Climate change and human evolution

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It has long been understood that the evolution of organisms involves dynamic, dialectical interaction between a species and its environment—both physical and biological. This applies to humans as well as all other species.

The very beginning of a distinct human lineage is linked to climate change marking the transition from the Pliocene to the Pleistocene, roughly 2.5 million years ago, during which a general drying trend in Africa caused forests to retreat and grasslands to expand. One group of apes, who as a whole are forest-dwelling, ventured or were driven from the forests into the grasslands. The radical shift in adaptation to this new environment initiated the evolutionary trajectory of a new ape lineage—the hominins of the genus *Australopithecus*—leading ultimately to modern humans.

New research, reported in the journal *Science Advances* , elucidates in detail the role played by another environmental change in a major transition in hominin biological and technological evolution, spanning the period from 500,000 to 300,000 years ago in Africa.

Data derived from a program of core drilling through sedimentary rock in the southern Kenyan Rift Valley documents changes in water availability, vegetation and other resources across the landscape that are chronologically correlated with a major technological shift in stone tools, from what are known as Acheulean industries, which had been in use for over a million years, to those of the Middle Stone Age (MSA).

This change is most clearly marked by the disappearance of large bifaces, known as handaxes, which dominated the tool assemblage, to a more diverse and sophisticated tool inventory. Other innovations which appear in the MSA are long-distance trade in lithic (derived from stone) raw materials and the use of coloring materials which may indicate the creation of symbolic representations (i.e., art).

Together, these technological and behavioral changes are taken to be representative of a significant cognitive advance among the humans in that region. Since cognitive abilities do not fossilize, they must be inferred based on material remains—artifacts and fossils. It is likely not a coincidence that the period in question also initiates the transition from the species *Homo erectus*, which had been in existence for over a million years, to a variety of new hominins, including the first appearance of our own species, *Homo sapiens*.

The evidence from the drill cores that significant environmental changes were taking place during the period in question comes in a variety of forms. The sedimentary sequence documented in the cores indicates relative environment stability from 1 million to half a million years ago, then a significant increase in episodes of drying after 500,000 years ago, marked by retreat of lake levels, reflecting a shift to a more unstable, frequently drier environment than had been the case previously. These drier episodes each lasted approximately 5,000 years.

Data from plant remains also indicate a shift from generally wetter to drier environments, including an increased presence of grasses (particularly short grasses), which are more drought-tolerant, as opposed to woody plants. This also suggests the development of a less varied array of plant resources. The cores document repeated, relatively rapid shifts in vegetation.

These vegetation shifts would be expected to affect the animal population that depend on them. Indeed, the fossil record indicates a massive, 85 percent replacement of large mammalian grazing herbivores (greater than 900 kg in body weight) with smaller mammals having a more varied, grazing/browsing herbivorous diet, who could survive in a drier environment. This suggests a less stable climate to which animals with more flexible adaptations and generally smaller body size were better suited. Larger animals also tend to have lower reproductive rates, making them more vulnerable to changing, unstable conditions.

Concurrent archaeological data suggests that humans living at that time also had to become more flexible, broadening their adaptive strategies to cope with a changing, less stable environment. One indication of the need to expand their range of resource procurement comes in the form of the exploitation of a wider range of lithic raw materials for stone tool manufacture.

In the region under study, raw materials used for making Acheulean tools typically came from a distance of no more than five kilometers. By contrast, MSA artifact assemblages include tools made of obsidian, a volcanic rock only available from sources 25 to 95 kilometers away. This may indicate not only a larger procurement/trade range, but also a greater sophistication in tool technology, both in manufacture and use, since obsidian, which is volcanic glass, can be used to make sharper, more delicate tools than coarser grained stones.

One notable change in tool technology at this time is the appearance of smaller projectile (presumably spear) points, which is suggestive of the hunting of smaller animals, consistent with the observed change in the fauna.

The authors of the *Science Advances* paper cite ethnographic evidence from recent populations that humans with a hunter-gatherer economy "tend to increase their investment in technology, expand their range of resource acquisition, and rely on distant social alliances and exchange networks in situations of heightened resource unpredictability and risk." They then postulate that environmental instability during the time range of 500,000 to 300,000 years ago, as documented in the core samples, would likely have prompted similar responses by humans at that time.

Human groups with hunter-gatherer economies are dependent on the natural spatial distribution, abundance, and seasonal availability of food resources as well as the distribution of lithic raw materials and other necessities such as potable water. To survive in a given environment, the group must develop a "seasonal round," placing them at the right places and times across the landscape in order to effectively and efficiently exploit the available natural resources necessary to maintain a sustainable diet and obtain the needed raw materials for their technology.

If a particular locality provides sufficient reliable food and raw materials in a limited geographic range, the human inhabitants will be able to maintain a fairly small "home range."

If, on the other hand, the necessary resources are spatially or temporally dispersed, and/or of limited quantity or quality at any given location, the group will have to travel more widely across the landscape to meet its needs.

If environmental conditions become less stable, altering the seasonality, spatial distribution, or abundance of food resources or sources of water on which a group relies, its economic adaptation will come under stress. This would necessitate a widening of the group's home range and/or the establishment of trade/exchange networks with adjacent groups.

Another adaptive measure is to develop new technologies that would increase the effectiveness of exploitation of existing resources and/or open new resources for incorporation into the diet. The shift from Acheulean to the more complex MSA stone tool technology is consistent with such a change.

The need for wider, inter-regional interactions between human populations during the period in question than had previously been the case would likely have necessitated the development of social mechanisms to mediate relations between different groups, such as shared symbolic representations (possibly including the use of pigments, which have been found in archaeological sites in this area) and perhaps intermarriage. The expansion and increased complexity of intergroup social relations along with the adoption of more sophisticated stone tool technology imply an expanded mental capacity. The contemporary first appearance of the earliest *Homo sapiens* strongly suggests an evolutionary correlation.

While this study is based on data from one region of Africa, the authors suggest that the MSA cultural practices and technology documented in the Kenya Rift Valley would have provided adaptive advantages across other areas as well.