Feature
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Human Origins from Afar

Sands and sediments in one corner of Ethiopia provide a time machine to revisit whence we came | By Ricki Lewis

In a dusty, barren area in the Great Rift Valley of Ethiopia, about 140 miles northeast of Addis Ababa, lies a place that holds unique renown among paleontologists. Over the eons, seasonal rains have washed out and exposed bits of the past, including a spectacular, if scattered, assemblage of human ancestors. Here, a triangular area, 310 miles per side, cradles an estimated six million years of prehistory, in rare pockets within mile-thick sediment. "Whenever it rains, new fossils are revealed," explains Yohannes Haile-Selassie, curator of physical anthropology at the Cleveland Museum of Natural History.

Recently published fossil finds from the area, each representing years of collection, preparation, and analysis, bracket in time what we know of our past. Over the last 20 years, paleontologists have uncovered a few of our ancestors in this region, the earliest being the 6-million-year old *Ardipithecus*, to the much more recent 156,000-year-old Herto people, who were a mere step away from modern humanity.

The 1997 discovery of *Homo sapiens idaltu*, or simply the Herto people,[1,2] with their significant cranial capacity, large faces and teeth, adds substantial weight to the theory that Africa was the only home to intermediaries between nonmodern and modern humans. "The Herto fossils are the earliest, well-dated *H. sapiens* of modern aspect," says Chris Stringer, head of human origins at the Natural History Museum in London. Moreover, the fossils' age places them in a contentious time period, when "Mitochondrial Eve," the most recent common maternal ancestor of us all, dwelled in Africa.

Discovered by an international team of paleoanthropologists, geologists, and archaeologists, the Herto fossils also presented a huge mystery from the outset: Their skulls were deliberately, carefully separated from their bodies.

The team, led by the late J. Desmond Clark and Tim White, of the Laboratory for Human Evolutionary Studies at the University of California,

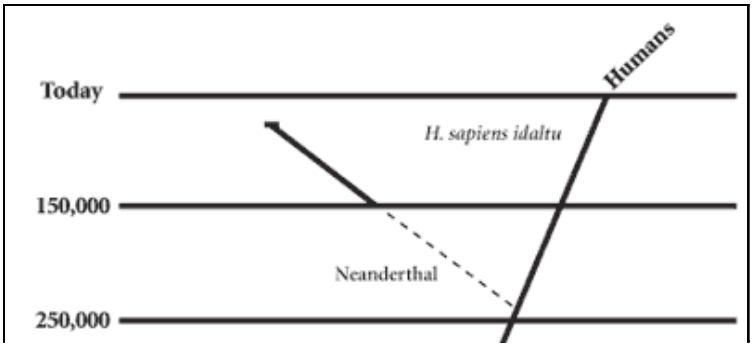
Berkeley, has come to this area, called Afar, since 1981. These trips last for months, but the researchers don't mind the endless hours, ever-present scorpions, stultifying heat, and the local, sometimes herpetological cuisine. They use eclectic tools and technologies, ranging from satellite views of terrain, to radiometric dating, to considering the habits of cannibals.

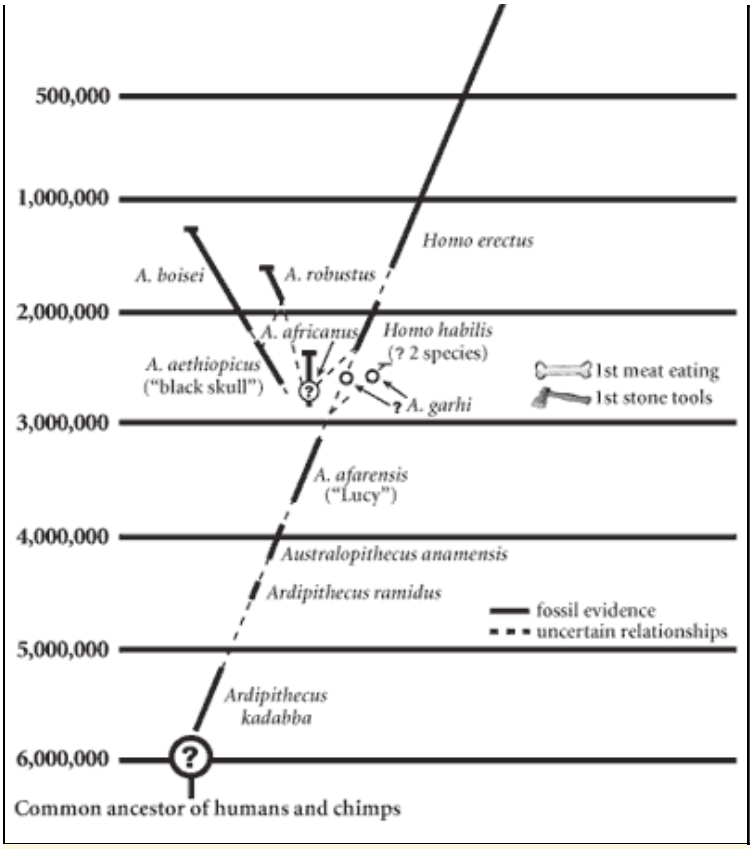
A GRAVEYARD FORMS The story begins an estimated 40 million years ago, when a dome of land rose in the horn of Africa. The Arabian Peninsula broke off and rotated counterclockwise, forming the Red Sea and the Gulf of Aden, while the Great African rift opened. The interaction of rift and dome formed a triangular-shaped lowland called the Afar Depression, which has shoulders of volcanic rock. Annual downpours sent water cascading from the surrounding highlands into the depression, creating rivers and lakes. Sudden floods occasionally transform the lush lowlands into a muddy mass grave. Over the millennia, sediments settled, entombing the remnants of a region once seething with life. Today Addis Ababa is 7,500 feet above sea level, but the adjacent Great Rift Valley has dropped and dried.

The area is unstable. Subtle earth movements periodically shift the layers and expose their telltale contents. But finding fossils in Afar requires familiarity with the terrain and climate. The approach isn't excavation, but observation. "Most discoveries are on the surface. Once we know an area, we go out and walk and walk. This is a huge area with many fossiliferous sites," explains Haile-Selassie. "When it rains in Afar," continues White, "it can do some amazing things. We let the natural erosion of the deposits work for us. Then we work the terrain, picking up pieces and placing them in geologic context to bring back the lost world."

RECENT HISTORY White wasn't even walking on a 1997 autumn day when, in passing the abandoned Herto village, he leaned out the window of his Toyota. He spied the top of a hippo's cranium, with stone tools nearby. Unusually relentless rains had forced the present-day nomads in Herto, with their livestock, to seek better pasture. The recent downpour had cleared the sand around the hippo head, and with the cattle gone, it escaped trampling. The team returned to Herto 11 days later and discovered pieces of three adult human crania. "What to a nonpaleontologist might have looked like a cow pie, to us was a fossil hominid cranium," recalls White.

Courtesy of Henry Gilbert, UCB 1999





EVOLUTIONARY TREE: Diagram of the pieces so far assembled in tracing humankind.

Berkeley graduate student David DeGusta found the first and most complete skull, catalogued as individual BOU-VP-16/1. It had much of its right side intact, which faced into the sediments, but most of the left had weathered away. The palate and teeth were in place, and the cranial capacity, at 1,450 cm, rivaled even the biggest of the 6,000 modern human skulls to which the researchers eventually compared it. A few features, such as the large face and teeth, with prominent brow ridges, most closely resembled Australian aborigines.

Turkish paleontologist Cesur Pehlevan discovered the second cranium, in 24 fragments, among stone tools and apparently butchered hippo bones. Six days later, Berhane Asfaw, from the Rift Valley Research Service in Addis Ababa, discovered 180 fossil fragments and realized it was a child's skull. In the laboratory, Asfaw meticulously removed the sandstone that blanketed the millimeter-thick pieces, then assembled them following anatomical clues, such as depressions left by blood vessels. "Some of the most important pieces that form a link between large chunks of skull are really small, matrix-encrusted pieces of bone from rocks. So when a skull is said to consist of 180 pieces, it means that we went through hundreds of pieces on nonhominid bone to locate them," says Berkeley's Gary Richards, a postdoc in archaeology, who worked on the child's skull. Over the next three years, the team removed, transported, cleaned, assembled, and restored the hominid fossils.

Other evidence, such as hippo and giant catfish fossils, suggested that the Herto people had lived near a lake or delta, says Berkeley postdoctoral researcher Henry Gilbert. The human-like skulls were eerily alone. "We found three crania out of 600 possible bones," says White. "These heads were removed from the body, moved around the landscape, and manipulated with stone tools. From this we can infer mortuary practice." Symmetrical marks at the base of the child's skull, obviously made before the tissue fossilized, suggest careful removal of brain matter, not the characteristically unrestrained damage inflicted by a hungry cannibal. "It would be difficult, if not impossible," says Richards, "to make these cuts with the head still attached. Also, polishing on the cranium suggests it was handled repeatedly, something hard to do with a body attached!"

ESTABLISHING TIME LINES In paleontology, time is as crucial as location. In the Afar region, the intimacy of sedimentary and volcanic rock makes radiometric dating possible. Giday WoldeGabriel, geology team leader from Los Alamos National Laboratory, explains how this happened. "The Afar region was continuously subsiding in some areas, as other parts were uplifted. Basaltic lava flows dammed streams and created lakes. Major streams cascading from the adjacent elevated rift margins carried voluminous sediments into the actively subsiding rift floor." So, adds team member William Hart, professor of geology at Miami University in Oxford, Ohio, this interlayering of volcanic materials with the fossil-bearing sediments "is critical to establishing the absolute ages of the fossil remains."

The team used laser-fusion argon-argon dating. This technique tracks the decay of potassium-40 to argon-40, and then argon-40 to argon-39 as the sample is bombarded in a nuclear reactor. Since the rate of decay is known, researchers can use the proportions of the isotopes in the sample to calculate the amount of time elapsed since the last volcanic eruption, which sets the clock to zero. "As soon as the volcanic rocks cooled down, the clock of radioactivity of potassium-40 starts ticking, and argon-40 starts to accumulate," explains WoldeGabriel. (The argon-39 step improves precision.)

This dating method placed the Herto people on their sandy lakeside about 156,000 years ago, a date that instantly electrified the team. For it was in that time period that Mitochondrial Eve also lived, the figurative name for the mitochondrial genome that has persisted in us all. In the mid-1980s, the late Allan Wilson of Berkeley, his graduate student Rebecca Cann and Mark Stoneking, sampled mitochondrial (mt) DNA sequences from modern human populations. They found great similarity, yet all were subsets of the African genomes.[3] MtDNA, passed only from the mother, is an excellent molecular clock for dating recent events, because the faster mutation rate reveals more differences than does slower-ticking nuclear DNA. Considering genes with known mutation rates, the team extrapolated back 100,000 to 200,000 years to a "lucky mother" who had lived in Africa and was dubbed Mitochondrial Eve.

It was a startling idea. Recalls White, "At the time, [Cann] came to me and asked, 'What's the fossil record like in Africa from 100,000 to 200,000 years ago?' I said, 'it's terrible.' So Becky published this highly controversial work, and the fossil record was mute on the whole thing." Cann, on sabbatical at the University of Hawaii at Manoa, agrees. "There was no other good explanation for our data, so we told it like it was and took our lumps. We simply predicted a model and stimulated them to look for fossils in the right place." Today, few doubt an African origin, but what happened after remains controversial. (See sidebar, at bottom)

***HOMO* EMERGES** Exactly a month after discovery of the first Herto skulls and in a neighboring sedimentary deposit near the village of Bouri, Gilbert found "Daka," a nearly-buried *Homo erectus* skull.[4] Daka and the Herto people were neighbors in space, if not in time, for Daka lived an estimated one million years ago. Gilbert says he was lucky; White tells the tale differently.

Main image: ©1998 David L. Brill\Brill Atlanta; Insert: ©1999 Tim D. White/Brill Atlanta

RECONSTRUCTING THE PAST: Henry Gilbert (left) from the University of California, Berkeley works with Alban Defleur of Marseilles at the Paleoanthropology Laboratory, National Museum of Ethiopia. They are reconstructing a fossilized hippopotamus cranium, the first fossil to be found at the Herto site. A modern hippo cranium is in the background to guide the reconstruction. **Insert:** A side view of the cranium bears a distinct chop-mark made by a stone tool while the bone was still fresh. The tusk and premolars plus molars point downward. The tool is one of the cleavers which was found in the same layer at the Herto site.

"It was the afternoon, and most of us were under the cars to escape the sun of the 110-degree day. Henry came back and said, 'I found something, you gotta see it.' It is rare for us to find something that is not already out and scattered. He had found a skull cap, and a piece of that was just emerging from the sediments." The hominid had a shallow forehead, massive brow ridges, and a brain of about 1,000 cm^3 (1,350 cm^3 is average today). "He still had about a softball's worth of brain

volume to go to reach Herto," says White. The team also discovered several hefty leg bones. Other fossils revealed how Daka lived, sharing the savannah with pigs, antelopes, elephants, wildebeests, and giant hyenas. The ever-present hippos indicated water nearby.

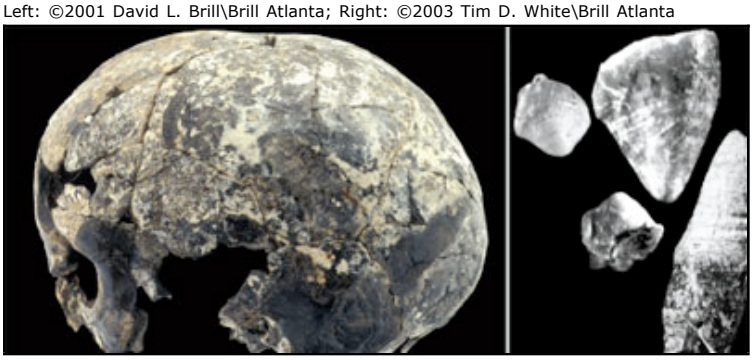
Surprisingly, Daka was remarkably similar to H. erectus fossils from Java, China, and Europe, countering the view that the non-African specimens represented different branches of the evolutionary tree. But before 1.2 million years ago, *Homo* wasn't the only hominid genus; several species of the smaller and more ape-like *Australopithecus* were scattered around Africa.

John Hawks, professor of anthropology at the University of Wisconsin, Madison, compares the situation to a freeway that was once wide, overrun with different species of *Australopithecus*. "Then a new lane was added, the human adaptation with large bodies, brains, and so on, without shutting down the rest of the road," says Hawks. But eventually our immediate forebears became "road hogs, driving in all the preexisting lanes."

These road hogs had tools. Many paleoanthropologists consider toolmaking the step that set Homo apart, with seeds sown among *Australopithecus*. "That sect formed the beginning of the lineage that would ultimately diverge from other *Australopithecus* that kept on being *Australopithecus*. That new lineage would go on to become early *Homo*," speculates White. He discovered the first carnivore with tools, *Australopithecus garhi*, in Bouri in 1999.

Though many have suggested that gradual changes led to the tool bearers, researchers at the University of Pennsylvania last month noted a single gene mutation which they say might have lifted constraints on brain case growth. They dated the frameshift deletion to a myosin heavy chain gene transcribed in jaw muscles and say that the protein change may have brought about the gross anatomical changes first seen in *Homo*.[5]

THE CHIMP AND THE HOMINID *Australopithecus* is thought to have reigned for millions of years, with the exact relationships of species in place and time still unknown. The group includes two celebrities: the Taung child discovered in a South African cave in 1924, and Lucy, from the Afar region in 1974. Lucy's skeleton was remarkably complete, but evidence of older *Australopithecus* is more scant.



TREASURED FINDS: This skull of this *Homo sapiens idaltu* child (left) shows evidence of having been handled so much that the bones on the back and sides (parietal bones) have been polished smooth. The skull also lacks the entire narrow bony opening through which the spinal cord passes to join to the brain. The polishing and intentional scraping modifications suggest that these hominids manipulated the crania of their dead in mortuary practices. Fossil teeth (right) from the newly named species *Ardipithecus kadabba*, found in the Middle Awash Valley. They are shown in the approximate positions as they would appear in the mouth. These teeth constitute a composite of the upper and lower canines and premolars.

Often, the story must be told, or amended, from teeth. In 1994, White, Asfaw, and Gen Suwa of the University of Tokyo described the oldest *Australopithecus*, *A. ramidus*, but then reassigned it to its own genus, *Ardipithecus*.[6] The reason: The large front teeth, small back teeth, thinner enamel, and canines were more apelike. For a time, it held the title "earliest hominid," but three others have since taken its place: an older *Ardipithecus* and two other genera found elsewhere in Africa. The youngest of the three contenders, *Ardipithecus kadabba*, lived from 5.2 to 5.8 million years ago in Afar.[7] "We are looking at more than a million years between *Ardipithecus* ramidus and kadabba. That is part of the evidence that they were two different species," says discoverer Haile-Selassie.

Whether the three hominids are the same or different, they emerged from a planet of apes and monkeys. Fifteen million years ago the world was overrun with at least 20 species of ape; today monkeys are diverse, says White. "What came in between? As the Miocene terminated, African ape diversity was extinguished, except for the lines leading to chimps and gorillas. And out of this came hominids, about 6 million years ago."

Some wonder what would have happened if those hominids had never emerged. The late paleontologist and essayist Stephen Jay Gould envisioned rerunning the tape of life, letting evolution unfold differently. It's humbling to think of alternative scenarios. Says White: "If we run the tape back to the point of divergence from the chimp, and if that doesn't happen, eventually you'd end up with chimps and gorillas and a world of monkeys. Or we might have had some bipedal apes, or *Australopithecus* might have done well for a longer time."

The answers to these queries cannot be found in the Great Rift Valley; and that's probably just as well. For if the extent of the past archaeological findings is any indication of what else can be found among Afar's sediment and dust, then more answers to more realistic questions surely lie out there.

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OUT OF AFRICA-THEN WHAT?

The idea that humans originated in Africa dates to Charles Darwin;[1] 116 years later, Berkeley paleontologists lent Darwin's hypothesis significant support with their "Mitochondrial Eve," the lone human mitochondrial genome found among modern-day people that dates back at least 100,000 years.[2] The team's work supported the "replacement hypothesis" that *Homo erectus* expanded to Europe and Asia about 1.7 million years ago and was replaced wholesale much later, perhaps with Eve's genome. In contrast, the "multiregional hypothesis" viewed the peopling of Europe and Asia as an ongoing gene exchange with periodic reinfusions from Africa. Over time, evolution molded distinctive traits in populations, both in Africa and beyond.[3]

When the 1997 discovery of the Herto people in Ethiopia (*Homo sapiens idaltu*) lent fossil support to Mitochondrial Eve, some researchers declared multiregionalism extinct, because replacement requires that Africa be the source of the first modern humans. But rumors of the impending extinction were premature; the idea of multiregionalism has simply evolved. "In my view, 'classic' multiregionalism is now dead, and we are talking about whether it is entirely out of Africa, or only mostly so," says replacement proponent Chris Stringer of the Natural History Museum in London.

Genetic evidence, mostly supporting total replacement, has accumulated since 1987. For example, Sarah Tishkoff, assistant professor of biology at the University of Maryland in College Park, looked at mitochondrial DNA variants among 600 living East Africans,[4] extrapolating 170,000 years ago for the start of the modern human lineage. This is strikingly similar to the radiometric date of 156,000 years ago for *H. sapiens* idaltu (see main story). "Tim [White] and I independently came up with similar dates. Several other analyses of mtDNA have come up with similar date estimates," says Tishkoff. She used a larger and more geographically specific population than the original Eve study.

Including other types of DNA sequence complicates the picture. In 2002, Alan Templeton, professor of biology at Washington University in St. Louis, statistically analyzed X-linked, Y-linked, and autosomal haplotypes, plus the mitochondrial genome, in several modern European, Asian, and African

populations.[5] X-linked and autosomal sequences are slower to change, and therefore reflect longer time periods than do Y-linked and mtDNA. The results suggest at least two expansions from Africa, at about 600,000 and 95,000 years ago, after the initial one. The data also can be interpreted to show that the more recent expansion was not a total replacement; genes flowed. "Eight out of eight such genes detected human evolutionary events in Eurasia before the latest out-of-Africa expansion, which falsifies the complete replacement theory," Templeton says. But detractors point to a large margin of error, small samples, lack of consideration of geographic distances, and influence of selection on protein-encoding genes.[6]

The recycled debate over replacement versus multiregionalism can sound like semantics. "Evolution in a species means some populations persist and interbreed," says staunch multiregionalist Milford Wolpoff, a professor of anthropology at the University of Michigan, Ann Arbor. "That's not a compromise between replacement and multiregionalism, that *is* multiregionalism. Independent of fossils, Templeton shows continual migrations out of Africa, and that is multiregionalism."

But Templeton thinks his view is more middle-of-the-road. "There is room for both a predominantly African ancestry in all modern humans and for interbreeding. Only by accommodating elements from both of these polarized models can we truly integrate genetic, fossil, and archaeological data into a coherent, unified framework, and this includes the *H. sapiens* idaltu finding."

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