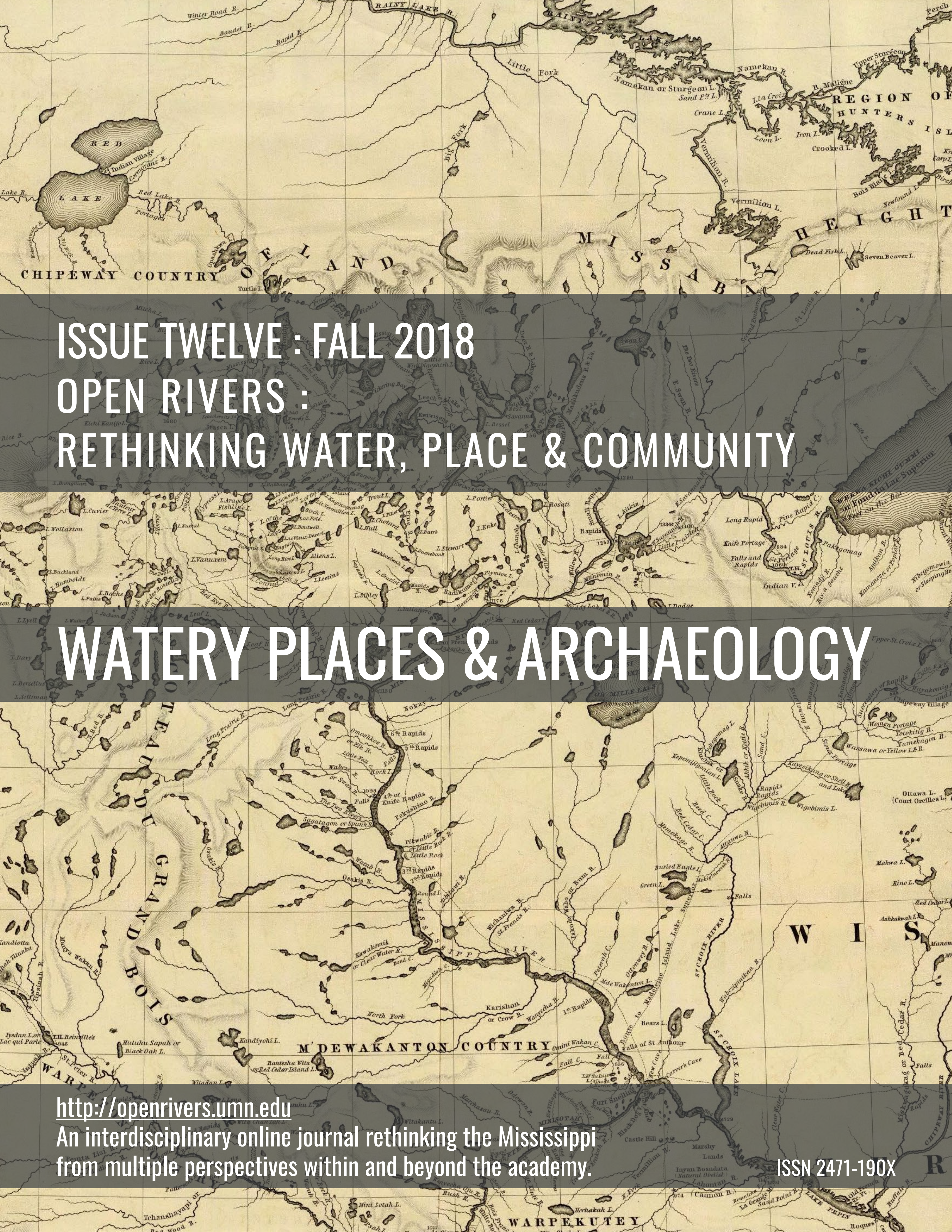

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FEATURE

RIVERS AND BONES

By Katrina Yezzi-Woodley, Martha Tappen, Reed Coil, and Samantha Gogol

The bones that lie below the ruins of a medieval fortress in Dmanisi, Georgia, tell a story about the exodus of early humans from Africa almost two million years ago. The remains of five early humans, known as *Homo erectus*, have been found at Dmanisi. This 1.78 million-year-old World Heritage site is located in the country of Georgia on a promontory above where the Masavera and Pinasauri Rivers converge. Nearly two million years ago, a series of volcanic ash falls led to the rapid burial and protection of bones belonging to a variety of extinct animals that found their resting place there. A rich fauna thrived at Dmanisi, including muskoxen, bison, antelopes, many species of deer, and carnivores, such as the Etruscan wolf, the saber-toothed *Megantereon,*

A picture of the Medieval citadel at Dmanisi that sits above the Pleistocene layers from 1.78 Ma. Photo courtesy of Katrina Yezzi-Woodley and Sean Greer.

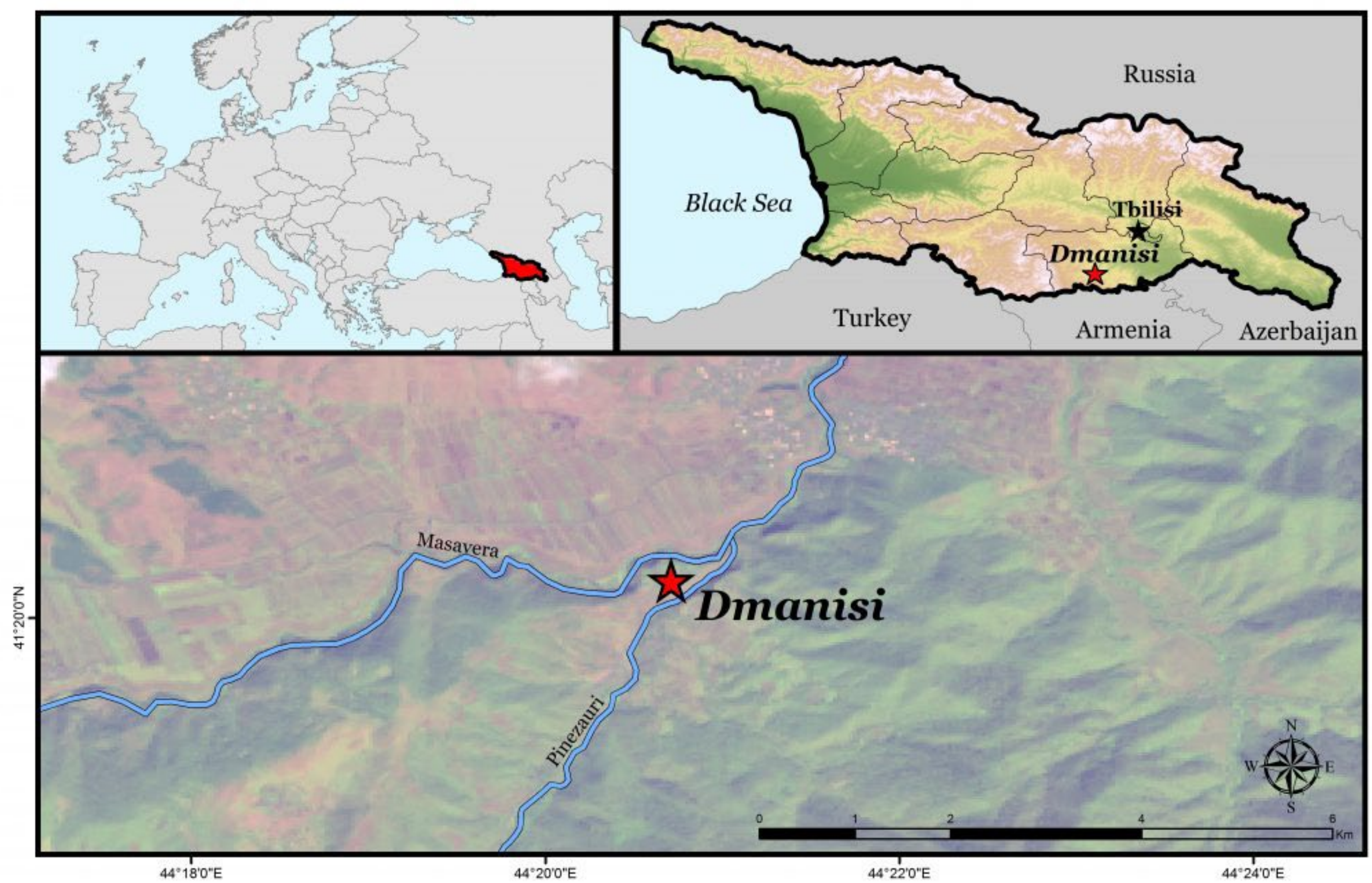
A picture of the Medieval citadel at Dmanisi that sits above the Pleistocene layers from 1.78 Ma. Photo courtesy of Katrina Yezzi-Woodley and Sean Greer.

Homotherium, and the massive, bone-crushing hyena, *Pachycrocuta* (Ferring et al. 2011; Tappen et al. 2007; Tappen 2009). Thousands of bones have been analyzed at Dmanisi and these bones bring to life what may have happened there almost two million years ago.

Considered to be one of the earliest human sites outside of Africa, Dmanisi is central to research on early human dispersals; several hypotheses have been put forth to explain this departure. Some have attributed geographic expansion to technological change; yet, the stone tools at Dmanisi are some of the oldest tool types. Others have suggested that early humans were one of many African taxa that were engaged in a range expansion (Anton and Swisher 2004), though few taxa indigenous to Africa were recovered from Dmanisi, and most of those migrated into Eurasia prior to the dispersal of early humans (Tappen 2009; Tappen et al. 2007). Brain or body size increase has also been suggested as a driver of early human expansion. However, some of the individuals found at Dmanisi have the smallest brain size and stature of this early human species, *Homo erectus* (Lordkipanidze et al. 2013; Anton and Swisher 2004).

It seems as though something intrinsic motivated *H. erectus* to branch out. It could be that *H. erectus* evolved to be a more flexible species in response to environmental fluctuations and instability within Africa between 2.5 and 1.5 million years ago. Such climatic adaptability may have allowed for the dispersal of our ancestors (Anton et al. 2016).

Environments have changed throughout time and these changes have led to the extinction and subsequent radiation of various species. Like all



Map of Dmanisi. Map courtesy of Reed Coil.

A picture behind the scenes at the Georgian National Museum in Tbilisi. Photo courtesy of Katrina Yezzi-Woodley and Sean Greer.

other species on the planet, we operate within the context of our environment, interacting with that environment and its occupants. Humans have demonstrated an incredible capacity to change our environment and manipulate it to meet our immediate needs, the consequences of which remain a focus of research today. Studying past ecologies (paleoecological reconstruction) is important, since we can learn from our responses to environmental changes of the past and address concerns we have about our future as a species and as members of various ecological communities. One way to reconstruct past environments is to examine the bones of animals that lived at the same time as early humans.

Bones reveal important evidence for determining how these animals died, decomposed, and were buried. Vertebrate taphonomy is a field of study within paleontology and anthropology that uses the remains of animals to determine what happened to organisms from the moment of death to the moment the remains are extracted from a site by a paleontologist or archaeologist (Behrensmeyer and Kidwell 1985; Behrensmeyer et al. 2000). A taphonomist not only identifies the animals to which the remains belong, but also determines how those remains have changed over time due to physical and biological processes at work in the environment. Many museums and labs around the world house thousands of animal bones extracted from various archaeological and paleontological sites, which offer clues to researchers about their life, death, and past environment.

The life history of a fossil is complex. An animal can die in a variety of ways; maybe it was killed by a carnivore or human, succumbed to illness or age, or fell victim to a catastrophe such as an earthquake or flood. After death, an animal's carcass can be exposed to the elements for a long period of time or buried immediately. If exposed, it could have been subjected to trampling by herds or scavenging by carnivores and/or humans.

Sometimes carcasses, or a portion thereof, are removed from the location of the animal's death; a carnivore or human may have brought it to another location to eat or butcher it. Maybe a river washed some of the bones downstream. Eventually, the soft tissues of the carcass are eaten or rot away and all that would be left are the bones. Even then, the denser, larger skeletal elements are more likely to preserve than the more delicate ones, so a skeleton is rarely preserved in its entirety.

A taphonomist does not have the luxury of witnessing the processes described above, which can happen over millions of years, and therefore must utilize the evidence left behind to determine what happened.

Bones Move

Sometimes animals are buried precisely where they lived and died, which can inform greatly on the habitat at that specific location. In other cases, bones are transported to that location by other means, including rivers. Assemblages that result from bones accumulating from several different places complicate reconstruction of the environment.

Rivers are powerful forces that can carry bones away from their original location. Rushing waters can carry bones greater distances and may cause a more violent trip downstream than a soft, steady flow. When there is a curve in a river, point bars emerge and bones can become trapped in the riverbend or embedded in the sediments. Sometimes rivers have more than one channel, offering different paths for bones to travel, in turn causing accumulations from different sources over undetermined periods of time.

By looking at the skeletal composition of the assemblage and by looking at the relative location and orientation of specimens, taphonomists can identify bones that were transported by hydraulic action. Some bones are more easily transported than others. The greatest transport potential resides in bones that have less volume but not necessarily less surface area. Some elements, like vertebrae, have wing-like projections that help carry them forward. Articulated bones and dessicated bones are also more easily transported than disarticulated or fresh bone (Behrensmeyer 1988; Boaz and Behrensmeyer 1976; Coard 1999). Long bones tend to orient in the direction of the flow and dip downstream; therefore, when

Bones being transported by flowing water. Notice that some bones become trapped in the riverbend and those that continue to flow become oriented parallel to the river. Image courtesy of Samantha Gogol and Traci Eicholz. See this animated gif here.

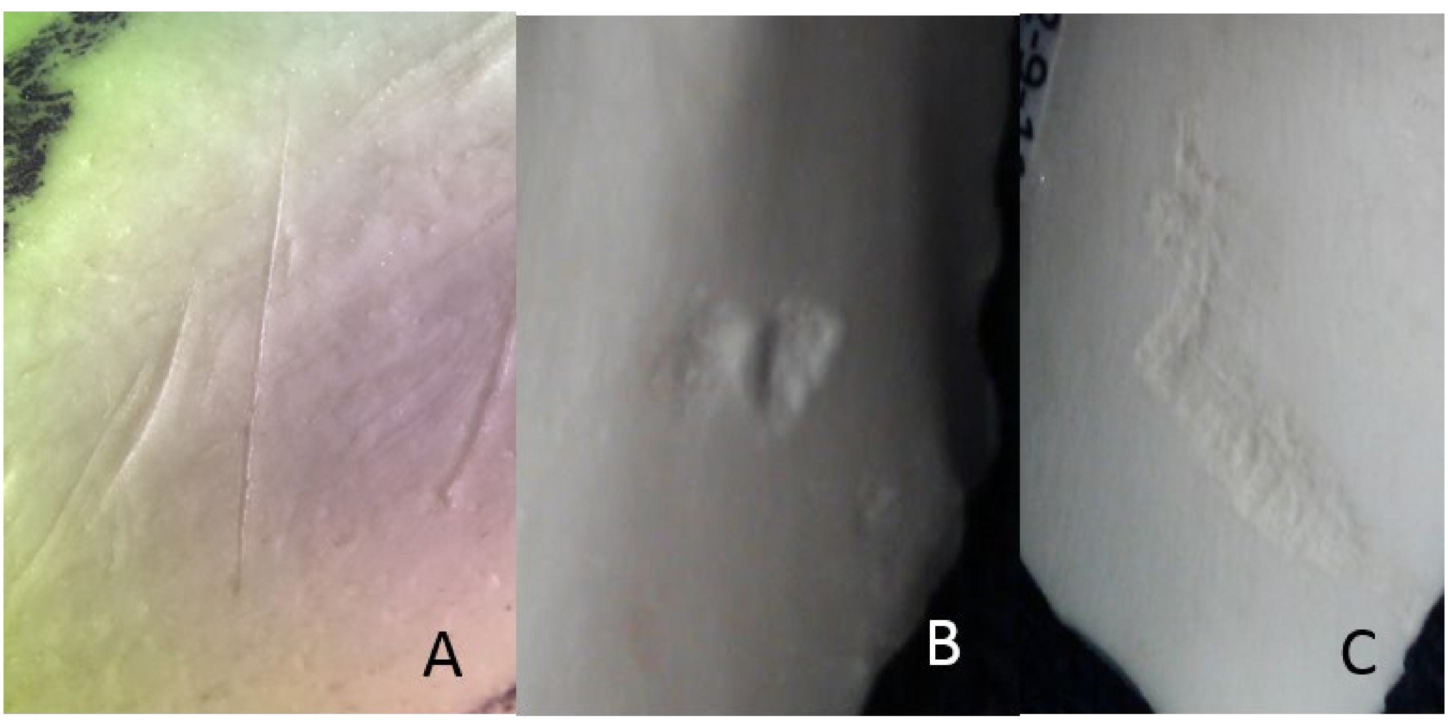
several bones are generally parallel and pointing in the same direction, it can indicate a fluvial environment.

Given that Dmanisi is located near the convergence of two rivers, it would seem likely that fluvial transport is the reason for the accumulation of animal bones there. However, taphonomic analysis suggests otherwise. The bones at Dmanisi are found in natural, underground pipes (tunnels) and gullies which are often created by groundwater erosion during periods of high precipitation. The bones were deposited there by something other than water flow after the gullies were carved out. There is no evidence for high velocity transport or long distance travel as would be expected had the deposition been the result of fluvial transport. Bones that traveled did not travel far; on average, bones were found less than one meter apart. Many whole bones were present and there was no sorting based on size, shape, or density. Many of the bones were articulated or found anatomically close to one another and few of the bones were uniformly oriented (Coil 2016; Tappen et al. 2007, 2015).

Bone Surfaces Get Damaged

Bone surfaces can be altered in many ways. Stone tools can leave cutmarks (pictured above) during the process of butchering a carcass. Humans used stone tools to break open bones to access marrow, leaving percussion marks behind. Acidic plant roots and microorganisms can etch patterns onto bones. Trampling and sediments can abrade bone. Carnivores can leave pits, punctures, and scores (pictured above) on bones as they bite down and scrape their teeth across the surface of a bone.

Processes that can damage bone surfaces are continually taking place and one can overlay the evidence left by another. To test one overlay process, Chisholm et al. (2014) securely fixed

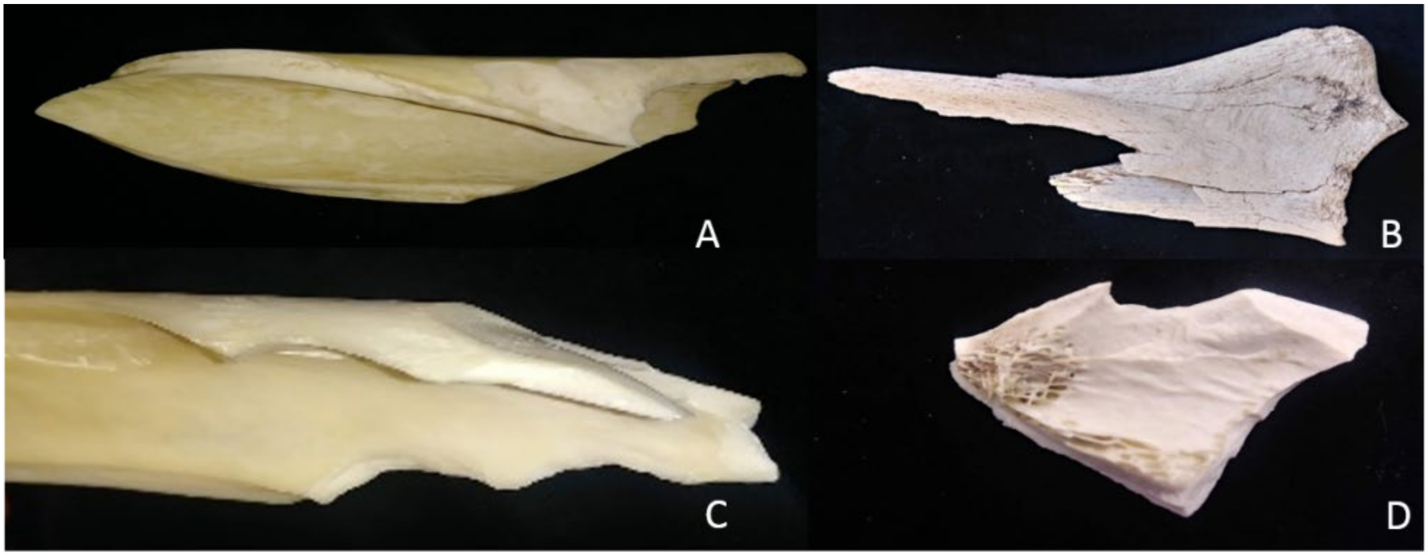


Bone surface modifications. (A) stone tool cut marks, (B) carnivore tooth pits, (C) carnivore tooth score. Photo courtesy of Katrina Yezzi-Woodley.

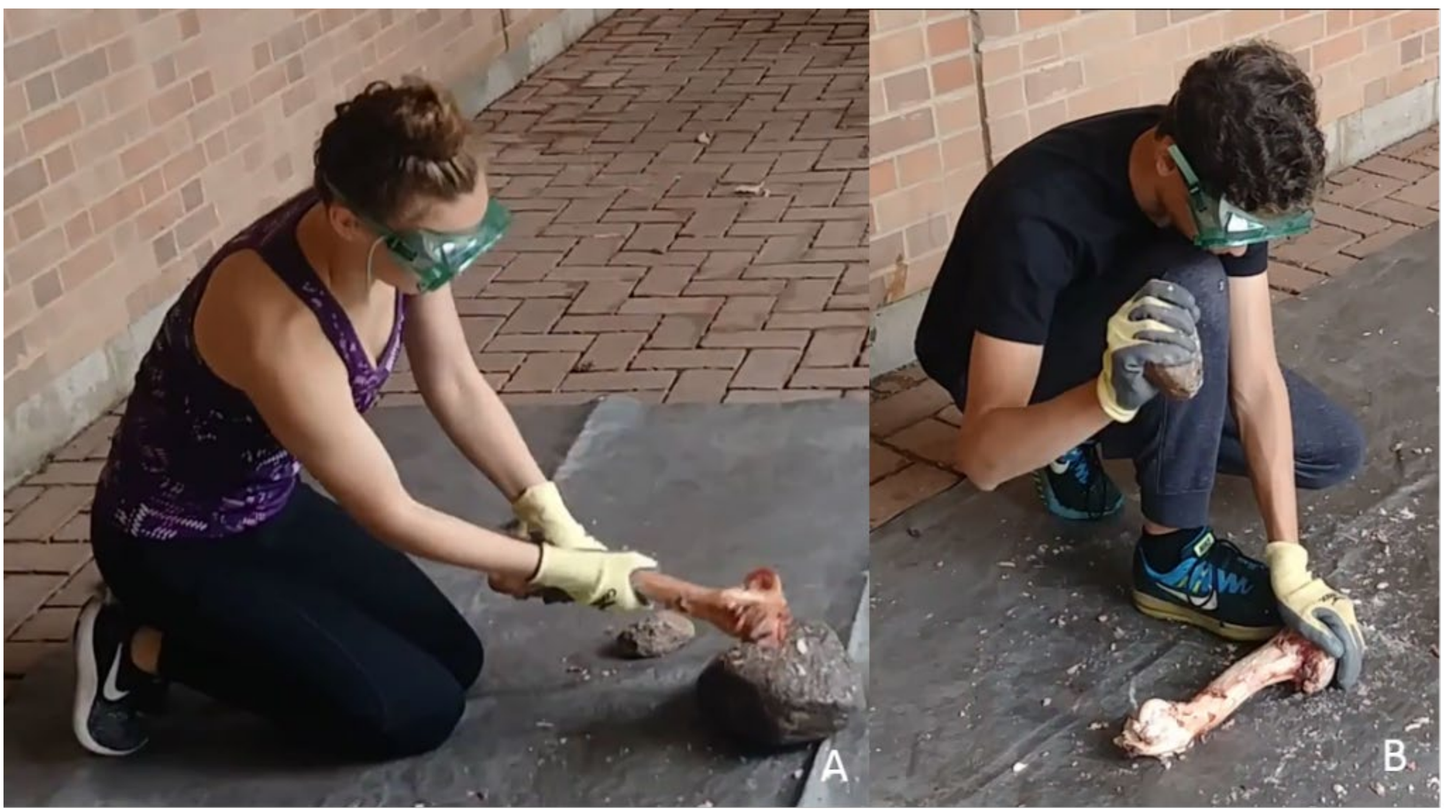
bones that were butchered using stone tools in a recirculating flume fed by the Mississippi River at the University of Minnesota's St. Anthony Falls Laboratory (SAFL) (see other articles about SAFL here and here). The water pushed sediment across the surface of the bone for several days; after 40 hours in the flume, attributes that are typically indicative of cut marks were completely erased by sediment abrasion.

There are stone tool cutmarks found at Dmanisi indicating that humans were butchering animals for meat, but the frequency of marks is low indicating humans were not the primary accumulators of bone at this site. Given that rounding and abrasion, key indicators of fluvial alteration, are minimal at Dmanisi, bone surfaces have been well preserved and cutmarks presumably have not been obliterated by fluvial sediments.

This collage shows a bone suspended in a flume at the St. Anthony Falls Laboratory, illustrating sediments washing over the bone surface.
Image courtesy of Katrina Yezzi-Woodley and Kirsten Jenkins.



(A) A smooth, spiral fracture indicative of a fresh break, (B) A jagged, rough fracture indicative of a dry break, (C) Notches created by carnivores, (D) A notch created by a stone tool. Photo courtesy of Katrina Yezzi-Woodley.



In both of these photos, bones are being broken for marrow. (A) The bone is being struck against a rock, referred to as batting, (B) the bone is being struck by a stone tool called a hammerstone. Pictured on the left is Gabriella Brisa Yezzi-Woodley. Pictured on the right is T.J. Palli. Photo courtesy of Katrina Yezzi-Woodley.

Bones Break

Humans and carnivores break open bones to access the nutrients in marrow inside the bone cavity. Humans broke bones using stone tools. Carnivores, like hyenas and wolves, break bones open with their teeth. When a bone is broken while it is fresh, the breaks are smooth and curved. When bones are dried, the break has edges that are jagged. Stone tools leave percussion marks on the bone surface and both carnivore and humans can create notches, which are arcuate indentations on the edges of broken bone. Notches created by stone tools tend to be broader and shallower, whereas carnivore notches are semicircular (Capaldo and Blumenschine 1994).

Many of the bones at Dmanisi have not been broken, but at least half of those that were broken were done so when fresh, as indicated by the smooth break surfaces. There are percussion marks and a variety of notch types that indicate stone-tool-wielding humans and bone-crushing carnivores were accessing the bone marrow. However, most of the notches at Dmanisi are indicative of carnivore activity (Tappen et al. 2007).

Bones Weather

When an animal dies and begins to decompose, the soft tissue falls away, leaving the bones unprotected and exposed to the elements. When bones are exposed to the sun, wind, rain, and other erosional processes, they too begin to break down and exhibit cracking, bleaching, and flaking of the outer surface, which can obscure modifications like cut marks and tooth scores (Behrensmeyer 1978). Fortunately, at Dmanisi, the bone surfaces are very well preserved. The bones were buried soon after the animal died and were not exposed to the elements for very long (Tappen et al. 2007). In fact, the majority of the specimens have no weathering damage at all.

A picture of weathered bone from the University of Minnesota Anthropology laboratory's faunal comparative collection. Photo courtesy of Katrina Yezzi-Woodley.

Humans and Rivers

Rivers are resource- and energy-rich components of our natural world from which we have greatly benefited and most likely it is the case that we have been doing so since the beginning of our existence. Some have argued that rivers have played an important role in our biological evolution, particularly encephalization (the increase in brain size relative to body size), by providing the necessary types of foods and fatty acids that are available through aquatic resources (Stewart 2010). Dramatic fluctuations in climate during the Pleistocene would have caused early hominins to seek resources in aquatic areas, especially during arid periods when terrestrial vegetation and animal resources were depleted. Though still ephemeral, evidence for the exploitation of aquatic resources in the Early Pleistocene is beginning to emerge. More evidence is still needed before hypotheses regarding aquatic resources and human brain evolution can be fully supported. Nonetheless, there are fish bone assemblages at Olduvai Gorge (Tanzania) where our human ancestors *Homo habilis* and *Homo erectus* may have been consuming catfish; *Homo erectus* may have been consuming freshwater oysters at Kao Pah Nam Cave (Thailand) (Erlandson 2010). Cutmarks have been found on catfish and other aquatic animals such as turtles and crocodiles dating to 1.95 million years ago in the Turkana Basin. In fact, there is evidence that early modern *Homo sapiens*, *Homo neanderthalensis*, and *Homo erectus* all exploited aquatic resources to some degree (Joordens et al. 2014).

Our ancestors' ability to leave Africa and populate the globe may have been due, in some part, to passageways created by rivers. For example, Coulthard et al. (2013) used computer modeling to test the Green Corridor hypothesis as a viable means for *Homo sapiens* to migrate out of Africa around 100,000 years ago. The Green Corridor hypothesis states that rainfall north of the Trans-Saharan Mountains created river channels that flowed toward the Mediterranean. These rivers provided lush pathways in the midst of an otherwise arid, inhospitable environment. By inputting known data about climate and precipitation at that time, Coulthard and colleagues were able to reconstruct river systems. They found that three paleo-river systems—the Irharhar River in the west and the Sahabi and Kufrah Rivers in the east—could have been active during this time and could have provided migratory passageways. This may explain how modern *Homo sapiens* left Africa more recently, but it does not provide an explanation for earlier migrations out of Africa by our ancestors such as *Homo erectus*. In fact, there seems to be decent evidence that the East African savannahs spread further northward, leading to a continual biome at least through North Africa, possibly even into Eurasia (Dennell and Roebroeks 2005; Dennell 2010).

At Dmanisi, the Masavera and Pinasauri Rivers cut into the landscape, which created a natural blockade that predators, human or otherwise, may have used to corner animals. However, one would expect the bones that were accumulated first to be more weathered than bones accumulated more recently, unless carnivores were taking the bones to their underground dens. The expected pattern of variation in weathering is not present on the Dmanisi specimens, but this does not mean that Dmanisi was not used as a predator "hot spot." Dmanisi is a complicated site with many biological and geological processes that contributed to the assemblage of bones found there. Though there was some downhill movement of bones into gullies that can account for some of the accumulation, hominins and, primarily, carnivores are largely responsible for the assemblage of bones found at Dmanisi.

Carnivores were the primary accumulators at Dmanisi. Carnivore bones account for a considerable amount of all faunal specimens and there are many coprolites (fossilized feces), which indicate a strong carnivore presence at the site. Tooth scores and tooth pits are present on bone surfaces, and tooth pit sizes are consistent with modern lion and hyena bite marks. Carnivores were hunting in the area and hyenas may have been using the pipes and gullies as dens (Tappen et al. 2015).

Though carnivores were mainly responsible for Dmanisi's bone assemblage, cutmarks, notches, and hammerstone marks found on a variety of taxa indicate that humans were butchering animals for food. Cutmarks found on specimens suggest that humans had early access to meaty portions of animals, meaning that they were hunting or, more likely, scaring predators away from a fresh kill (Tappen et al. 2015).

Dmanisi is not a classic example of fluvial bone deposition because there is little evidence that bones were deposited there by hydraulic action. Nonetheless, the site is flanked on two sides by rivers. Gullies, resulting from high precipitation run-off, perforate the site and made the preservation of the greatest number of bones at the site possible. At first glance, it may look as though these bones were amassed by the rivers, but a closer taphonomic analysis of the bones reveals that they were accumulated primarily by carnivores and to some extent by early humans who took advantage of the landscape created by the rivers. Although the rivers did not cause the bone accumulation, they shaped the behaviors that did.

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Katrina Yezzi-Woodley is a Ph.D candidate in Anthropology at the University of Minnesota. She is interested in the impact of meat-eating on human behavioral evolution, particularly how early humans were competing with large-bodied carnivores for meat resources. Katrina uses 3D modeling, differential geometry, and machine learning to determine how animal bones were broken at archaeological sites and how to put them back together again. Katrina is also a founding member of Science and Social Studies Adventures (SASSA), a K-12 educational outreach program.

Dr. Martha Tappen is an Associate Professor of Anthropology at the University of Minnesota. Her research focuses on the evolution of human behavior especially human-animal interactions, archaeological site formation, the adoption of meat-eating and the spread out of Africa. For over a decade Dr. Tappen has been excavating and analyzing Dmanisi, a *Homo erectus* site in the country of Georgia, looking at bone accumulating mechanisms and modification by hominins, carnivores and natural processes.

Reed Coil finished his PhD in anthropology at the University of Minnesota in 2016 and now works as an Assistant Professor in the Department of Sociology and Anthropology at Nazarbayev University in Astana, Kazakhstan. His research focuses on human spatial organization, both past and present, and early human carnivory. He is currently working on archaeological projects in Georgia and Kazakhstan to explore trends in local space use and the extent of northward human range expansion in Pleistocene Eurasia.

Samantha Gogol is a second-year PhD student at the University of Minnesota working with taphonomist Dr. Martha Tappen. She is interested in taphonomic research examining bone modifications. Samantha’s previous research examined paleoecology through ecomorphological signals and and extant faunal habitat occupation.