mentor undergraduate research students and engage them in fieldwork. Candidates must possess the Ph.D. in an appropriate discipline at the time of appointment.

The University of Mary Washington is a primarily undergraduate, public, liberal arts institution that stresses teaching excellence and the engagement of students in research. The University is located in the Chesapeake Bay watershed on the margin between the Coastal Plain and Piedmont of Virginia, with nearby access to Washington, D.C. (including the Smithsonian Institute), the Chesapeake Bay, and Appalachian Mountains. The Department currently has expertise in GIS, structural geology, mineralogy/petrology, soil science, watershed analysis, aquatic ecology, hydrology, environmental geochemistry, and environmental policy, and is well equipped for sedimentological work, with sampling and coring equipment, subbottom profiling instrumentation, and a new 22-ft research boat. Faculty in the Department work closely with those in the Biology and Chemistry departments and have access to well-equipped, shared laboratories with instrumentation for the chemical analysis of water, soil, and sediment (e.g., variable-pressure SEM, ICP-AES, GC-MS, etc.).

To obtain additional information about the Department or University, please visit our websites at https://cas.umw.edu/ees/ and https://www.umw.edu. Applications must be submitted online via the UMW Careers site at https://careers.umw.edu. Only applications submitted through the university site will be considered; faxed, mailed, or emailed applications or documentation will not be considered. A complete application package includes a completed online application form, letter of application, curriculum vitae, undergraduate and graduate transcripts, a brief statement of teaching philosophy, a brief statement of how undergraduate students would be engaged in research, and contact information for three references. The deadline for application submission is November 15, 2016. Send e-mail enquiries to jhayob@umw.edu.

The University of Mary Washington seeks to enrich its academic environment by continuing to provide equal educational and employment opportunities. We actively encourage women, minorities, individuals with disabilities, and veterans to apply. Employment offers are contingent upon the successful completion of criminal background checks.

APPLIED GEOINFORMATICS DARTMOUTH COLLEGE

The Dept. of Earth Sciences at Dartmouth College invites applications for a junior rank tenure-track position in the area of geoinformatics with application to one or more of our core research areas including (i) ice and climate systems, (ii) water and environmental biogeochemistry, and (iii) planetary evolution and surface processes. We especially welcome applications from candidates who link traditional geologic approaches and state-of-the-art computational geoinformatics in their research. Particular attention will be given to candidates who combine a focus on understanding fundamental processes with laboratory and/or field research programs that complement and contribute to ongoing research activities in the Departments of Earth Sciences, Mathematics, and Computer Sciences, as well as the Thayer School of Engineering. The successful candidate will continue Dartmouth's strong traditions in graduate and undergraduate research and teaching. Teaching responsibilities consist of three courses spread over three of four ten-week terms.

The Dept. of Earth Sciences is home to 11 tenured and tenure-track faculty members in the School of Arts and Sciences, and enjoys strong Ph.D. and M.S. programs and outstanding undergraduate majors. To create an atmosphere supportive of research, Dartmouth College offers new faculty members grants for research-related expenses, a quarter of sabbatical leave for each three academic years in residence, and flexible scheduling of teaching responsibilities.

Dartmouth College has undergraduate and graduate student populations that are diverse by many measures. We seek applicants with a record of successful teaching and mentoring of students from all backgrounds (including first-generation college students, low-income students, racial and ethnic minorities, women, LGBTQ, etc.). Dartmouth provides opportunities to participate in undergraduate diversity initiatives in STEM research, such as our Women in Science Program, E. E. Just STEM Scholars Program, Academic Summer Undergraduate Research Experience (ASURE), and the Mellon Mays Undergraduate Fellowship.

Dartmouth, a member of the Ivy League, is located in Hanover, New Hampshire (on the Vermont border). Dartmouth has a beautiful, historic campus located in a scenic area on the Connecticut River. Recreational opportunities abound all year round.

To learn more about Dartmouth College and the Dept. of Earth Sciences, visit www.dartmouth.edu/~earthsci.

To submit an application, upload a cover letter, curriculum vitae, statements of teaching and research interests and objectives, reprints or preprints of up to three of your most significant publications, and the name, address (including street address), e-mail address and fax/phone numbers of at least three references to: http://apply.interfolio.com/20038.

Application review will begin November 1, 2016, and continue until the position is filled. The appointment will be effective July 1, 2017.

Dartmouth College is an equal opportunity/affirmative action employer with a strong commitment to diversity. In that spirit, we are particularly interested in receiving applications from a broad spectrum of people, including women, minorities, individuals with disabilities, veterans or any other legally protected group.

WIESS POST-DOCTORAL RESEARCH FELLOWSHIP, DEPT. OF EARTH SCIENCE, RICE UNIVERSITY

The Dept. of Earth Science at Rice University is inviting applications for the Wiess Post-Doctoral Research Fellowship in the broad fields of Earth, atmospheric, and planetary sciences.

Applicants must have a Ph.D. awarded within three years of the time of appointment.

The research fellowship will be supported by the Dept. of Earth Science for two years pending satisfactory progress in their first year. The fellowship covers an annual stipend of $60,000 with a benefits package and an additional annual discretionary research allowance of $3,500.

Applicants are requested to develop a proposal of research to be undertaken during the fellowship period. The principal selection criteria are scientific excellence and a clearly expressed research plan to address questions at the forefront of Earth science, broadly defined. Applicants are encouraged to explore possible research synergies with faculty in the Dept. of Earth Science (http://earthscience.rice.edu), but the proposed research should encompass independent research ideas and explore new directions beyond the applicant's Ph.D. Preference will be given to candidates whose proposals demonstrate independence and originality, and also the potential for collaboration with one or more faculty in the Dept. of Earth Science.

Candidates are required to submit: (1) A cover letter addressed to the search committee chair; (2) A research proposal of no more than 3 pages (single-spaced) including figures; (3) A current CV, including a list of publications.

All documents should be submitted as a single PDF file by 15 November, 2016, to the chair of the fellowship search committee (esci-postdoc@rice.edu). In addition, three letters of reference should be submitted separately by each referee to the chair of the fellowship chair committee (esci-postdoc@rice.edu) by 15 November, 2016.

The highest ranked candidates will be invited to visit Rice in early 2017. Following acceptance, the appointment may begin any time before January 1st 2018. For further information or questions contact the chair of the search committee at esci-postdoc@rice.edu.

Rice University, located in Houston, Texas, is a private, coeducational, nonsectarian university that aspires to path-breaking research, unsurpassed teaching, and contributions to the betterment of our world. Rice fulfills this mission by cultivating a diverse community of learning and discovery that produces leaders across the spectrum of human endeavor.

Rice University is an Equal Opportunity Employer with commitment to diversity at all levels, and considers for employment qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national or ethnic origin, genetic information, disability or protected veteran status.

ASSISTANT PROFESSOR OF GEOLOGY, CALIFORNIA STATE UNIVERSITY BAKERSFIELD

The Dept. of Geological Sciences at California State University Bakersfield (CSUB) invites applications for tenure-track Assistant Professor position beginning in Fall 2017. We seek a broadly trained Geologist with a preferred specialization in engineering geology, soil science, or hydrology/aqueous geochemistry. Review of applications will begin December 1, 2016 and continue until the position is filled. CSUB fosters and appreciates ethnic and cultural diversity among its faculty and students, and is committed to increasing the diversity of its faculty to reflect the diversity of the campus community. Applications from women, ethnic minorities, veterans, and individuals with disabilities are welcome. The full announcement and instructions on how to apply can be found at www.csub.edu/geology/_files/Geology-TT-Search-2016-position-announcement%20PDF.pdf.

ASSOCIATE OR FULL PROFESSOR IN ENVIRONMENTAL GEOSCIENCES DEPT. OF EARTH & ENVIRONMENTAL SCIENCES, RENSSELAER POLYTECHNIC INSTITUTE Troy, New York 12180-3590

The Dept. of Earth & Environmental Sciences at Rensselaer Polytechnic Institute in Troy, NY invites applications for the position of Associate or Full Professor in Environmental Geosciences, with emphasis on individuals with research interests in the areas of environmental geochemistry, hydrogeology, environmental remote or local sensing, global climate science/modeling (paleo or future), environmental data analysis, or environmental field-imaging visualization.

The successful candidate will have duties that include teaching graduate and undergraduate courses in the Dept. of Earth & Environmental Sciences, fulfilling the duties of the Director of the Environmental Sciences undergraduate program, developing and maintaining robust programs of research and scholarship, and providing service to the department, the School of Science, and to Rensselaer.

Rensselaer has recently initiated several bold, new initiatives; the successful candidate should interface with one or more of these areas. Examples of these include the Rensselaer Institute for Data Exploration and Applications (IDEA; http://idea.rpi.edu), the Darrin Fresh Water Institute (DFWI), a comprehensive freshwater ecological field station and Institute-wide research effort that hosts The Jefferson Project at Lake George (http://jeffersonproject.rpi.edu). In addition, the Institute is conceptualizing a new, broader initiative that will bring together research and education activities in water, environment, ecology, and sustainability.

The successful candidate will have a Ph.D. or foreign degree equivalent in geoscience or related discipline, along with the ability to demonstrate, through accomplishments achieved over a post-graduate academic career of seven or more years, an international reputation and record of excellence in scholarship, along with a sustained level of high quality educational activities including teaching and advising, and a significant level of professional service.

To apply, applicants must submit as single pdf document a curriculum vitae, a statement of research accomplishments and goals, a description of teaching interests, and a list of four professional references to: E&ES Faculty Search, Dept. of Earth and Environmental Sciences, Rensselaer Polytechnic Institute, 110 8th Street, Troy, NY 12180-3590; Email: spearf@rpi.edu (electronic submissions are preferred). Up to four select publications may be sent as separate files. Consideration of candidates will begin upon receipt of application. Applications are encouraged by midnight, December 24, 2016, and recruiting will continue until the position is filled. Preliminary interviews will be conducted at GSA and AGU in Fall 2016.

We welcome candidates who will bring diverse intellectual, geographical, gender, and ethnic perspectives to Rensselaer's work and campus communities. Rensselaer Polytechnic Institute is an Affirmative Action/Equal Opportunity, Race/Gender/Veterans/Disability Employer.

Opportunities for Students

Lindahl Ph.D. Scholarships, The University of Alabama. The University of Alabama, Dept. of Geological Sciences seeks Ph.D. students with specializations that complement faculty research interests. Exceptional students will receive Research or Teaching Assistantships and a Lindahl Scholarship totaling $22,000 for a nine month appointment, and the cost of non-resident tuition is covered. Funding is renewable for 4 years if expectations are met. Other fellowships are available from the Graduate School. Further details are at www.geo.ua.edu/. Applicants should contact Dr. Robinson (dmr@ua.edu) to express interest. Review of applications for Fall 2017 admission will begin January 15, 2017.

Graduate Assistantship Opportunities at Indiana University–Purdue University Indianapolis (IUPUI). With broad expertise in applied geosciences and particular strengths in Geochemistry, IUPUI's Earth Sciences department provides opportunities for graduate training and research in the heart of downtown Indianapolis. We offer an M.S. in Geology and a Ph.D. in Applied Earth Sciences. The Ph.D. program provides opportunities for advanced interdisciplinary research at the interface of earth sciences, public health, and geospatial analysis, and will prepare graduates for tackling interdisciplinary problems of the 21st century. Given the interdisciplinary nature of this program, we welcome individuals with backgrounds in Geology, Environmental Science, Chemistry, Biology, Physics, Engineering, Medical or Mathematics and who have an interest in working on earth and environmental science issues. Several new state-of-the-art geochemistry labs have been built and equipped with stable isotope ratio mass spectrometers, cavity ring down spectrometers, GC-MS, ICP-MS, ICP-OES, electrochemical equipment, chromatographs (IC, HPLC, GC), spectroscopes, XRD, multisensor core scanner, and a full suite of chemical and biological lab and field equipment. Assistantships include salary, tuition remission, and health insurance. Visit http://earthsciences.iupui.edu/graduate/degrees for more information on our graduate degrees, or contact Dr. Pierre Jacinthe for general inquiries at:pjacinth@iupui.edu.

MS Student in Structural Geology, University of Alaska Anchorage. Opportunity for a fully-funded, graduate student research assistantship position broadly in the field of structural geology at the University of Alaska Anchorage (www.uaa.alaska.edu/geology) beginning in the Spring 2017 or Fall 2017 semester. Our MS degrees in geological sciences are offered through the UAA Interdisciplinary Studies program (www.uaa.alaska.edu/academics/college-of-arts-and-sciences/departments/geology/ms-inds-geol.cshtml). Applicants must have a BS in geology or a closely related field. Please note that acceptance into the university is not a guarantee of funding. Inquiries may be sent to Dr. Simon Kattenhorn (skattenhorn@alaska.edu).

Check out the Job Board for the latest recruitment postings.

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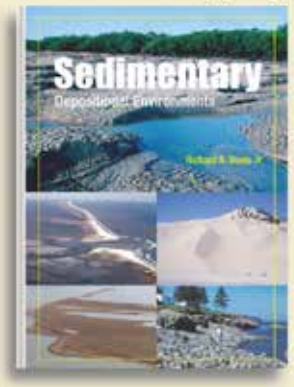

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CONTENTS

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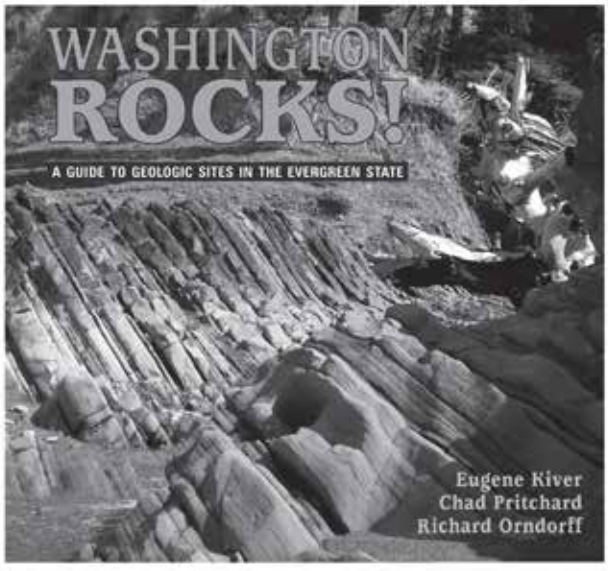

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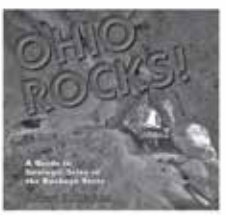

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John W. (Jack) Hess, *GSA Foundation President*

GSA Members Lead the Foundation

The Geological Society of America Foundation is fortunate to have the leadership of prominent, dedicated geologists to govern its activity and efforts. The 17 members of the Board of Trustees generously volunteer their time and expertise to guide the Foundation in supporting GSA priorities. While their presence is often behind-the-scenes, their impact on the success of GSAF is significant.

The following five Trustees made up the 2016 Executive Committee of the Board; the Foundation values their service.

Margaret Eggers, Ph.D., current Chair, is in her second term as a GSAF Trustee. Her extensive background in consulting, and with her own independent consulting firm for the last thirteen years, brings effective leadership to the group and to the Foundation's direction. Eggers captures the sentiment of the Board:

> Service on the GSAF Trustee Board is a wonderful opportunity to personally have an impact on our core mission of supporting GSA's programs. This collegial group consists of professional geologists from consulting, government service, and academia that work together to increase the support and success of programs in mentoring, support for student research, and to enhance the voice for geosciences in the public arena. As a member of this Board and its Executive Committee, I have found this to be a personally rewarding experience, a true opportunity to work with other geologists to "pay it forward" by supporting geosciences as a career path for young students who are also passionate about our science and the world around us.

Vice Chair **George Linkletter, Ph.D.,** brings a corporate perspective to the Trustees from his former role as Principal and Senior Vice President at ENVIRON International Corporation. That experience, along with his later work focused on risk management and decision making related to critical environmental issues, has contributed to important questions asked of the Foundation as it discerns the best way forward to meet the needs of GSA.

Charlie Andrews, Ph.D., Principal of S.S. Papadopulos & Associates, serves as Treasurer of the Foundation Board. His focus is on creative solutions to difficult groundwater problems, and his expertise in assessment keeps him on top of Foundation budgeting and finances, ensuring that funds are being used most effectively and are well managed. This aspect is of utmost importance to a fundraising organization for transparency and effectiveness to report to our donors.

Lisa Rossbacher, Ph.D., member-at-large on the Executive Committee, brings perspective from the academic sector to the Board. As the first woman geologist to become a university president, and prior roles with the USGS, NASA, a geothermal exploration company, and National Public Radio, in addition to time spent with public and private higher education institutions, Rossbacher poses important perspectives to consider in Foundation deliberations to continue improving its operations every step of the way.

A. Wesley Ward, Jr., Ph.D., has served as member-at-large on the Executive Committee and adds insights from his perspective as a member of the government sector. He capped a 33-year career with the USGS as the Western Regional Geologist for the Survey. A two-term President of the National Association of Black Geoscientists and two-term Chair of the Committee on Women and Minorities (now Diversity), Ward contributes significantly to GSA's and GSAF's diversity initiatives and mentoring.

As is apparent with this representation of the entire GSAF Board of Trustees, the Foundation benefits from a wide range of expertise and sectors of professional geoscientists. The Foundation thanks the entire Board for its generous service to their professional society. To learn more about all members of the Board of Trustees, go to **www.gsafweb.org/trustees.**


Margaret Eggers, Ph.D.


George Linkletter, Ph.D.


Charlie Andrews, Ph.D.


Lisa Rossbacher, Ph.D.


A. Wesley Ward, Ph.D.

Tour California's Wine Country with Free GSA Field Guides

November is the best time to visit California's wine region if you prefer smaller crowds, sunny but brisk weather, and vibrant fall foliage. In between winery tours, take some time to explore the many geological points of interest that this region has to offer with free digital access to the following GSA field guides. Available now through the end of November.

A discussion of geology, soils, wines, and history of the Napa Valley region
2000, v. 2, p. 415–422

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2006, v. 7, p. 339–372

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Learn more at **www.geosociety.org/csf** or by contacting Kasey White, +1-202-669-0466, kwhite@geosociety.org

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Call For Field Trip, Short Course, and Technical Session Proposals

GSA 2017

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Seattle, Washington, USA

GSA 2017 Seattle Meeting

Thank you to all the 2016 GSA Denver Annual Meeting attendees. We hope you enjoyed the geology, networking, and libations. It's time to plan for our 2017 Annual Meeting in Seattle, Washington, USA. GSA is excited to head back to the Pacific Northwest. Our 2009 meeting in Portland, Oregon, USA, attracted nearly 6,500 attendees from over 50 countries, so our 2017 meeting should be international, well attended, and full of excitement!

A highlight will be the Seattle-area geology: Glaciation, deposition, tectonics, crustal deformation, unconformities, erosion, bedrock structures, and drumlins. We challenge you to propose a field trip, short course, and/or technical session that will teach your colleagues and promote discussion about the incredible regional geology.

SHOW THE GEOLOGY BY LEADING A FIELD TRIP.

Field Trip proposal deadline: 1 Dec. 2016

Trips can be anywhere from a half day to 5 days long. Field trip proposals may be submitted by any member of GSA, its affiliated societies, or anyone else. The proposal form is online at **https://gsa.confex.com/gsa/2017AM/fieldtrip/cfs.cgi.**

EXCHANGE THE GEOLOGY BY ORGANIZING AND CHAIRING A TECHNICAL SESSION.

Technical Session deadline: 1 Feb. 2017

Proposals are being taken for both Pardee Keynote and Topical Sessions. The proposal form is online at **https://gsa.confex.com/gsa/2017AM/cfs.cgi.**

SHARE THE GEOLOGY AS AN INSTRUCTOR THROUGH A SHORT COURSE.

Short Course proposal deadline: 1 Feb. 2017

Courses run the Friday and Saturday before the Annual Meeting and are typically a half day to two full days. The proposal form is online at **https://gsa.confex.com/gsa/2017AM/shortcourse/cfs.cgi.**

Glaciated peaks of the North Cascades National Park, Washington. Photo by Marli Miller, Dept. of Geological Sciences, University of Oregon.

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