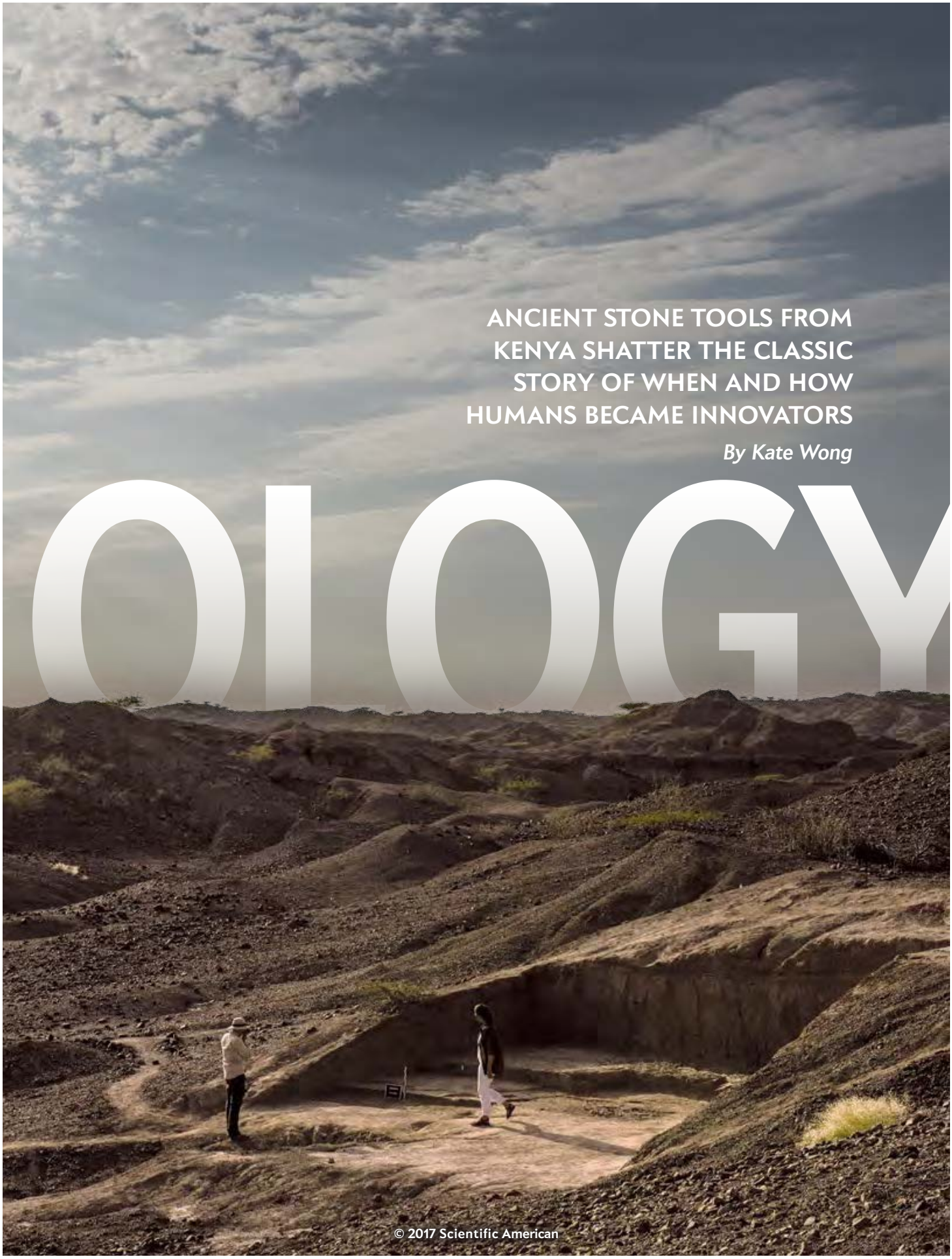
ARCHAEOLOGY

THE NEW ORIGINS OF TECHN

ARCHAEOLOGISTS at a site in northwestern Kenya called Lomekwi 3 have unearthed the oldest stone tools in the world.

Photographs by Andrew Renneisen



ANCIENT STONE TOOLS FROM KENYA SHATTER THE CLASSIC STORY OF WHEN AND HOW HUMANS BECAME INNOVATORS

By Kate Wong

OLOGY

The desert badlands on the northwestern shores of Kenya's Lake Turkana offer little to the people who live there. Drinking water is elusive, and most of the wild animals have declined to near oblivion. The Turkana scrape by as pastoralists, herding goats, sheep, cattle, donkeys and the occasional camel in the hot, arid countryside. It is a hard life. But millions of years ago the area brimmed with freshwater, plants and animals. It must have been paradise for the human ancestors who settled here.

Kate Wong is a senior editor at *Scientific American.*

2

Sonia Harmand has come to this region to study the legacy these ancestors left in stone. Harmand is an archaeologist at Stony Brook University. She has an intense gaze and a commanding presence. On a hazy July morning Harmand sits at a small, wood folding table, scrutinizing a piece of rock. It is brownish-gray, about the size of her pinkie fingernail, and utterly unremarkable to the untrained eye. But it is exactly what she has been looking for.

Nearby 15 workers from Kenya, France, the U.S. and England are digging their way into the side of a low hill. They tap hammers against chisels to chip away at the buff-colored sediments, searching for any bits of rock that could signal ancient human activity. At the top of the hill, the workers' water bottles hang like Christmas ornaments on the thorny branches of an acacia tree; the early breeze will keep their contents cool a little longer before the heat of the day sets in. By afternoon the air temperature will top 100 degrees Fahrenheit, and the excavation floor, windless and sun-cooked, will live up to its nickname: the Oven.

In 2015 Harmand and her husband, Jason Lewis, a paleoanthropologist at Stony Brook, announced that their team had discovered 3.3-million-year-old stone tools at this site, which is called Lomekwi 3. They were the oldest stone tools ever found by far—so old that they challenged a cherished theory of human evolution. The scientists want to learn who made the tools and why. But they also have a more immediate task: unearthing more evidence that the tools are, in fact, as old as they appear.

The fragment in Harmand's hand is the first evidence of ancient stone-tool production the researchers have recovered since they got here. It is a piece of debris produced by knapping—the act of striking one rock against another to produce a sharp-edged flake. Small and light, the fragment implies that the site has not been disturbed by flowing water in the millions of years since. That fact, in turn, supports the argument that the Lomekwi 3 tools come from this ancient sedimentary layer and not a younger one. Now that the excavators have hit the artifact-bearing level of the site, they must proceed with care. "*Pole pole,*" Harmand instructs them in Swahili. Slowly, slowly.

Paleoanthropologists have long viewed stone-tool production as one of the defining characteristics of the *Homo* genus and the key to our evolutionary success. Other creatures use tools, but only humans shape hard materials such as rock to suit their purposes. Moreover, humans alone build on prior innovations, ratcheting up their utility—and complexity—over time. "We seem to be the only lineage that has gone fully technological," says Michael Haslam of the University of Oxford. "It isn't even a crutch. It's like an addition to our bodies."

The conventional wisdom holds that our techno dependence began to form during a period of global climate change between three million and two million years ago, when Africa's woodlands transformed into savanna grasslands. Hominins, members of the human family, found themselves at a crossroads. Their old food sources were vanishing. They had to adapt or face extinction. One lineage, that of the so-called robust australopithecines, coped by evolving huge molars and powerful jaws to process the tougher plant foods available in grassland environments. Another—the larger-brained *Homo*—invented stone

IN BRIEF

A traditional view of human evolution holds that stone-tool technology originated with members of our genus, *Homo,* as an adaptation to shifting climate.

In this scenario, that adaptation quickly helped to establish a feedback loop that dramatically expanded brain size and technological prowess in our lineage.

Recently discovered stone tools from Kenya that date to 3.3 million years ago—long before the oldest known *Homo* fossils—have overturned this scenario.

1

WORKERS DIG into the side of a hill at Lomekwi 3 in July 2016, looking for artifacts (*1*). They sift each bucket of sediment they remove, hoping to recover even the smallest fragments of interest (*2*). Every pebble is studied for signs of human modification.

tools that gave it access to a wide variety of food sources, including the animals that grazed on these new plants. With the rich stores of calories from meat, *Homo* could afford to fuel an even bigger brain, which could then invent new and better tools for getting still more calories. In short order, a feedback loop formed, one that propelled our brain size and powers of innovation to ever greater heights. By one million years ago the robust australopithecines disappeared, and *Homo* was well on its way to conquering the planet.

The Lomekwi tools have smashed that scenario to pieces. Not only are they too old to belong to *Homo,* but they also predate the climate shift that supposedly kindled our ancestors' drive to create. And without any cut-marked bones or other signs of butchery at the site, it is not at all certain that the tools were used to process animal foods. What is more, such a vast expanse of time separates the Lomekwi tools from the next oldest implements on record that it is impossible to connect them to the rest of humanity's technological endeavoring, suggesting that the advent of stone tools was not necessarily the watershed moment that experts have always envisioned it to be.

These new discoveries have scientists scrambling to figure out when and how our predecessors acquired the cognitive and physical traits needed to conceptualize and fashion stone tools and to pass their craft to the next generation. If multiple lineages made tools from rock, researchers will need to rethink much of what they thought they knew about the origins of technology and how it shaped our branch of the family tree.

DAWN BREAKS GENTLY IN THE BUSH—A SLOW brightening of sky, a creeping swell of birdsong—and the team's campsite, on the bank of a dry riverbed about a mile from Lomekwi 3, comes to life. By 6:30 A.M. the workers emerge from their tents and head to the makeshift dining table for breakfast, walking along a gravel path lined with stones to deter the snakes and scorpions. Within the hour they pile into Land Cruisers and set off on a bone-rattling ride to the excavation.

The team is down one vehicle and short on seats in the remaining two, so archaeologist Hélène Roche has decided to stay at camp. Roche is an emeritus director of research at the French National Center for Scientific Research and an expert in early stone-tool technologies. She has short, sand-colored hair, and she dresses in desert hues. Her voice is low and crisp. Roche led the archae-

Map by Amanda Montañez

ological research in western Turkana for 17 years before handing the reins to Harmand and Lewis in 2011. She has returned for the second half of this expedition to see how they are faring. I remain at camp for the day to ask her about the history of work in this region.

"When I started in archaeology, we were just getting used to having stone tools at 1.8 [million years ago] at Olduvai," Roche recalls. In 1964 Kenyan paleoanthropologist Louis Leakey announced that he had found *Homo*-like fossils in association with what were then the oldest known artifacts in the world, stone tools from Tanzania's Olduvai Gorge (referred to as Oldowan tools). He assigned the fossils to a new species, *Homo habilis,* the "handy man," cementing the idea that stone toolmaking was linked to the emergence of *Homo*.

Hints that stone tools might have originated before *Homo* soon arrived, however. In the 1970s Roche, then a graduate student, discovered older Oldowan stone tools at a site in Ethiopia called Gona. When archaeologist Sileshi Semaw, now at the National Center for Research on Human Evolution in Burgos, Spain, and his colleagues eventually analyzed the tools, they reported them to be 2.6 million years old. Because no hominin remains turned up with the tools, researchers could not be sure which species made them. Semaw and his team proposed that a small-brained australopithecine species found at a different site nearby—*Australopithecus garhi*—was the toolmaker. Few were swayed by that argument, however. *Homo* was still the favorite candidate, even though, at the time, the oldest known *Homo* fossil was only 2.4 million years old. (A recent find has extended the fossil record of *Homo* back to 2.8 million years ago.)

Yet as old as they were, the Gona artifacts looked too skillfully wrought to represent humanity's first foray into stone-tool manufacturing. So did other ancient tools that began to emerge, including some from western Turkana. In the 1990s Roche found 2.3-million-year-old Oldowan stone tools at a site five miles from here known as Lokalalei 2c. She realized that in many instances, the site preserved entire knapping sequences that she could piece together like a 3-D puzzle. By refitting the Lokalalei flakes to the cores from which they were detached, Roche and her colleagues could show that toolmakers struck as many as 70 flakes from a single core. This impressive feat required an understanding of the rock shape best suited to flaking (flat on one side and convex on the other) and careful planning to maintain that shape while knapping. "You cannot imagine what it is like to hold the pieces together and reconstruct what [the toolmaker] has done and how he has done it, to go inside the prehistoric mind," she says.

It was becoming clear that the sophistication evident in the tools from Gona, Lokalalei and elsewhere could not have sprung fully formed from the minds of these knappers. Some kind of technological tradition must have preceded the Oldowan.

In 2010 far older signs of stone-tool technology came to light. Zeresenay Alemseged, now at the University of Chicago, and his colleagues reported that they had found two animal bones bearing what appeared to be cut marks from stone tools at the site of Dikika in Ethiopia. The bones dated to 3.4 million years ago, hundreds of thousands of years before the earliest known traces of *Homo*. The researchers credited the marks to *Australopithecus afarensis,* a species that was still apelike in many respects, with about as much gray matter as a chimpanzee has and a body that retained some adaptations to life in the trees—hardly the brainy, fully terrestrial hominin that researchers had traditionally expected the first butcher to be. The claims did not go unchallenged, however. Some experts countered that animals could have trampled the bones. Without the stone tools themselves, the critics argued, the Dikika scars could not qualify as tool-inflicted marks—and the question of just how far back in time technology originated remained unresolved.


1

AROUND THE TIME THE BATTLE OVER THE DIKIKA bones erupted, Harmand and Lewis began to hatch a plan to look for the older stone tools that the Dikika marks, along with the too-good-to-be-first tools from Gona and Lokalalei, implied should exist. In the summer of 2011 they set out in search of new archaeological sites on the western side of Lake Turkana.

The Turkana basin, as well as much of the Great Rift Valley in which it sits, is a paleoanthropologist's dream. Not only does it harbor an abundance of fossils and artifacts, but it preserves them in rocks that, with some sleuthing, can be dated with a relatively high degree of certainty. The region's history of volcanic eruptions and fluctuating water levels is recorded in the layers of sediment that have accumulated over eons to form a sort of layer cake. Water and wind erosion have exposed cross sections of the cake in locations throughout the basin. Tectonic activity has pushed some sections higher and other sections lower than they once were, but as long as any given exposure preserves at least a few layers of the cake, researchers can figure out where in the geologic sequence it comes from and thus how old it is.

2

EXCAVATORS CHIPPED away at the sediments for weeks before finding any artifacts (*1*). The first finds were flakes produced incidentally during knapping (*2*). A volcanic ash layer called the Toroto Tuff helped to establish the age of the site (*3*).

3

To navigate the rough, roadless landscape, the team drives in the dry riverbeds, called *lagas,* that snake through the region, running from the lake to points west. On July 9 of that year the researchers were headed to a site where, 12 years earlier, a different team had found a 3.5-million-year-old skull of another hominin species, *Kenyanthropus platyops,* when they took the wrong branch of the Lomekwi *laga* and got lost. Climbing a nearby hillside to get a better view of the terrain, they realized that they had ended up in just the kind of place that is promising for finding ancient remains. Outcrops of soft lake sediments, which tend to preserve fossils and artifacts well, surrounded them. And the researchers knew from previous geologic mapping of the region that all the sediments along this *laga* were more than 2.7 million years old. They decided to look around.

Within a couple of hours Sammy Lokorodi, one of the Turkana members of the team, found several rocks bearing hallmarks of knapping—adjacent, scoop-shaped scars where sharp flakes had been chipped off. Could these be the older, more primitive tools that the team was looking for? Maybe. But the tools were found on the surface. A modern-day human—perhaps a passing Turkana nomad—could have made them and left them there. The researchers knew that to make a convincing case that the tools were ancient, they would have to find more of them, sealed in sediments that had lain undisturbed since their deposition, and conduct detailed geologic analyses of the site to establish the age of the artifacts more precisely. Their work had just begun.

By the time the researchers went public with their discovery, describing it in 2015 in *Nature,* they had excavated 19 stone tools from a 140-square-foot area. And they had correlated the position of the sediment layer that held the tools to layers of rock with known ages, including a 3.31-million-year-old layer of compacted volcanic ash called the Toroto Tuff and a magnetically reversed layer from a time, 3.33 million years ago, when the earth's magnetic poles switched places. They had also located the source of the raw material for the tools—a 3.33-million-year-old layer of beach containing cobbles of volcanic basalt and phonolite, along with fish and crocodile fossils that show just how much higher lake levels were back then as compared with today. Together these clues indicated that the tools dated to a stunning 3.3 million years ago—700,000 years older than the Gona tools and half a million years older than the earliest fossil of *Homo.*

The artifacts have little in common with Oldowan tools. They are far larger, with some flakes the size of a human hand. And experiments indicate that they were knapped using different techniques. Oldowan knappers favored a freehand style, striking a hammerstone held in one hand against a core held in the other, Harmand explains. The Lomekwi knappers, in contrast, would either bang a core they held in both hands against an anvil lying on the ground or place a core on the anvil and hit it with a hammerstone. The methods and finished products demonstrate an understanding of the fracture mechanics of stone but show considerably less dexterity and planning than are evident in tools from Gona and Lokalalei. The researchers had found their pre-Oldowan stone-tool tradition. They call it the Lomekwian.

Not everyone is convinced that the Lomekwi tools are as old as the discovery team claims. Some skeptics contend that the team has not proved that the artifacts originated from the sediments dated to 3.3 million years ago. Discoveries made this field season, including the knapping debris, as well as a handful of new tools recovered during excavation, may help allay those concerns. But even researchers who accept the age and the argument that the rocks were shaped by hominins are grappling with what the find means.

First, who made the tools? To date, the team has not recovered any hominin remains from the site, apart from a single, enigmatic tooth. The age and geographical location of the tools

suggest three possibilities: *K. platyops,* the only hominin species known to have inhabited western Turkana at the time; *A. afarensis,* the species found in association with the cut-marked animal bones from Dikika; and *Australopithecus deyiremeda,* a species that was recently named, based on a partial jawbone found in Ethiopia. Either *K. platyops* or *A. afarensis* would be surprising because both those species had a brain about the size of a chimp's—not the enlarged brain researchers thought the first toolmaker would have. (*A. deyiremeda*'s brain size is unknown.)

Small brain size is not the only anatomical trait that experts did not expect to see in an ancient knapper. Paleoanthropologists thought that tool use arose after our ancestors had abandoned life in the trees to become committed terrestrial bipeds. In this scenario, only after their hands had been freed from the demands of climbing could hominins evolve the hand shape needed to make stone tools. Yet studies of *A. afarensis,* the only one of these three species for which bones below the head have been found, indicate that although it was a capable biped on the ground, it retained some traits that would have allowed it to climb trees for food or safety. Just how important was the shift away from life in the trees to life on the ground in the emergence of stone-tool technology?

The Lomekwi 3 tools are also forcing scientists to reconsider why hominins invented stone tools to begin with. Reconstruction of the paleoenvironment of the greater Lomekwi area 3.3 million years ago indicates that it was wooded, not the savanna experts thought had forged *Homo*'s stone-working skills.

Perhaps the biggest question: Why are the Lomekwi 3 tools so isolated in time? If stone-tool manufacture was the game-changing development that experts have always thought it to be, why did it not catch on as soon as it first appeared and initiate the feedback loop that expanded the brain?

RECENT STUDIES MAY HELP EXPLAIN HOW A HOMININ MORE primitive than *Homo* could have come to make stone tools. It turns out that some of the differences in cognitive ability between hominins and other primates may not be as great as previously thought.

Observations of our closest primate cousins, for example, hint that even though they do not manufacture stone tools in the wild, they possess many of the cognitive abilities needed to do so. David Braun of George Washington University and Susana Carvalho of Oxford have found that in Bossou, Guinea, wild chimps that use stones to crack open nuts understand the physical properties of different rocks. The researchers shipped assorted stones from Kenya to Bossou and made them available to the chimps for their nut-cracking activities. Despite not having prior experience with these kinds of rock, the chimps consistently selected the ones with the best qualities for the job. And experiments with captive bonobos carried out by Nicholas Toth of the Stone Age Institute in Bloomington, Ind., and his colleagues have shown that they can be trained to make sharp flakes and use them to cut rope. "I have no doubt that our apes could replicate what [Harmand and her team] have at Lomekwi, given the right raw material," Toth asserts.

Even inventing stone tools in the first place may not have required special genius. Last fall Tomos Proffitt of Oxford and his colleagues reported that they had observed wild capuchin monkeys in Brazil's Serra da Capivara National Park unintentionally making sharp stone flakes that look for all the world like Oldowan tools. Quartzite cobbles abound in the monkeys' environment, and they will often pick up one cobble and bash it against another embedded in the ground that serves as an anvil. All the bashing dislodges sharp flakes that have the hallmarks of intentionally produced stone tools, including the scooplike shape that arises from what is known as conchoidal fracturing. The monkeys ignore the flakes, however. Instead they seem to be pulverizing the quartz to eat it—they pause between strikes to lick the resulting dust from the anvil. Perhaps early hominins invented their stone flakes by accident, too, or found naturally sharp stones in their environment, and only later, once they found a good use for them, began fashioning them on purpose.

The possibility that the Lomekwi toolmakers had hands that were at once capable of knapping and climbing in trees does not seem so improbable either, once one considers what our primate cousins can manage. The modern human hand, with its short, straight fingers and long, opposable thumb, is purpose-built for power, precision and dexterity—traits we exploit every time we swing a hammer, turn a key or send a text. Yet as the observations of chimps, bonobos and capuchins show, other primates with hands built for grasping tree branches can be surprisingly dexterous. The hands of partially arboreal hominins could have been similarly clever.

In fact, recent studies of the fossilized hand bones of three small-brained hominin species from South Africa—*Australopithecus africanus, Australopithecus sediba* and *Homo naledi*—show evidence for exactly this combination of activities. All three species have curved fingers—a trait associated with climbing. Yet in other respects, their hands look like those of toolmakers. Tracy Kivell and Matt Skinner, both at the University of Kent in England, examined the internal structure of the hand bones, which reflects the loading forces sustained in life, and found a pattern consistent with that seen in hominins known to have made and used stone tools and different from the internal structure of the hand bones of chimps. "Being a good climber and a dexterous toolmaker are not mutually exclusive," Kivell says. A variety of hand shapes can make and use stone tools, she explains. The changes the human hand eventually underwent just optimized it for the job.

FRIDAY IS *CHOMA* NIGHT FOR THE LOMEKWI TEAM—ROASTED goat will be served for dinner. Nick Taylor of Stony Brook, a droll Brit, is taking advantage of the menu to try to figure out what purpose the Lomekwi stone tools served. This morning one of the local Turkana shepherds brought the purchased animal for slaughter. This afternoon, as the sun begins its descent and meal preparations begin, Taylor asks camp kitchen manager Alfred "Kole" Koki to try to process the carcass with replicas of the Lomekwi tools. Koki, an experienced butcher, doubts they will work. But he gamely takes a two-inch-long flake and starts slicing. He manages to skin most of the animal and carves some of the meat with the sharp-edged rocks, discarding them as they become dull, before reclaiming his steel knife to finish the job.

Taylor observes how Koki instinctively holds each flake and how long it retains its edge before Koki requests a new one. Taylor keeps the used replica flakes so that later he and his colleagues can compare their damaged edges with those of the real

SONIA HARMAND and husband, Jason Lewis, co-direct the West Turkana Archaeological Project that discovered Lomekwi 3.

flakes. He will also collect some of the bones to study what kind of cut marks the carving might have left on them. And he will try using the tools to cut plant materials, including wood and tubers. In addition, Taylor is looking for any residues on the Lomekwi tools that might provide clues to what they were processing.

For whatever reason the Lomekwi hominins made stone tools, their tradition does not appear to have stuck. Nearly 700,000 years separates their implements from the next oldest tools at Gona. Perhaps hominins did indeed have a stone-tool culture spanning that time, and archaeologists have just not found it yet. But maybe the Lomekwi stone-working was just a flash in the pan, unrelated to the Oldowan technology that followed. Even the Oldowan record is patchy and variable, showing different tool styles at different times and places, without much continuity among them. As Roche puts it, "There is not one Oldowan but Oldowans."

This pattern suggests to many archaeologists that populations in multiple lineages of hominins and possibly other primates may have experimented with stone-tool production independently, only to have their inventions fizzle out, unbequeathed to the next generation. "We used to think that once you have toolmaking, we're off to the races," observes Dietrich Stout of Emory University. But maybe with these early populations, he says, technology was not important to their adaptation, so it simply faded away.

Around two million years ago, however, something changed. The tools from this period start to look as though they were manufactured according to the same rules. By around 1.7 million years ago a more sophisticated technology arises: the Acheulean. Known for its hand ax, the Swiss Army knife of the Paleolithic, the Acheulean tradition spread across Africa and into other parts of the Old World.

Braun thinks the shift has to do with improved information transmission. Chimps appear to have what he calls low-fidelity transmission of behavior based on observational learning. It works pretty well for simple tasks: by the end of his team's six-week-long experiment with the Bossou chimps, the entire community was using the rocks the same way. The activity seemed to spread by means of a recycling behavior in which one individual, typically a juvenile, would watch another, usually an adult, use a certain type of rock to crack nuts, after which the youngster would try to use the adult's tool set to achieve the same ends.

Modern humans, in contrast, actively teach others how to do complex things—from baking a cake to flying a plane—which is a high-fidelity form of transmission. Perhaps, Braun suggests, the variability seen in the Lomekwi tools and in those of the early Oldowan is the result of lower-fidelity transmission, and the standardization of the later Oldowan and the more sophisticated Acheulean signals the development of a more effective means of sharing knowledge, one that allowed humans to ratchet up their technological complexity.

As ancient as the tools from Lomekwi 3 are, the team suspects that even older ones are out there, awaiting discovery. One day, while the rest of the team is excavating, Lewis, Lokorodi and Xavier Boës, a geologist at the French National Institute for Preventive Archaeological Research, set out to look for them. They head for an area known to have sediments older than those at Lomekwi 3, speeding up the *laga* in a cloud of dust. They are taking the same branch they meant to take on that day five years ago when they lost their way and discovered Lomekwi 3.

When they reach their destination, they fan out, eyes trained on the ground, scanning for signs of human handiwork in a sea of rocks baked red by the sun. Before long, Lokorodi spies cobbles bearing scoop-shaped scars. In theory, they could be more than 3.5 million years old. But the team will have to follow the same painstaking procedures it carried out at Lomekwi 3. The researchers will have to determine whether the rocks have been shaped by humans and, if so, figure out which stratigraphic level they eroded from, pinpoint the age of that level and then find more of them undisturbed in the ground. Lewis photographs the rocks and notes their location for possible survey in the future. The team will also explore a promising area about three miles from Lomekwi 3 that has sediments dating to more than four million years ago.

Figuring out what technology came before and after Lomekwi 3 and getting a clearer picture of how the environment was shifting will be critical to elucidating the correlations among dietary change, tools and the origins of *Homo*. "Maybe the links are all the same, but everything happened earlier," Lewis offers. "The pieces have exploded, but that doesn't mean they won't reassemble."

"We know quite a lot now but not enough," Roche says of the discoveries in western Turkana. "This is only the beginning." SA

MORE TO EXPLORE

3.3-Million-Year-Old Stone Tools from Lomekwi 3, West Turkana, Kenya. Sonia Harmand et al. in *Nature*, Vol. 521, pages 310–315; May 21, 2015.

Wild Monkeys Flake Stone Tools. Tomos Proffitt et al. in *Nature*, Vol. 539, pages 85–88; November 3, 2016.

FROM OUR ARCHIVES

Tales of a Stone Age Neuroscientist. Dietrich Stout; April 2016.

scientificamerican.com/magazine/sa