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Replica of a complete skull of an *Australopithecus africanus*, discovered by Robert Broom and John T. Robinson in 1947 in South Africa near Sterkfontein in the Cradle of Humankind. See related article on pages 4–10.

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SCIENCE

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The First Geologists?

Jon Spencer[1,*]

ABSTRACT

The rate of evolutionary brain growth (encephalization) in African human ancestors increased dramatically at ca. 3.5 Ma. Crude stone tools first appear in fluvial sediments in eastern Africa at about this time, as does evidence for tool-assisted butchery that left scrape marks on animal bones. Early hominins were selective in their choice of rock types for tool production, preferring rocks that, when broken, yielded planar or conchoidal fractures with sharp and durable edges. In addition to butchery, early stone tools might have been used to process roots and tubers, while abrasive stones might have been used to sharpen spears and digging sticks. Regardless of specific tool use, evolutionary pressures for the cognition and dexterity necessary for effective stone selection and stone-tool fabrication and use were relevant only in areas with rocks with appropriate mechanical properties, as with areas of geologically young volcanic rocks associated with the east African rift system. The first geologists, aware of different rock types, their mechanical properties, and their distributions within natural landscapes, were also products of a specific geologic environment.

INTRODUCTION

The Great Acceleration in human population growth and anthropogenic environmental modification in the mid-twentieth century represents the beginning of a proposed Anthropocene Epoch. This was preceded at ca. 3.5 Ma by a great acceleration in the rate of evolutionary brain growth (encephalization) in human ancestors (hominins) that coincided with initiation of the earliest archaeological evidence for fabrication and use of stone tools (McPherron et al., 2010; Harmand et al., 2015; Du et al., 2018). The association of encephalization with stone-tool fabrication and use is consistent with the concept that the benefits of stone-tool use contributed to evolutionary selective pressures for greater cognitive abilities. Increasing cognitive abilities and associated creation of increasingly sophisticated tools led eventually, and perhaps inexorably, to the Anthropocene.

Early stone-tool fabrication and use marked the beginning of a suite of behavioral and anatomical changes associated with encephalization, but the nature and timing of these changes and their relative significance for encephalization are poorly understood. Increased cognitive abilities applied toward stone-tool use appear to have led to additional behaviors and skills that conferred additional survival advantages. This article is an attempt to evaluate the origins of stone-tool use and the significance of associated changes, both as causes and consequences of early encephalization.

HOMININ BRAIN GROWTH AND TOOL USE

The late Miocene African hominin *Sahelanthropus tchadensis,* from the Lake Chad region of central Africa and dated at ca. 7 Ma, is the oldest known hominin with evidence for upright posture as indicated by the morphology of a partial femur and a digitally reconstructed fossil skull (Daver et al., 2022). Endocranial volume (inside of the skull), at 360–370 cm^3, is similar to that of chimpanzees (Zollikofer et al., 2005). Two partial skulls of the younger Pliocene hominins *Ardipithecus ramidus* and *Australopithecus anamensis* have similar brain volume (Suwa et al., 2009; Haile-Selassie et al., 2019). At ca. 3.5 Ma, the rate of brain growth accelerated dramatically from near zero to an average rate of ~4.2%/10^5 yr, reaching a modern volume of ~1350 cm^3 that is almost quadruple its early Pliocene value (Fig. 1; Du et al., 2018). Numerous skeletal features indicate that the transition to rapid encephalization occurred after adaptation to upright posture, although some of these features have been interpreted to indicate a mix of arboreal and terrestrial locomotion.

From its beginning at ca. 3.5 Ma, rapid encephalization was associated with stone-tool production and use in eastern Africa. The subtle beginnings of tool use are represented by 3.4-Ma animal bones with scrapes and cut marks interpreted as products of stone-tool butchery (McPherron et al., 2010) and by crude, 3.3-Ma stone tools that were likely used for chopping, scraping, and/or crushing animal and/or plant matter (Harmand et al., 2015). The oldest known stone tools, at Lomekwi 3 on the west side of Lake Turkana in northwestern Kenya (Fig. 2), consist of locally available basalt and alkalic basaltic rocks. Compared to more abundant and younger stone artifacts, the Lomekwi 3 cores are unusually massive and were broken with a low level of skill, perhaps by block-on-block percussion (Fig. 3A; Harmand et al., 2015).

OLDOWAN TOOLS

Oldowan tools are simple stone tools produced at ca. 1.6–2.6 Ma by impact removal of rock chips from a “core” to

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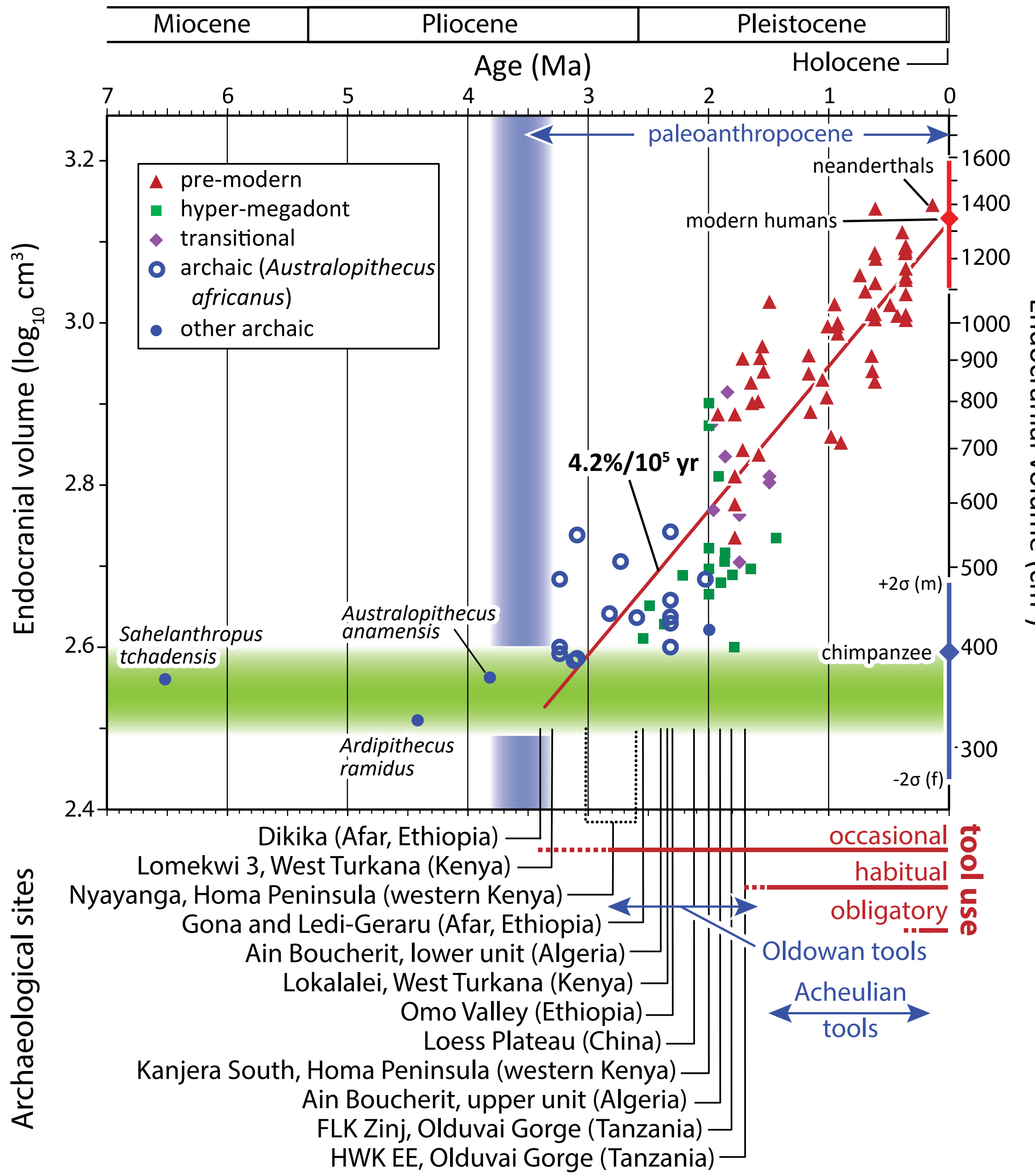

Figure 1. Endocranial volume vs. fossil age for hominins over 0–7 Ma and the chronology of early hominin archaeological sites. Endocranial volume data from compilation of Du et al. (2018), with additional points for the older hominins *S. tchadensis* (Zollikofer et al., 2005), *A. ramidus* (Suwa et al., 2009), and *A. anamensis* (Haile-Selassie et al., 2019). Least-squares linear regression of data points <3.5 Ma reveals an average volume increase of 4.2%/10^5 yr (~0.001% per generation; coefficient of determination $r^2 = 0.78$). Green indicates background hominin endocranial volume before ca. 3.5 Ma acceleration and is projected forward to the present, where it encompasses the average brain volume of modern chimpanzees. Note that various data points do not necessarily represent human ancestors and could be now-extinct branches from the human ancestral lineage (e.g., Du et al., 2018; Diniz-Filho et al., 2019). Estimated times of occasional, habitual, and obligatory stone-tool use are from Shea (2017a).

produce sharp but generally irregular edges. These tools are not as sophisticated as younger Acheulian stone tools produced, for example, by coarse knapping to yield an approximately shaped tool followed by fine chip removal to produce straight, or more evenly curved, sharp edges. (Attaching sharpened stones to wood to make axes or stone-tipped spears occurred much later [<300 ka].) Oldowan tools appear to have been made by hitting a stone held in one hand with a stone held in the other (pebble-core reduction), hitting or throwing a stone at another stone or stone surface (anvil percussion), or placing the target stone on a stone surface and hitting the target stone with another stone held in the other hand (bipolar-core reduction; e.g., Shea, 2017b). The rock chips themselves may have been desired products.

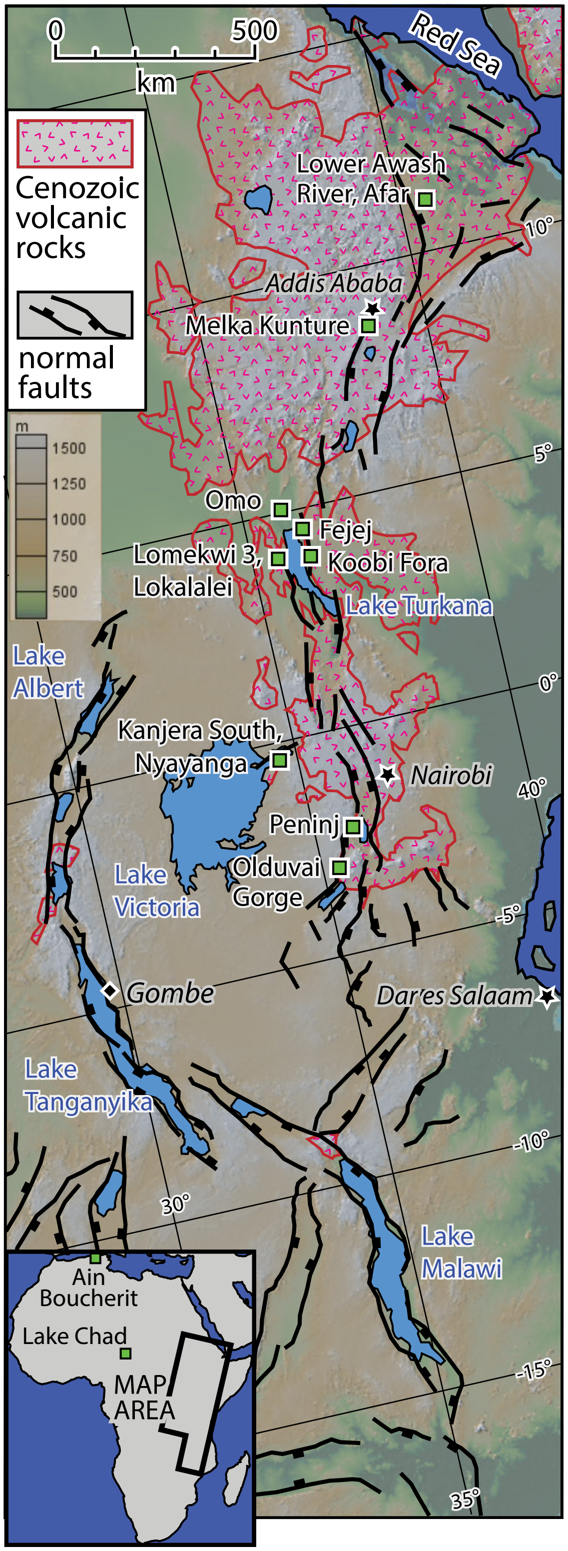

Figure 2. Relief map of the east African rift system, with rectangular symbols on the downthrown side of normal faults. Also shown are the distribution of volcanic rocks associated with the rift system and areas where significant numbers of hominin-related stone tools and/or bones have been recovered (green squares). These areas include all 22 stone-tool sites included in the compilation of stone-tool dimensions by Braun et al. (2019).

Tools made by these methods are not generally distinctive of tool-making cultures or geographic areas and are simple enough that cultural transmission might not have been necessary, leading to the inference of occasional rather than habitual fabrication (Fig. 1; Shea, 2017a).

A compilation of measurements of rocks interpreted as cores (targets of tool fabrication) by hominins at 21 eastern African archaeological sites, all dated to between 1.4 and 2.6 Ma, includes the average of the maximum dimension of the cores from each site (Braun et al., 2019). The average of the averages from all 21 sites, 6.5 ± 3.7 cm (2σ) (equivalent to 2.5 ± 1.5 in.), indicates that these cores are generally small, consistent perhaps with the small size and less developed thumbs of early hominins (Grabowski et al., 2015; Karakostis et al., 2021). These small tools are inferred to have been used for butchery because cut and scrape marks on associated animal bones have been found at some of the sites (e.g., de Heinzelin et al., 1999, *Bouri, Afar, Ethiopia, 2.5 Ma*; Domínguez-Rodrigo et al., 2005, *Gona, Afar, Ethiopia, 2.1–2.6 Ma*; Ferraro et al., 2013, *Kanjera South, Kenya, ca. 2.0 Ma*). Stone tools from many of these sites include subangular to subrounded pebbles and cobbles that are partially knapped (Figs. 3A–3B) so that a hominin could hold at least some of the smoother side or end of the tool while chopping, sawing, or scraping with the sharp edge of the other side or end ("pebble tools"; e.g., Leakey, 1971; Stout et al., 2010; Harmand et al., 2015; Shea, 2017b). Some clasts may have been selected for their planar surfaces that would provide natural targets for percussive removal of chips at the edges (Goldman-Neuman and Hovers, 2012).

Regardless of the general simplicity of Oldowan stone tools, some tools were crafted with significant skill. Reassembly of stone tools and chipped debris at the 2.34 Ma Lokalalei site west of Lake Turkana in western Kenya indicates skill and consistency in exploiting the edges and faces of cores during tool fabrication (Roche et al., 1999). Reassembly and analysis of artifacts from three of the oldest known Oldowan tool sites (ca. 2.6 Ma) at Gona in the Afar region of eastern Ethiopia indicates that cores "were efficiently reduced through the production of large, invasive flakes, using a range of strategies comparable to that seen in later Oldowan times" (Stout et al., 2010, 488). Two-handed pebble-core reduction with good manual dexterity was inferred, with the suggestion of cultural transmission of knapping technique that influenced core-reduction strategies (Stout et al., 2010).

ROCK-TYPE SELECTIVITY

Production of stone tools requires selection of rock types with appropriate mechanical properties, as most rocks would not make good cutting or scraping tools and some are difficult to break. Stone tools were likely intended for some purpose that the stone knapper had in mind, thus requiring forethought, although the specificity of forethought might have been only of a generally sharp object with multiple potential uses.

A variety of hominin preferences can be discerned from stone artifact assemblages from different geologic environments. An early example of rock selectivity is apparent for 2.5–2.6 Ma stone tools from sites in Gona, Afar, in which the

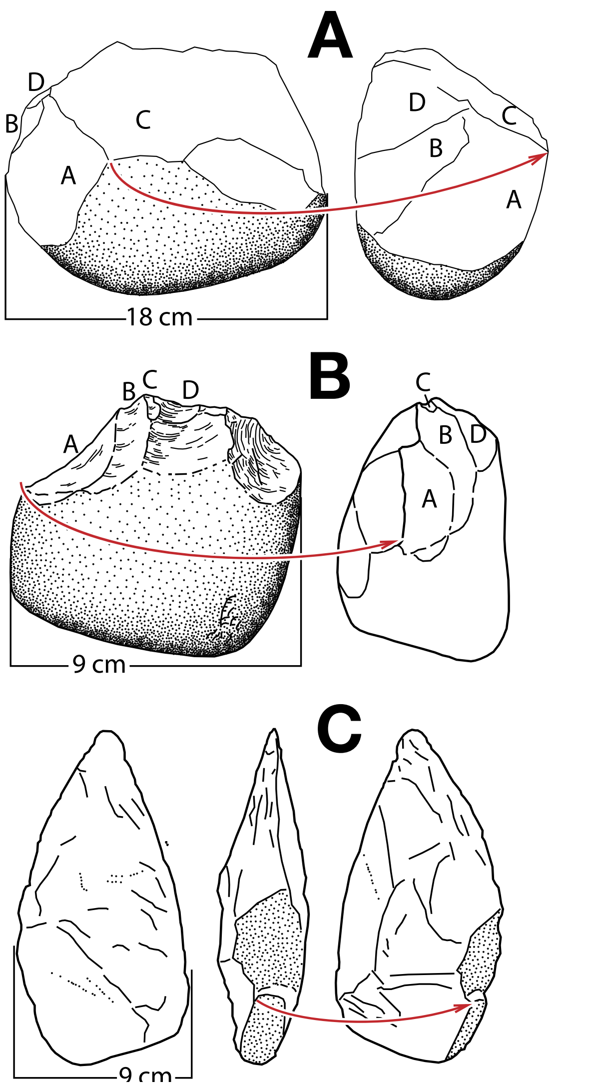

Figure 3. Examples of stone-tool artifacts. Red arrows and lettered faces show correlation between features with different view direction. (A) Lomekwian (3.3 Ma) core from the west of Lake Turkana, Kenya (simplified from Harmand et al., 2015). (B) Oldowan core (1.7 Ma) from Olduvai Gorge, Tanzania (redrawn from Leakey, 1971). (C) Middle to late Pleistocene Acheulian core from Santa Ana Cave, Spain (simplified from García-Vadillo et al., 2022).

stone tools were derived from local conglomerate or streambed gravel containing a variety of clast types. Hominins preferred aphanitic and vitreous volcanic rocks and avoided basalt (Stout et al., 2005). At another archaeological site near the lower Awash River, ca. 2.6 Ma hominins preferred rhyolite, dacite, and cryptocrystalline silica and avoided basalt (Braun et al., 2019). Durability of stone tools rather than fracture predictability appears to have influenced rock selection at Kanjera South in western Kenya (Braun et al., 2009). At Olduvai Gorge, late Oldowan and early Acheulian artifact assemblages (ca. 1.7–1.4 Ma) include large fractions made of quartzite, which was apparently preferred because angular fragments from nearby bedrock outcrops presented attractive faces and angles for flake removal, unlike the generally rounded shapes characteristic of volcanic rocks forming streambed pebbles and cobbles (McHenry and de la Torre, 2018).

TOOL USE

The uses of Oldowan tools for purposes other than butchery are not apparent from the tools themselves, but perhaps can be discerned from inventories of vertebrate bones from areas of hominin butchery. At Kanjera South in western Kenya (Fig. 2), three excavations of ca. 2.0 Ma fluvial and lacustrine strata near the shore of Lake Victoria yielded several thousand bones, bone fragments, and lithic artifacts (Ferraro et al., 2013). An inventory of the bones indicates that hominins butchered small herbivores generally as whole or nearly whole carcasses, whereas medium-sized herbivore bones are disproportionately overrepresented by skulls and long limb bones. This was interpreted to indicate that small herbivores were hunted and whole carcasses brought to sites of butchery, while medium-sized herbivores were scavenged for parts that contain nutritious marrow and brain. Demographic profiles of bovid bones at the 1.8 Ma FLK Zinj archaeological site at Olduvai Gorge, Tanzania (Fig. 2), approximate natural herd demographics rather than the greater abundance of the old and young that characterize lion kills and scavenged remains (Bunn and Gurtov, 2014). Ambush hunting, most likely with wooden spears sharpened with abrasive stones, was inferred for these Olduvai bones.

Hunting small- to medium-size mammals with wooden spears seems likely in eastern Africa by 2 Ma, regardless of the lack of direct evidence for spear fabrication and use. Evidence of hominin wood use is indirect or inferential as wood does not survive burial under generally warm, oxidizing soil conditions and so is absent in fluvial, paleosol, and subaerially exposed lake-margin strata that contain African hominin fossil and bone matter. Wooden spears are preserved in 300 ka anoxic lake sediments deposited under temperate to arctic conditions in northern Europe (Schoch et al., 2015), but similar preservation is unknown at African hominin fossil sites. Important points here are that ambush hunting with wooden spears would have led to more consistent meat-rich diets and, with sufficient hunting success, habitual rather than occasional fabrication and use of stone tools for carcass butchery.

ENVIRONMENTAL CONSEQUENCES

The appearance in eastern Africa of hominins armed with wooden spears and butchery tools, whenever it occurred, might be expected to have had ecological consequences. Gradual drying and the spread of C_4 grasses since ca. 4 Ma in eastern Africa (Cerling et al., 2011) was associated with declining megaherbivore diversity (Faith et al., 2018; Bibi and Cantalapiedra, 2023). These changes began, however, before the archaeological appearance of the oldest known stone tools at 3.3 Ma and well before evidence of hominin hunting of small herbivores at Kanjera South at ca. 2.0 Ma (Ferarro et al., 2013) and larger bovids at the 1.8 Ma FLK Zinj archaeological site at Olduvai Gorge (Bunn and Gurtov, 2014).

The fossil record of carnivores, however, is different than that of herbivores. Statistical analysis of bone and tooth remains from eastern Africa indicates that a major reduction in the diversity of large carnivores (>21.5 kg) began at ca. 2.0 Ma (Werdelin and Lewis, 2013). Another analysis determined that extinction rates of large carnivores began to increase at ca. 4 Ma and occurred at increasing rates up to the present (Faurby et al., 2020). Smaller carnivores, however, did not experience increased extinction rates during this time interval. Early extinction of large carnivores was attributed to loss of carcasses due to direct confrontation with hominins, potentially wielding spears (kleptoparasitism), and to hominin scavenging of undefended carcasses (Faurby et al., 2020). The increasing rate of extinction over time was attributed to progressive reduction of available prey because of increasingly effective hunting and scavenging by hominins.

A NEW DIET AND A NEW BODY

A variety of anatomical and behavioral changes accompanied encephalization. The size of hominin teeth began shrinking at ca. 2 Ma, roughly at the transition from *Australopithecus* to *Homo*. Using stone tools to process animal and plant matter into smaller fragments, tenderize meat, and remove animal tissues that are mechanically resistant to chewing could all contribute to evolution of smaller teeth and chewing muscles (Zink and Lieberman, 2016). Dental reduction has been linked to cooking, which softens food, destroys pathogens and toxins, and increases nutritional value (Gowlett and Wrangham, 2013). Evolution toward a less flared rib cage indicates less space for a smaller gut, consistent with digestion of cooked rather than raw foods (Andrews and Johnson, 2019). Combined with encephalization, dental reduction changed skull shape, leading eventually to a short mouth and greater capacity to shape sounds with the tip of the tongue (Lieberman, 2011), which likely facilitated language development. Changes in the hominin body that reflect a new and changing lifestyle include a longer and stronger thumb more capable of tool fabrication and use (Karakostis et al., 2021) and greater adaptation to walking and running.

DISPERSAL

Regardless of crude fabrication skills and the possibility of only occasional tool use, early stone-tool–using hominins dispersed out of tropical and subtropical Africa into temperate environments. Stone tools at Ain Boucherit near the town of Beni Fouda in northeastern Algeria, dated at ca. 2.4 Ma and located less than 100 km from the Mediterranean Sea, are ~4500 km away from eastern African hominin fossil sites (Fig. 2; Sahnouni et al., 2018). By 2.12 Ma, hominins had reached the Loess Plateau near Xi'an in central China (Zhu et al., 2018). Hominins at this time had developed the capacity to live in and disperse through diverse environments that were increasingly temperate at more northern latitudes. Use of stone tools for butchery, wooden spears for hunting and defense, sharpened sticks for digging for roots and tubers, and fire for warmth and cooking would have enabled dispersal and survival in diverse environments, but it is uncertain if any or all of these factors were particularly relevant to long-distance dispersals.

ENCEPHALIZATION WITHOUT TOOLS?

The crude nature of Oldowan tools, and the miniscule improvement in fabrication in the first ~1.5 m.y. of tool use, allows for the possibility that early encephalization was only marginally related to tool fabrication and use. Another likely cause of early hominin encephalization is an increasingly complex social environment with larger social-group populations, as indicated by positive correlations between brain size and social group size in primates (Dunbar, 2009). In other words, it takes a lot of brain power to form and maintain long-term social bonds that generally provide mutual benefits to all parties. In this context, evolutionary development of the extensive and uniquely complex kinship relations of human societies (Chapais, 2017) provided survival benefits and selective pressures that contributed to encephalization. More recent (post-Oldowan) and more sophisticated stone-tool use might have contributed more effectively to selective pressures for greater cognition and brain growth.

THE FIRST GEOLOGISTS?

The east African rift system is a divergent plate boundary that is gradually accommodating tectonic breakup of eastern Africa and its separation from the rest of the continent (e.g., Martin, 2023). Volcanic activity associated with rifting produced generally basaltic lava flows and alkalic volcanic and shallow intrusive rocks, and locally produced volcanic rocks with a wide range of silica content, as is characteristic of continental rifts. Where these volcanic rocks were nonvesicular and fresh (unaltered by weathering, diagenesis, or hydrothermal processes), and hard but not too tough, they were commonly the dominant material selected by hominins for tool fabrication. Toughness is a mechanical property that can make a rock difficult to break, even with a steel rock hammer and a strong human arm. In contrast, glassy rocks such as obsidian are not very tough but yield sharp edges when broken and are hard enough to sustain a sharp edge during light to moderate use. Other types of volcanic rock, quartzite, quartz (probably vein quartz), and amorphous silica such as chert have also been used, as they are typically hard and can yield sharp edges upon impact, but are not so tough as to greatly inhibit breakage by stone-wielding hominins.

If earliest hominin use of sharp-edged stone tools resulted from use of chipped debris generated when breaking bones or nuts, then areas underlain by suitable rock units would be necessary to foster the behavioral transition from breaking with stones to cutting or scraping with broken stones. The east African rift system south of Ethiopia consists of western and eastern branches, with abundant volcanic rocks associated only with the eastern branch (Fig. 2). Sediment accumulation and erosional incision occurred along both branches, but major early hominin sites are located almost entirely within or near the eastern branch. This spatial relationship suggests that early hominin tool use was associated specifically with areas of geologically young volcanic rocks. Thus, even if it is a stretch to think of tool-fabricating, small-brain hominins as geologists, such a hominin appears to have been a product of a specific geologic environment.

There are other reasons why hominin fossils and tools from the western branch of the east African rift system might be largely unknown, including more rainfall and vegetation that would conceal fossil-bearing strata, and more adverse political and societal environments for archaeological fieldwork. The western branch is also characterized by deep grabens with abundant lakes, perhaps concealing evidence of hominin tool use, while rift shoulders could have been sites of persistent erosion rather than erosion with occasional sediment accumulation and preservation. This would contrast with the eastern branch, where volcanic activity was associated with more complex and varied structural and topographic changes that led in many areas to exhumation of Pliocene and Pleistocene, fossil- and tool-bearing strata (e.g., Quade et al., 2004). The fact remains, however, that Lomekwi 3 and most Oldowan stone tools were derived from volcanic and shallow intrusive rocks in an environment of abundant and geologically young volcanic rocks associated with the eastern rift.

CONCLUSION

Hominin encephalization began at about the same time as stone-tool production and carcass butchery with sharp stone tools. This is consistent with the concept that early encephalization was triggered by the survival benefits of making and using stone tools. The advantages of stone-tool–assisted butchery, however, seem inadequate as the primary driver of early encephalization. A variety of other changes were associated with encephalization, but the relative significance and timing of these changes in producing evolutionary selective pressures for greater cognitive abilities and fine motor skills are poorly known. These changes include (1) use of stone-sharpened wooden spears for hunting and defense; (2) use of stone-sharpened sticks to dig for roots and tubers; (3) use of fire for cooking; (4) development of a stronger and more dexterous thumb; (5) development of language; and (6) development of increasingly complex social relationships with increasing social-group size.

Regardless of these uncertainties, stone tools appear to have been foundational in triggering 3.5 m.y. of rapid evolutionary brain growth. I suggest that sharp rock fragments produced inadvertently by bone and/or nut cracking at sites located on hard and brittle volcanic rocks within the east African rift system provided a setting where hominins learned to use the sharp edges of broken rocks for butchery and then gradually transitioned to deliberate fabrication of stone tools. Effective tool production was then based partially on increasing recognition of the variable mechanical properties of rocks relevant to stone-tool fabrication and knowledge of the color, texture, and distribution of useful rock types. Increasingly complex communication among hominins would have led to expressions for relevant rock properties and distributions, eventually leading to exchanges of knowledge crudely resembling discussions among geologists.

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This theme focuses on the dynamic, tectonically active regions where geology is in constant flux. This theme explores the challenges of living in areas marked by shifting terranes, dramatic mountain formations, and frequent geological hazards like earthquakes and landslides. It underscores the importance of geological knowledge in urban planning and sustainability. The meeting will serve as a platform for discussing the unique geological processes, biodiversity, and abundant natural resources of these regions. Sessions and field trips will highlight the distinctive landscapes and tectonics of Southern California.

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Are you interested in hosting a ticketed event and/or a non-technical event at GSA Connects 2024 in Anaheim?

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You can request space for non-technical events (receptions, luncheons, alumni events, board meetings, etc.) beginning in early April.

Please email Lindsey Henslee at lhenslee@geosociety.org for more information.

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Abstracts Submission Deadline: 18 June

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Northeastern Section Meeting

Manchester, New Hampshire
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Left: Beach near Portsmouth, New Hampshire.


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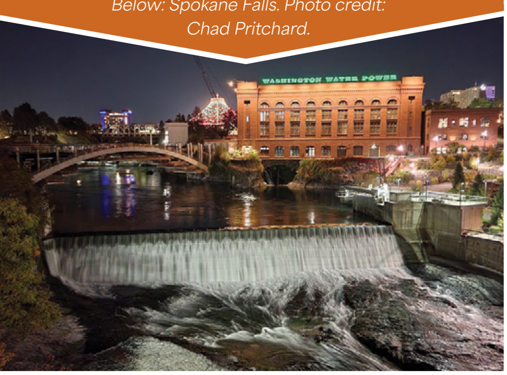
Below: Spokane Falls. Photo credit: Chad Pritchard.

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Southeastern Section Meeting

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Above: Blue Ridge Mountains. Photo by Ashley Lynn.


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Joint North-Central/ South-Central Section Meeting

Springfield, Missouri
21–23 April

Early Registration Deadline: 18 March

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Right: Smallin Civil War Cave. Photo credit: Springfield CVB.

Developing a New Paradigm for the Late Cretaceous to Eocene North American Cordillera: A Dominantly Oblique Plate Boundary

18–25 August 2023 | McCall and Riggins, Idaho, USA

An increasing number of robust data sets provide support for models of obliquely convergent plate motion along the western North America margin since the mid-Cretaceous. Furthermore, a variety of data sets indicate significant terrane translation along this oblique margin from the Jurassic until the Eocene, with dextral motion starting in the mid-Cretaceous or earlier. The original hypothesis of far-traveled terranes was based on paleomagnetic data from the northern Cordillera (e.g., Beck and Noson, 1972; Wynne et al., 1995; Irving et al., 1996; Enkin, 2006). A new group of reconstructions for the Pacific realm and North America have been developed based on tectonic analysis of subducted plates interpreted using seismic tomography (Sigloch and Mihalynuk, 2013, 2017; Clennett et al., 2020; Fuston and Wu, 2021). In addition, detrital zircon analysis has provided another data set that can potentially test between different models (e.g., Garver and Davidson, 2015; Matthews et al., 2017; Sauer et al., 2019; Boivin et al., 2022).

The objective of this Penrose Conference was to bring together an international group of scientists, from a variety of different subdisciplines and professional career stages, to address the problem of obliquely converging plate boundaries, terrane collisions, and strike-slip tectonism along the western North America Cordillera. The conference participants met for six full days of talks and field trips in western Idaho. The first and fifth days included field trips to visit the accretionary margin—modified by a major transpressional shear zone—in western Idaho, showing the abundant evidence in this region for significant dextral strike-slip motion. On the second day, participants presented all three major models for the Cretaceous–Paleogene tectonic evolution of the North American Cordillera. For each model, both a geologist and a geophysicist presented data based on exposed crustal rocks and/or mantle tomography. Each of the remaining three days was devoted to a section of the North American Cordillera (Northern, Southern, Central) and contained two keynote talks, a poster session with lightning talk introductions, breakout groups, breakout group reporting, a panel discussion, and whole-group discussions. Below we address the conference goals and how we achieved them during the conference.

CONFERENCE GOALS

Bring together people across borders and disciplines. A broad range of participants was important for discussing the 4D obliquely convergent history of the North American Cordillera. Participants came from the U.S., Mexico, and Canada, ensuring that the presented data and discussions were not limited by national borders. Participants used a variety of different data sets—including field-based structural geology and sedimentology, paleomagnetism, geochronology, geochemistry, mantle tomography, etc.—to support major tectonic models for the North American Cordillera. The goal was to ensure that people were able to

Strongly foliated orthogneiss, deformed by the western Idaho shear zone, exposed in the canyon country of Idaho, USA. The view is to the south and the foliation dips steeply east, rotated from its pre-Miocene vertical orientation by normal faulting. Photo by Basil Tikoff.

talk to fellow scientists within their geoscience subdiscipline, but also, more importantly, to discuss with other subdisciplines how different data sets can be integrated. Finally, participants in attendance supported different models of the North American Cordillera, including, but not limited to, westward subduction, flat-slab subduction, and major collision and translation. It was critical to bring together scientists to reconcile how the different data sets can be integrated in space and time to work toward a model consensus and discuss critical new data sets that need to be collected to better understand the tectonic system.

Find consensus where it exists. Some topics at the conference were, of course, contentious (e.g., large-scale terrane translation). The meeting started with a discussion about GSA's RISE initiative, which advocates for respecting your colleagues and making comments and asking questions in a non-aggressive, inclusive manner. It was emphasized that we all have the same goal of better understanding the North American Cordillera and that the Penrose Conference was a rare opportunity to discuss this orogenic system with a variety of scientists with different backgrounds, including different biases. To further set the tone for the conference, the first day of talks included a presentation about the role of uncertainty for data and models, and the role of salience. Salience provides a communication tool for discussing the importance of a particular data set for a specific model.

In the end, we think that we reached a consensus that parts of current British Columbia and other areas of the North American Cordillera were translated significant distances northward starting at ca. 90 Ma.

Encourage the interest and future research of early career scientists. The scheduled activities were designed to encourage the engagement and interaction of early career scientists, both with senior researchers and among themselves. Multiple breakout group meetings were convened to discuss ideas and ask questions throughout the conference. The breakout groups—consisting of assigned participants from various career stages and different parts of the Cordillera—were viewed as particularly helpful. The breakout groups changed composition multiple times, giving participants the chance to engage with a variety of perspectives. The early career scientists reported on these breakout sessions, and they were also given the opportunity to ask questions first during the broader group discussions before opening questions to all participants. Finally, an evening event was held for early career scientists and students to get to know each other and to talk with senior participants who had taken various career paths (e.g., liberal arts college, major research university, state survey, working abroad, etc.), as well as an NSF program manager. We were able to fund this event, plus the registration and travel for most early career participants, from an NSF conference grant and funding from the Geological Society of America associated with holding a Penrose Conference.

Identify scientific questions that are important and tractable ("low-hanging fruit"). One of the tasks given to breakout groups was to think about key data sets that would provide some of the missing links in developing and finding consensus among a model for the Cretaceous–Eocene Cordillera development. Some major questions and suggestions for missing data sets arose from the conference, including the following:

- In the mantle tomography data sets, what does the slab wall under the east coast of North America represent?
- Better timing is needed for the docking of the Guerrero terrane to Mexico.
- Better constraints on the paleogeography and relationships between Guerrero and other North America terranes.
- More data is needed to understand the movement and the timing of the movement of the Carmacks Group along the Rocky Mountain trench.
- Where are the breaks between terranes that clearly translated northward versus those that did not?

These are just a few of many topics that were discussed during the conference. By the end of the week, many participants were discussing collaborative proposals and projects to better understand the Cordilleran tectonic history.

Find ways of moving forward as a community. The conference consisted of many discussions during breakout sessions, during poster sessions, after talks, and after panel discussions. The afternoon of the last conference day was dedicated to thinking about ways to keep these conversations going. Some events that have and will occur include:

- Sarah Roeske and Carla Eichler have taken the lead on an approximately biweekly seminar series on Zoom that is focused on North American Cordilleran tectonics. The goal of the Zoom series is to include as many participants as possible, knowing that traveling to conferences can be costly. All are welcome to join in on the Zoom series.
- A series of sessions at GSA Connects 2024 in Anaheim that will look at the tectonic history of the Cordilleran through time.
- A workshop to reconvene the group at the 2026 GSA Cordilleran Section Meeting in Loreto, Mexico.
- A paleomagnetism "what you need to know" short course at a future GSA Connects or Cordilleran Section Meeting.
- Developing a mechanism, such as a short course or webinar, to work as a community with GPlates, a software for the visualization of plate tectonics.
- A GSA Special Paper that will include papers that highlight the conference theme. We are still currently seeking papers for this volume, with a due date of 1 May 2024. Please email the Penrose leaders (basil@geology.wisc.edu; staciag@unr.edu) if you are interested in contributing.

BROADER IMPACT

The Penrose Conference also included a broader impact component, made possible by the participation of Nick Zentner. Nick recently finished a "Baja-BC A-to-Z" YouTube series, in which he had engaged an international community of the broader public (the self-proclaimed "Zentnerds") with the science and scientists studying the western margin of North America. The Penrose leaders led a two-day field trip in western Idaho for a group of ~80 Zentnerds immediately prior to the Penrose Conference, so they could experience a geology field trip and see some of the rocks that show evidence of dextral motion along the North American margin. During the Penrose Conference, Nick

Penrose participants enjoying one of the conference field trip stops in the western Idaho shear zone outside of McCall, Idaho.

made videos, interviewing participants during the field trips and hosting a livestream from one day of the conference. Nick also did a follow-up video that summarized the conference and its outcomes. Overall, Nick's presence was beneficial to his dedicated audience of Zentnerds, who had the chance to see how scientific conferences work and how science can move forward through group discussions. Nick's videos were also very beneficial to the Penrose participants, who saw a potential new way to share science effectively with the broader public.

Finally, we note that two active participants passed away prior to the meeting. Paul Umhoefer was a proposer of the original Penrose application and Robert Molina wrote a letter of support. Their presence was sorely missed, and the GSA Special Paper will be dedicated to these two great scientists.

This Penrose Conference was supported by the Geological Society of America and the National Science Foundation Tectonics Program (EAR-2310789). Ellen M. Nelson is gratefully acknowledged for providing significant logistical support. Thank you to all the participants for making this a highly successful conference.

Leaders: Stacia Gordon (University of Nevada–Reno), Elena Centeno-García (UNAM), and Basil Tikoff (University of Wisconsin–Madison)

Participants: Matthew Aleksey, Christopher Alfonso, Chuck Bailey, Sarnav Bakshi, Elizabeth Balgord, Arturo Barron Díaz, Andrew Barth, Amar Jyoti Baruah, Mark Beaufait, Scott Bennett, Jeff Benowitz, Joseph Biasi, Ericka Boudreau, Daniel Brennan, Matt Brueseke, Robinson Cecil, Jay Chapman, Edward Clennett, Manuel Contreras-López, Darrel Cowan, Claire Currie, Michael Darin, Erin Donaghy, Carla Eichler, Elisa Fitz-Díaz, Megan Flansburg, George Gehrels, Christine Griffith, Luis Javier Gutiérrez-Trejo, Stephen Harlan, Bernie Housen, Eugene Humphreys, Stephen Johnston, Tim Lawton, Allen McGrew, Robert Miller, Elena Miranda, Rebecca Morris, Sean Mulcahy, Suzanne Mulligan, Rijumon Nandy, Ellen Nelson, Devon Orme, Diego Alberto Osorio Afanador, Terry Pavlis, Dave Pearson, Daniel Quick, Anthony Ramírez-Salazar, Andrea Richardson, Ken Ridgway, Sarah Roeske, Margi Rusmore, Keegan Schmidt, Joshua Schwartz, Gabriel Serrano-López, Nikki Seymour, Jessie Shields, Karin Sigloch, Natalia Siqueiros-Moreno, Harold Stowell, Kathleen Surpless, Carolyn Tewksbury-Christle, Sarah Trevino, Nicholas Van Buer, Karissa Vermillion, Adolph Yonkee, Trevor Waldien, Jordan Wang, John Weber, Michael Wells, Jonny Wu, Sandra Wyld, and Nick Zentner

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Shlemon Mentor Program: Monday, 15 April
Mann Mentor Program: Tuesday, 16 April

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21–23 April, Springfield, Missouri, USA
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Mann Mentor Program: Monday, 22 April

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To join the tournament:

- Submit your geology club's t-shirt logo or artwork by 31 March to www.geosociety.org/tee-off.
- It's free to enter and, if you win, your club will receive a cash prize.
- The contest and publicity will raise awareness of your club.

To vote:

- Starting on Earth Day, 22 April 2024, you can begin voting for your favorite geology club logo.
- Help your geology club, or the geology club from your alma mater, win a cash award.
- Join us each day on social media to vote and see who has advanced in our bracket-style tournament.

The winning logo will be featured on t-shirts sold at GSA Connects 2024 in Anaheim, California!

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- Ace your interviews with professional coaching

Get started using the ultimate resource for geology jobs at **careers.geosociety.org**

Above: Photo Credit: shotbydave / iStock / Getty Images Plus via Getty. Images.

GSA Awards & Nominations

CONTINENTAL SCIENTIFIC DRILLING DIVISION

DISTINGUISHED LECTURERS

Nominations due **29 March**

Submit nominations to the CSDD chair: Brett M. Carpenter, brett.carpenter@ou.edu

Three awardees will be outstanding scientists who, through a series of lectures at academic institutions and other public events during the year of the award, highlight the outstanding discoveries and science undertaken through continental drilling. **community.geosociety.org/continentaldrilling/awards/award2**

ENERGY GEOLOGY DIVISION

CURTIS-HEDBERG AWARD

Nominations due **31 July**

Submit nominations to the Curtis-Hedberg Award chair: Denise J Hills at denise.j.hills@gmail.com

The Curtis-Hedberg Award will be considered annually in accordance with the bylaws of the Society. The award will be made for outstanding contributions in the field of petroleum geology. **community.geosociety.org/energydivision/awards/curtishedberg**

ENVIRONMENTAL AND ENGINEERING GEOLOGY DIVISION

DISTINGUISHED PRACTICE AWARD

Nominations due **31 March**

Submit questions or nominations to the EEGD chair: Francis Kevin Rengers, frengers@usgs.gov

The Distinguished Practice Award recognizes outstanding individuals for their continuing contributions to the technical and/or professional stature of environmental and/or engineering geology. A nominee need not be a member of the EEGD, but must have made a major contribution to environmental and/or engineering geology in North America. Each nomination must be accompanied by a written citation. **community.geosociety.org/eegdivision/awards/new-item3**

GEOARCHAEOLOGY DIVISION

RICHARD HAY STUDENT PAPER/POSTER AWARD

Nominations due **31 August**

Submit nominations to gsa.agd@gmail.com

At the 2006 Annual Meeting in Philadelphia, Pennsylvania, USA, the Division's management board elected to rename the student travel award for a distinguished scientist in archaeological geology. After consulting with his family, the award was officially named the Richard Hay Student Paper/Poster Award. Hay was a long-standing member of the Division and had a long and distinguished career in sedimentary geology, mineralogy, and archaeological geology. He is particularly well known for his work on the Olduvai Gorge and Laetoli Hominid-bearing sites and was awarded the Division's Rip Rapp Award in 2000. The Division is proud to have our student travel award bear his name.

The award is a travel grant for a student (undergraduate or graduate) presenting a paper or poster at GSA Connects. The grant is competitive and will be awarded based on evaluation of the scientific merit of the research topic and the clarity of an expanded abstract for the paper or poster prepared by a student for presentation in the Division's technical session at the meeting. **community.geosociety.org/geoarchdivision/awards/student/hay**

CLAUDE C. ALBRITTON JR. AWARD

Nominations due **15 April**

Submit nominations to gsa.agd@gmail.com

Under the auspices of the Geoarchaeology Division, family, friends, and close associates of Claude C. Albritton Jr. have formed a memorial fund in his honor through the GSA Foundation. Initially, the fund was set up with a gift of several thousand dollars. Members of the Division, other GSA members, and those who know Albritton are being asked to consider contributing to this fund.

The Albritton Award Fund provides scholarships and fellowships for graduate students in the earth sciences or archaeology for research. Recipients of the award are students who have (1) an interest in achieving a master's or PhD degree in earth sciences or archaeology; (2) an interest in applying earth science methods to archaeological research; and (3) an interest in a career in teaching and academic research. Awards in the amount of US$650 are given in support of thesis or dissertation research, with emphasis on the field and/or laboratory aspects of the research. **community.geosociety.org/geoarchdivision/awards/student/albritton**

GEOLOGY AND SOCIETY DIVISION

E-AN ZEN FUND FOR GEOSCIENCE OUTREACH GRANT

Applications due **30 June**

Submit nominations to the Division past chair: Lily Jackson, Lily.Jackson@uwyo.edu

This is a grant opportunity for Geology and Society Division members interested in developing innovative methods to bring geoscience knowledge to public audiences. Two grants of $1,500 each will be awarded to fund projects designed by the applicants to communicate geoscience information to a lay audience with the goal of increasing the understanding of geoscience and its impact on society among non-geoscientists and decision-makers. Applicants may apply as individuals or as groups, depending on the best fit for their project design. While the grant application requirements are intentionally broad to encourage creative thinking and innovation, review of applications will emphasize the potential for impacting communities that traditionally have not had significant exposure to the geosciences. **community.geosociety.org/gsocdivision/news/zenfund**

HISTORY AND PHILOSOPHY OF GEOLOGY DIVISION

HISTORY AND PHILOSOPHY OF GEOLOGY STUDENT AWARD

Nominations due **15 June**

Submit nominations to the Division secretary/treasurer: Christopher Hill, chill2@boisestate.edu

The History and Philosophy of Geology Division provides a student award in the amount of US$1,000 for a paper to be given at GSA Connects. Awards may also be given for second place. Oral presentations are preferred. Faculty advisors may be listed as second author, but not as the lead author of the paper. The proposed paper may be (1) a paper on the history or philosophy of geology; (2) a literature review of ideas for a technical work or thesis/dissertation; or (3) some imaginative aspect of the history or philosophy of geology we have not thought of before. Students should submit an abstract of their proposed talk and a 1,500–2,000-word prospectus for consideration. Currently enrolled undergraduates and graduate students are eligible, as are students who received their degrees at the end of the fall or spring terms immediately preceding GSA Connects. The award is open to all students regardless of discipline, provided the proposed paper is related to the history or philosophy of a geological idea/person. The award is made possible by a bequest from the estate of Mary C. Rabbitt. Monies for the award are administered by the GSA Foundation. **community.geosociety.org/histphildiv/awards/student**

KARST DIVISION

KARST DIVISION MERITORIOUS CONTRIBUTION AWARD

Nominations due **31 March**

Submit nominations to awards.gsakarst@gmail.com; cc the Division secretary: Daniel Jones, daniel.s.jones@nmt.edu

Awarded to the author of a published paper or body of work of distinction that has significantly influenced the intellectual direction of karst or broadly enhanced the knowledge of the discipline. If you are submitting a self-nomination, please include a letter of recommendation from a karst professional that can attest to your qualifications. Nominees do not need to be Karst Division members to be eligible for these awards, but it does add merit to the nomination.

Nominators are required to affirm the following statement on the award nomination form: “To my knowledge the person I am nominating has not breached GSA’s Code of Ethics & Professional Conduct nor is this person under investigation for any action that would be a breach of GSA’s Code of Ethics & Professional Conduct.”

KARST DIVISION EARLY CAREER AWARD

Nominations due **31 March**

Submit nominations to awards.gsakarst@gmail.com; cc the Division secretary: Daniel Jones, daniel.s.jones@nmt.edu

Awarded to a distinguished scientist (35 years or younger throughout the year in which the award is to be presented, or within five years of their highest degree or diploma) for outstanding achievement in contributing to the karst profession through original research and service, and for the demonstrated potential for continued excellence throughout their career. If you are submitting a self-nomination, please include a letter of recommendation from a karst professional that can attest to your qualifications. Nominees do not need to be Karst Division members to be eligible for these awards, but it does add merit to the nomination.

Nominators are required to affirm the following statement on the award nomination form: “To my knowledge the person I am nominating has not breached GSA’s Code of Ethics & Professional Conduct nor is this person under investigation for any action that would be a breach of GSA’s Code of Ethics & Professional Conduct.”

KARST DIVISION DISTINGUISHED SERVICE AWARD

Nominations due **31 March**

Submit nominations to awards.gsakarst@gmail.com; cc the Division secretary: Daniel Jones, daniel.s.jones@nmt.edu

Awarded to a highly esteemed scientist in recognition of distinguished personal service to the karst profession and to the Karst Division. If you are submitting a self-nomination, please include a letter of recommendation from a karst professional that can attest to your qualifications. Nominees do not need to be Karst Division members to be eligible for these awards, but it does add merit to the nomination.

Nominators are required to affirm the following statement on the award nomination form: “To my knowledge the person I am nominating has not breached GSA’s Code of Ethics & Professional Conduct nor is this person under investigation for any action that would be a breach of GSA’s Code of Ethics & Professional Conduct.”

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

MGPV awards emphasize achievements in geologic and multidisciplinary approaches. Geologic work is by nature generalistic and has an important field component, with Earth as the natural laboratory. More information is online at **community.geosociety.org/mgpvdivision/home.**

MGPV DISTINGUISHED GEOLOGIC CAREER AWARD

Nominations due **31 March**

Submit nominations to the Division secretary: J. Alex Speer, jaspeer@minsocam.org

The MGPV Distinguished Geologic Career Award will go to an individual who, throughout his/her career, has made distinguished contributions in one or more of the following fields of research: mineralogy, geochemistry, petrology, or volcanology, with emphasis on multidisciplinary, field-based contributions. Nominees need not be citizens or residents of the United States, and membership in the Geological Society of America is not required. The award will not be given posthumously. **community.geosociety.org/mgpvdivision/awards/dgca**

MGPV EARLY CAREER AWARD

Nominations due **31 March**

Submit nominations to the Division secretary: J. Alex Speer, jaspeer@minsocam.org

The MGPV Early Career Award will go to an individual near the beginning of his/her professional career who has made distinguished contributions in one or more of the following fields of research: mineralogy, geochemistry, petrology, or volcanology, with emphasis on multidisciplinary, field-based contributions. Nominations are restricted to those who are within eight years past the award of their final degree. Extensions of up to two years will be made for nominees who have taken career breaks for family reasons or caused by serious illness. Nominees need not be citizens or residents of the United States, and membership in the Geological Society of America is not a requirement. The award will not be given posthumously. **community.geosociety.org/mgpvdivision/awards/earlycareer**

PLANETARY GEOLOGY DIVISION

EUGENE M. SHOEMAKER IMPACT CRATERING AWARD

Nominations due **15 August**

Submit nominations here: https://www.lpi.usra.edu/Awards/shoemaker

The Eugene M. Shoemaker Impact Cratering Award is for undergraduate or graduate students, of any nationality, working in any country, in the disciplines of geology, geophysics, geochemistry, astronomy, or biology. The award, which will include US$2500, is to be applied to the study of impact craters, either on Earth or on the other solid bodies in the solar system. Areas of study may include but shall not necessarily be limited to impact cratering processes; the bodies (asteroidal or cometary) that make the impacts; or the geological, chemical, or biological results of impact cratering. **community.geosociety.org/pgd/awards/shoemaker**

RONALD GREELEY AWARD FOR DISTINGUISHED SERVICE

Nominations due **1 August**

Submit nominations to the Division chair: Sam Birch, sbirch@mit.edu

In 2011, the Planetary Geology Division established the Ronald Greeley Award for Distinguished Service. This award may be given to those members of the PGD, and those outside of the Division and GSA, who have rendered exceptional service to the PGD for a multi-year period. The award is not open to currently serving members of the management board but may be awarded to past members of the management board who have provided exceptional service to the PGD after their term on the management board has ended. Nominations for the award, which should include a description of what the nominee has given to the PGD community, may be made by any PGD member to the management board. **community.geosociety.org/pgd/awards/greeley**

QUATERNARY GEOLOGY AND GEOMORPHOLOGY DIVISION

FAROUK EL-BAZ AWARD FOR DESERT RESEARCH

Nominations due **1 April**

Submit nominations to the Division first vice chair: Jennifer L. Pierce, jenpierce@boisestate.edu. Please submit electronically unless hardcopy previously approved.

The Farouk El-Baz Award for Desert Research rewards excellence in desert geomorphology research worldwide. It is intended to stimulate research in desert environments by recognizing an individual whose research has significantly advanced the understanding of the Quaternary geology and geomorphology of deserts. Although the award primarily recognizes achievement in desert research, the funds that accompany it may be used for further research. The award is normally given to one person but may be shared by two people if the recognized research was the result of a coequal partnership. Any scientist from any country may be nominated. Because the award recognizes research excellence, self-nomination is not permitted. Neither nominators nor nominees need be GSA members. Nominations must include (1) a statement of the significance of the nominee's research; (2) a curriculum vitae; (3) letters of support; and (4) copies of no more than five of the nominee's most significant publications related to desert research. Monies for the award are derived from the annual interest income of the Farouk El-Baz Fund, administered by the GSA Foundation. **community.geosociety.org/qggdivision/awards/el-baz**

DISTINGUISHED CAREER AWARD

Nominations due **1 April**

Submit nominations to the Division secretary: Lisa Ely, ely@geology.cwu.edu. Please submit electronically unless hardcopy previously approved.

The Distinguished Career Award is presented annually to a Quaternary geologist or geomorphologist who has demonstrated excellence in their contributions to science.

Because the award recognizes research excellence, self-nomination is not permitted. Neither nominators nor nominees need be GSA members.

Nominations must include (1) a brief biographical sketch; (2) a statement of no more than 200 words describing the candidate's scientific contributions to Quaternary geology and geomorphology; (3) a selected bibliography of no more than 20 titles; and (4) a minimum of four letters from colleagues supporting the nomination. **community.geosociety.org/qggdivision/awards/distinguished-career**

STRUCTURAL GEOLOGY AND TECTONICS DIVISION

STEPHEN E. LAUBACH STRUCTURAL DIAGENESIS RESEARCH AWARD

Nominations due **1 May**

The Stephen E. Laubach Structural Diagenesis Research Award Fund promotes research combining structural geology and diagenesis and curriculum development in structural diagenesis. This award addresses the rapidly growing recognition that fracturing, cement precipitation and dissolution, evolving rock mechanical properties, and other structural diagenetic processes can govern recovery of resources and sequestration of material in deeply buried, diagenetically altered and fractured sedimentary rocks. The award highlights the growing need to break down disciplinary boundaries between structural geology and sedimentary petrology, exemplified by the work of Dr. Stephen Laubach and colleagues. The award alternates between being awarded by the Sedimentary Geology Division on odd numbered years, and the Structural Geology and Tectonics Division on even-numbered years, reflecting the focus of the award on this cycle. Graduate students, postgraduate, and faculty-level researchers are eligible. **community.geosociety.org/sgt/awards/laubachaward**

GSA Award

Nominations due 31 March for best published environmental geology paper.

JOHN C. FRYE ENVIRONMENTAL GEOLOGY AWARD

Nominations due **31 March**

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.

2023 Awardee: Dunbar, N.W., et al., 2022, Climate change in New Mexico over the next 50 years: Impacts on water resources: New Mexico Bureau of Geology and Mineral Resources, Bulletin 164, 218 p., https://doi.org/10.58799/B-164. **www.geosociety.org/GSA/About/awards/GSA/Awards/Frye.aspx**

Shape GSA's Future by Voting in This Year's Election

GSA's success depends on you—its members—and the work of Officers and Councilors serving on GSA's Executive Committee and Council. Notice of the election will be posted on the secure GSA website with instructions for accessing the online ballot. When the ballot opens on 6 March, information on the candidates will be available online for review. Paper versions of the ballot and candidate information are also available upon request. Ballots must be submitted electronically or postmarked by 5 April.

Congratulations to our incoming president who was elected by GSA membership in 2023.

PRESIDENT
(July 2024–June 2025)

Carmala N. Garzione
Dean, College of Science
Professor of Geosciences
University of Arizona
Tucson, Arizona, USA

2024 Officer and Council Candidates

PRESIDENT-ELECT/ PRESIDENT
(July 2024–June 2026)

Nathan A. Niemi
Professor, Dept. of Geological Sciences
University of Michigan
Ann Arbor, Michigan, USA

TREASURER
(July 2024–June 2027)

Brian G. Katz
Environmental Consultant
Weaverville, North Carolina, USA

COUNCILOR POSITION 1
(July 2024–June 2028)

David E. Fastovsky
Professor, Dept. of Geosciences
University of Rhode Island
Wakefield, Rhode Island, USA

Eric Kirby
Professor and Chair
Earth, Marine and Environmental Sciences
University of North Carolina
Chapel Hill, North Carolina, USA

COUNCILOR POSITION 2
(July 2024–June 2028)

Jason A. Flaum
Research Sedimentologist
U.S. Geological Survey
Broomfield, Colorado, USA

Darryl Reano
Assistant Professor,
School of Earth and Space Exploration
Arizona State University
Tempe, Arizona, USA

COUNCILOR POSITION 3
(July 2024–June 2028)

Tandis S. Bidgoli
Assistant Professor,
Dept. of Geological Sciences
California State University
San Bernardino, California, USA

Martha Cary (Missy) Eppes
Professor of Earth Sciences,
University of North Carolina
Charlotte, North Carolina, USA

Capture Captivating GEOLOGY

2025 GSA Calendar Photo Search

Do you have an aptitude for photographing beautiful natural surroundings? Take part in a GSA tradition by submitting up to three of your most captivating, awe-inspiring geologic images for the chance to appear in GSA's 2025 calendar.

Photo credit: Twenty47studio / Moment, AlexmarPhoto / iStock / Getty Images Plus, Kevin Key / Slworking / Moment via Getty Images.

Deadline: 15 March

Send up to three of your best images in landscape orientation, using the following categories as a guide:

Iconic Landscapes

Share striking or notable geologic landscapes and features.

Abstract Images

Unveil the mesmerizing patterns of geology at any scale from photomicrographs to satellite images.

Geologic Processes Past and Present

Showcase the dynamic results of specific processes, whether it's the eruption of a volcano or volcanic rocks that represent ancient eruptions.

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How to Enter

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

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

By submitting image(s) to the 2025 GSA Calendar Photo Search, you agree to gratis use of your images by GSA in a calendar and in promotional materials. GSA employees are not eligible to enter.

Visit **www.geosociety.org/GSA/Publications/GSA/Pubs/Photos.aspx** for more information.

Field Camp Teaches Newfound Geological Techniques

Rebecca Buwalda, J. David Lowell Field Camp Scholar 2023, University of Miami Class of 2025

After four years of postponement, the University of Miami geology department's traditional field camp in Newfoundland and Labrador, Canada, was renewed, and I was lucky enough to partake in the adventure. I spent the month of July in the thicket of the beautiful, mountainous countryside of Newfoundland, touring the western coast, and even ferrying up to Labrador to explore some of the most fascinating geological landmarks in the world.

The J. David Lowell Field Camp Scholarship provided me with the financial means necessary to attend this educational and culturally immersive experience. Our camp began in Port au Port, Newfoundland, where we observed and identified the various sedimentological layers of the Taconic orogeny, which includes sandstones, limestones, and large stromatolite and thrombolite beds. My time in Port au Port was the most geologically satisfying for me because it was geared toward my interest in studying sedimentology and geochemistry for my professional career. However, as we moved northward from Port au Port, the educational focus of the trip shifted, and my gifted Brunton compass became a key component to my success.

Huge thrombolite mounds in Port au Port, Newfoundland. Photo courtesy of Rebecca Buwalda.

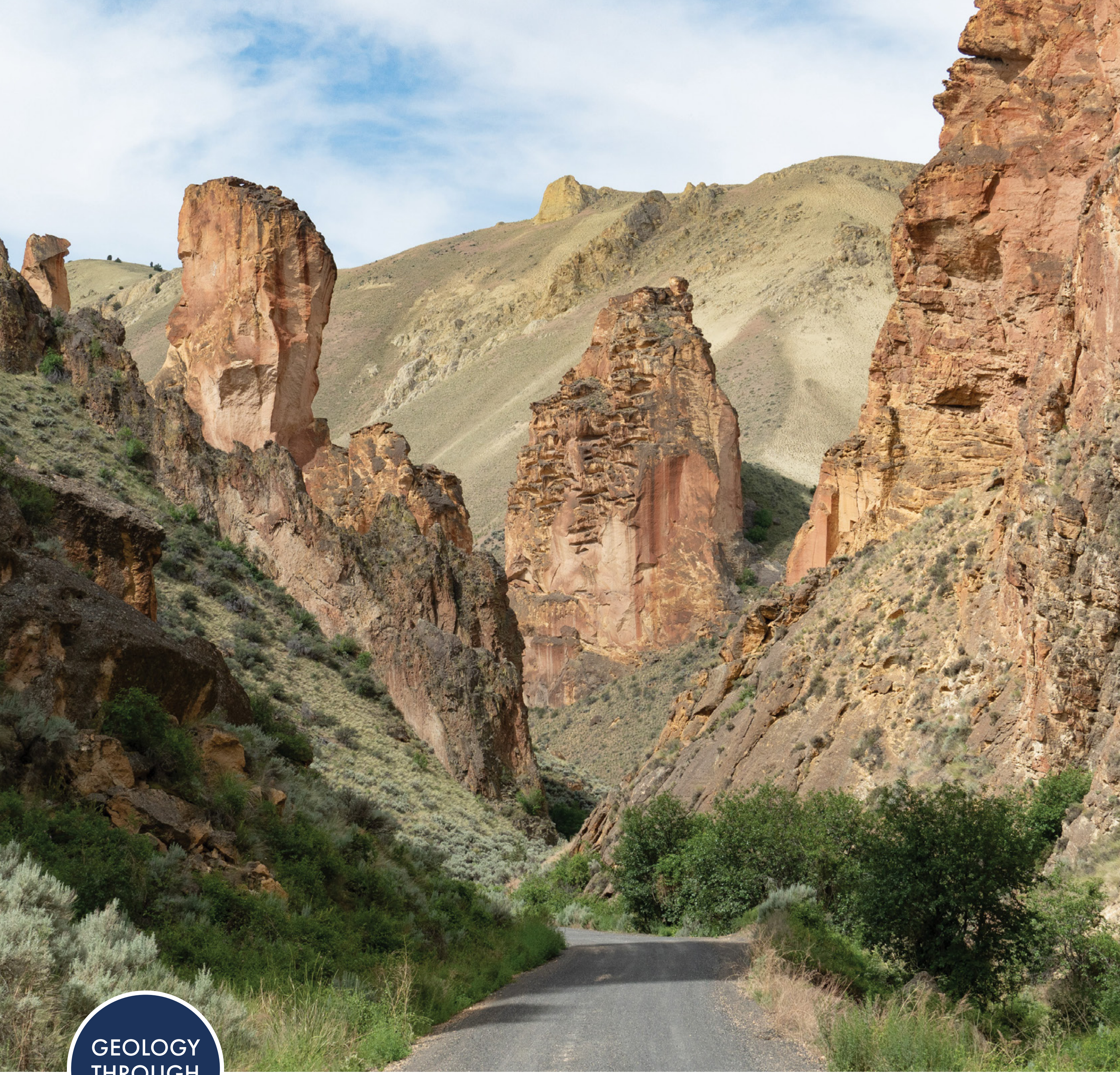
Visit page 18 for application details.

ULTIMATELY, THE TRIP TAUGHT ME A VARIETY OF GEOLOGICAL AND CULTURAL LESSONS THAT I WOULD NOT BE ABLE TO LEARN ANYWHERE ELSE.

We spent several days in Battle Harbour, Labrador, mapping the unusual series of lithologies and utilized strikes and dips to define discontinuities. Battle Harbour was my favorite stop on the trip because of the rich culture and history it provided. I stayed in a historic house that harbored the first medical facility in Newfoundland and Labrador, ate traditional foods in the town kitchen, and partook in the tradition of jumping into the icy Labrador Sea alongside my classmates. The isolation of Battle Harbour from the mainland helped facilitate a focused learning environment for my peers and me to learn about mapping techniques and identifying various metamorphosed sedimentary layers.

The last leg of the trip took place in Gros Morne National Park and Cow Head, Newfoundland. The sites are famous for the ophiolite sequence exposure and large thrombolite mounds that supposedly make the shape of a cow head. Hiking the ophiolite sequence and touching rocks from the mantle was a transformative experience that undoubtedly aided me in better understanding mantle composition. In Cow Head, we completed our third and final map of lithologies and discontinuities of sedimentological cycles up the oceanic shelf, which included the largest thrombolite mounds I have ever seen. By this point in the trip, I was confident to call my new Brunton my best friend.

Ultimately, the trip taught me a variety of geological and cultural lessons that I would not be able to learn anywhere else. The large transportation and tuition expenses of the trip put my attendance at risk, but the scholarship provided me with the funds necessary to have this once-in-a-lifetime experience. I will continue to cherish the memories I made and the geological techniques I learned from my field camp for the rest of my life.



GEOLOGY THROUGH THE LENS

Oregon's Ancient Landscape

Road descending Leslie Gulch, eastern Oregon. The orange cliffs and greenish slopes behind are both part of the Leslie Gulch Tuff, which erupted during formation of the Rooster Comb caldera 15.8 million years ago.

Photo credit: Marli Miller is a faculty member of the Earth Sciences Department at the University of Oregon. Her website, geologypics.com, provides free earth science photographs for teachers.

Want your photo to be featured in *GSA Today*? Email submissions to gsatoday@geosociety.org.

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Feeling Relieved: Creating a Positive Bathroom Field Culture in the Geosciences

Mo E. Snyder[1,*] and Merilie A. Reynolds[2]

ABSTRACT

Fieldwork typically poses some level of disruption to regular bathroom habits, which can lead to discomfort, distraction, and, in some cases, serious health and safety risks. We all have a role to play in mitigating these hazards and ensuring field bathroom matters are not a barrier to participation.

Geoscientists carry out fieldwork in a variety of settings, including urban environments, remote wilderness areas, and industrial sites, such as active mines. Field experiences may take the form of day trips or multiday excursions requiring camping or hotel stays. As such, fieldwork can pose some level of disruption to regular bathroom habits. Bathroom behaviors directly impact the physical and emotional well-being of field workers; negative outcomes range from minor discomfort to serious physical health problems. This topic is an important component of field safety but receives relatively little attention. Bathroom-related concerns can distract from participants' abilities to fully engage in fieldwork and may become a barrier to participation entirely. Although this is an issue that can affect anyone, it disproportionately impacts some groups, including those who squat to pee, menstruate, have chronic UT or GI conditions, have a physical disability, or are from cultural backgrounds with bathroom-related taboos or sensitivities. This likely contributes to the lack of diversity in the ranks of geoscientists.

MOTIVATION

With experience working in academia, industry, and government, we have heard negative bathroom-related stories from many individuals. Examples include individuals who have avoided going to the bathroom in the field, leading to consequences such as fainting, urinating themselves, urinary tract infections, kidney stones, and debilitating constipation. There are stories of anxiety attacks brought on by swarms of mosquitoes and people being hurt by cactus, poison ivy, stinging nettle, and tick bites while squatting. We heard from a field geologist who was concerned for the safety of their field assistant because they were going so far away to go to the bathroom but felt unable to address the uncomfortable issue. We listened to stories of teaching assistants taking on the emotional labor of advocating for a pit stop for a car full of students. Despite these experiences indicating that this is a real problem, we have also encountered many colleagues who ascertain that going to the bathroom in the field poses no difficulties or barriers.

PREVIOUS WORK

There is no direct bathroom-related peer-reviewed literature pertaining to the geosciences. However, there are discussions related to inclusion that indirectly refer to bathroom culture. For example, John and Khan (2018) discuss mental health in the field and argue that it is impacted by environmental and interpersonal factors. Giles et al. (2020) discuss barriers to fieldwork including lack of exposure, experience, and physical and mental differences that could lead to exclusion or even avoidance of geoscience entirely. Although not peer-reviewed, Greene et al. (2020) detail considerations regarding toilet stops on academic field trips in urban settings and provide a list of recommendations for field trip leaders. The Prospectors & Developers Association of Canada Health and Safety (2009) e-toolkit lists "bathroom and privy facilities" as a suggested topic for pre-field season safety meetings but does not go into further detail. Overall, there is a general lack of discussion of field bathroom matters as they relate to the health and safety risks of fieldwork, responsibility of communication, intra-group relationships, and inclusion.

HEALTH AND SAFETY

Going to the bathroom in the field is associated with an increase in the health and safety risks involved in fieldwork, yet it is commonly excluded from safety discussions and documentation. For example, field workers may purposely restrict their water intake to avoid going to the bathroom because of discomfort with the lack of privacy, concern about missing important information, or to avoid exposure to physically uncomfortable conditions like insects or extreme

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temperatures. This behavior can contribute to dehydration, and ramifications of “holding it” include an increased risk of urinary tract infections, kidney stones, and/or constipation (e.g., McCauley et al., 2012; Scott et al., 2020; Jagtap et al., 2022). Risks involving exposure to wildlife (e.g., ticks, mosquitos, snakes, etc.) and poisonous plants (e.g., poison ivy) are higher for those who squat to pee or defecate, as there is a need to remove clothing and get closer to the ground. The risk of having a dangerous encounter with wildlife (e.g., bears, moose, wild cats) or heavy machinery (e.g., haul trucks on a mine site) is increased for those who isolate themselves from the group, possibly without any communication, to fulfill a need for privacy while going to the bathroom.

LEVELS OF POWER AND BEST PRACTICES

As people who work in the field, we find ourselves in three different roles: participant, leader, and/or organizer. These roles correspond to different levels of power, where the higher a person is in the power structure, the greater the opportunity and level of responsibility it is to improve bathroom culture in the field.

Participants (e.g., undergraduate students, contract employees, field assistants) are the majority of field workers. Participants depend on those above them to communicate operational procedures and to set the pace and tone of fieldwork. Workplace field culture can be a barrier to participants asking about bathroom access and code of conduct.

A participant can prepare for fieldwork by arming themselves with information. There are informal resources (e.g., REI, 2023; Meyer, 2020; Nodding, 2021) that provide handy how-tos related to using the bathroom in the field. A participant should consider carrying their own bathroom supplies, including toilet paper and a small shovel. Stand-to-pee devices (e.g., pStyle, Freshette, Pee-buddy) are useful for those who usually urinate sitting or squatting and come in a variety of textures, sizes, and compositions (e.g., disposable paper-based, flexible plastic). A pee cloth and portable bidet (e.g., Kula Cloth, TUSHY Travel) are useful in places where folks cannot, or choose not to, use toilet paper. Portable travel urinals can be used in the safety and comfort of a tent or vehicle. For participants who menstruate, reusable menstrual cups and discs (e.g., DivaCup, nixit) only need to be removed and washed every 12 hours. Over-the-counter medications, including pain relievers, antidiarrheal tablets, and yeast infection treatments, are useful to have on hand.

Finally, in group settings, participants should establish a buddy system. A bathroom buddy can help by staying in close contact for safety, aiding in ensuring privacy, and if needed, taking notes to make sure the bathroom user doesn’t miss important information. For the buddy system to be most successful, clear communication is key. Use phrases like “I am going to pee here” and “Don’t turn, I am going to the bathroom.” Be aware of consent in these situations and check in with your buddy by asking, “Am I far enough away for you to feel comfortable?”

Leaders (e.g., field trip leaders, instructors, supervisors) are those who have the most influence on day-to-day operations in the field and carry the largest burden of establishing a positive bathroom culture. The most important thing that a leader can do is communicate so that participants go in prepared. Leaders need to review hazards associated with (not) going to the bathroom in the field. For example, a field school instructor should have a preliminary meeting a few weeks before the course begins discussing important materials to pack; this pack list should include bathroom materials that will be provided versus those that participants must bring themselves.

When preparing a field activity plan or a field guide itinerary, a leader should include times and locations of possible bathroom stops. If in a relatively populated area, leaders should consider scheduling bathroom stops throughout the day at gas stations, highway rest stops, or campsites, and they should have a fully stocked first aid kit that includes bathroom materials. If in remote areas, leaders should discuss safe and accessible places to use the bathroom. Leaders should indicate multiple locations for those who require more or less privacy. After a long drive or hike, pause the lesson or work and let participants use the bathroom without fear of missing information or falling behind.

At the top of the power pyramid are the organizers (e.g., administrators, policy makers, senior geologists). An organizer establishes rules for fieldwork. Although organizers may not be in the field with the leaders and participants, they have the power to enact and enforce rules and wise practices, as they are the ones with the money, decision-making power, and ability to directly delegate tasks.

Organizers should always include bathroom accessibility in safety and field activity plan requirements. When standard operating procedures or other guidelines include bathroom access and safety, folks who are lower in the power structure will be introduced early and often to positive bathroom culture. Organizers are often the people who purchase, or approve the purchase of, gear for fieldwork. These purchases should include bathroom-related items.

CONCLUSION

Feeling safe is a key component in increasing positive field experiences. The most important practice for creating a positive bathroom culture during fieldwork is communication. Expectations for professional conduct regarding bathroom behavior should be explicitly discussed in advance of any excursion and revisited frequently throughout the duration of fieldwork. Bathroom-related information should be integrated with other key information regarding safety and logistics.

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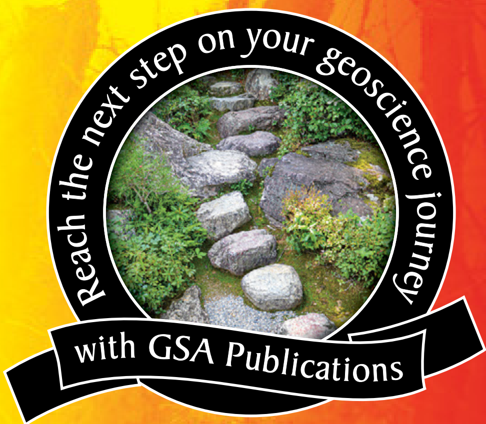

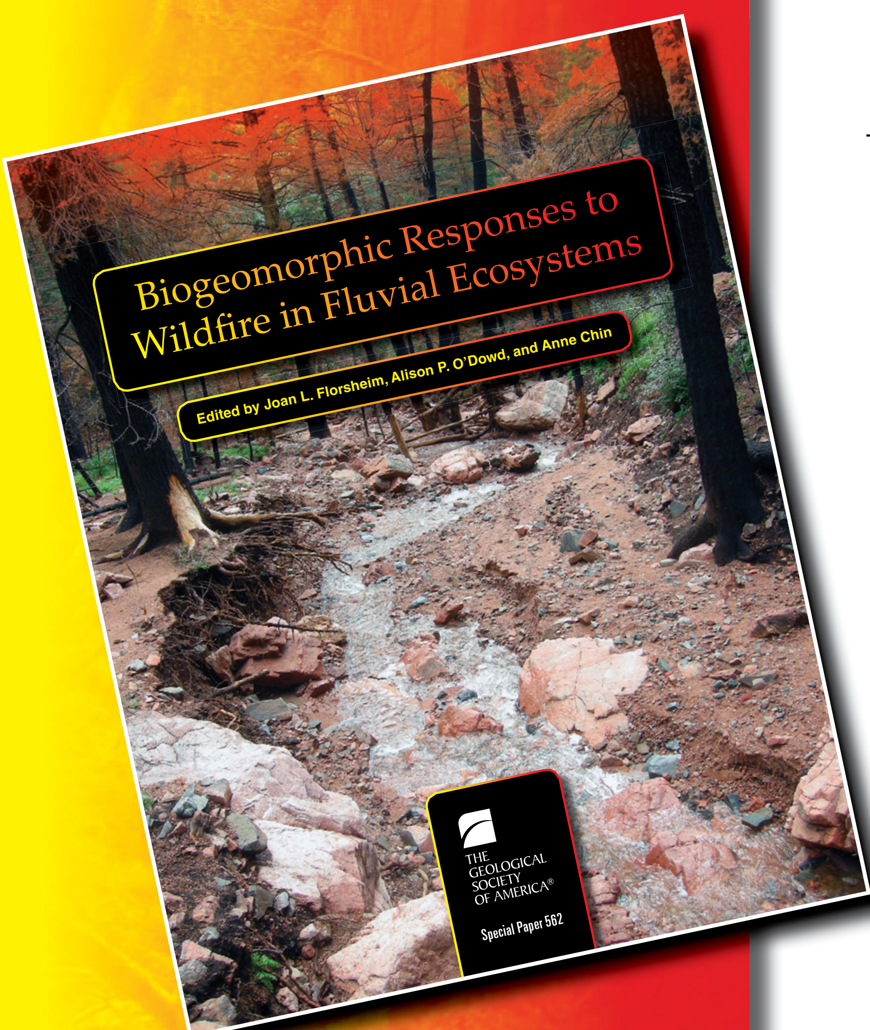

Biogeomorphic Responses to Wildfire in Fluvial Ecosystems

Edited by Joan L. Florsheim, Alison P. O'Dowd, and Anne Chin

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