The taming of fire was a turning point in prehistory.
When and where did it begin?

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The ability to control fire is undoubtedly a crucial turning point in human evolution, but to date there is no consensus as to when humans first developed this ability. According to Richard Wrangham's "cooking hypothesis," the cranial and digestive tract anatomy of *Homo erectus* indicates that this group of early humans was already adapted to a diet based on cooked food and therefore was capable of controlling fire. Recent phylogenetic studies on non-human and human primates of body mass, feeding time, and molar size support the hypothesis of the adoption of a cooked diet at least as early as the first appearance of *Homo erectus* around 1.9 Myr.

Yet to date, the archaeological evidence for controlled use of fire in association with *Homo erectus* is scant and inconclusive, as pointed out in a recent review of the archaeological record by Wil Roebroeks and Paola Villa. They suggest that *Homo erectus* may have used fire occasionally but not habitually. On the other hand, archaic Neanderthals and *Homo sapiens* were the first to control fire and use it to survive in the glacial landscapes of Europe and Asia. Indeed, macroscopic and microscopic evidence from the archaic *Homo sapiens* site of Qesem Cave in Israel convincingly show that by about 350 kyr ago humans were producing fire regularly inside the cave.

Then again, Dennis Sandgathe, Shannon McPherron, and Harold Dibble, who worked for decades in Neanderthal sites in France, claim that the archaeological evidence from important securely Neanderthal sites such as Roc de Marsal and Pech de l'Azé do not prove that Neanderthals used fire to cope with the cold climate of the glacial phases nor they were capable of habitually using fire.

Indeed, as archaeologists we are facing a very difficult task when we have to determine if evidence of fire in early human archaeological contexts is unequivocally anthropogenic. Although it is possible to detect the presence of fire and burning in archaeological contexts, it is objectively extremely difficult to securely determine to what extent humans were responsible for starting and controlling that specific fire. A well-controlled fire, such as a small ephemeral camp fire, will produce very limited amounts of ash, charcoal, and burnt bones and sediments. After abandonment, these macroscopic traces will rapidly lose their original spatial distribution, and evidence of controlled camp fire will fade away. Similarly, there are several ways of starting a fire that will leave no evidence. Early humans in particular could have scavenged natural fires that were extremely frequent in the African savannas and carry live embers as did Otzi, the Ice Man of the Similaun, at the moment of his death while trying to cross the Alps 5,000 years ago. Paradoxically, the more humans are capable of controlling fire, the less of a macroscopic trace they are expected to leave behind.

Upon reviewing the archaeological record, the earliest claims for traces of fire are indeed associated with *Homo erectus* for sites in Africa, Asia, and Europe starting ca. 1.5 Myrs ago. In East Africa, these sites include Koobi Fora FxJj 20 East, Chesowanja GnJi 1/6E, and Gadeb 8E. At Koobi Fora FxJj 20 — dated to 1.5 Myr — discolored sediment patches were identified as having been burned on the basis of thermoluminescence (TL) properties and infrared spectroscopy. At Chesowanja, dated to ca. 1.4 Myr, 40 pieces of discolored clay aggregates were found intermingled with Developed Oldowan lithics and fauna and determined to be burned by magnetic susceptibility. Similarly, at Gadeb 8E magnetic properties of welded tuff cobbles indicate that these were burned. Comparable finds have been made on sites in the Middle Awash. At Swartkrans (South Africa), burned bones were identified from Member 3, dated to between 1.0 to 1.5 Myr, on the basis of histological characteristics and chemical identification of charred collagen. Unfortunately Member 3, being the fill of a sink hole, is in secondary context and no information is available on the original location and condition of the burnt bones. Some of the most intensive research on early use of fire has focused on the site of Gesher Benot Ya'akov in the Jordan Valley (Israel), dated to between 0.7 and 0.8 Myr. Here, pot-lid fractures and TL have been used to identify burned microdebitage (minute stone tools and wastes). Their spatial distribution, together with the presence of charred wood, seeds, and grains, led to the hypothesis of the presence of 'phantom hearths'.

Nevertheless, the evidence and acceptance for controlled use of fire at any of these sites associated with *Homo erectus* is still controversial. The controversies stem from the fact that all of these are open-air sites and it is not possible to completely exclude the action of wild fires. And more importantly, in none of these sites was the microscopic analysis of the intact deposits constituting the context of the archaeological finds performed. In fact, it has been demonstrated that the most appropriate scale of investigation to untangle the traces left behind by cultural activities and natural processes in archaeological contexts is below the mm-scale, as was shown at Qesem Cave.

In this perspective, the history of the discovery of the earliest evidence of fire in archaeological context at Wonderwerk Cave is very significant. Wonderwerk Cave is a massive ~140m-long phreatic tube that formed in Precambrian dolostones of the Kuruman Hills (Northern Cape Province, South Africa). Beginning in the 1970s and ending in the 1990s, extensive archaeological excavations were carried out by P.B. Beaumont in seven different areas within the cave. Since 2004, a research project initiated by Michael Chazan of the University of Toronto and Liora Kolska Horwitz of the Hebrew University has renewed fieldwork, performed site formation analysis and chronometric dating, and re-analyzed the archaeological record of the site. The longest Earlier Stone Age (ESA) sequence, ~2 m deep, is found in Excavation 1, currently located ~ 30 m in from the cave mouth. Here the archaeological sequence begins with a small tool industry attributed to the Oldowan in basal Stratum 12, which is overlain by an Acheulean sequence. This sequence shows developments from rare proto-bifaces (Stratum 11) through bifaces with non-invasive retouch in Stratum 10, to highly refined biface production beginning in Stratum 9. In Excavation Area 6, the sequence continues with a Fauersmith assemblage with the earliest blade industry and exploitation of pigment ores, and with other

Middle Stone Age industries. Hence, Wonderwerk overall exhibits one of the longest archaeological sequences ever unearthed, extending from the Oldowan into the Later Stone Age. Indeed, archaeological work at Wonderwerk has so far produced the earliest evidence for cave occupation, fire in archaeological context, blade industry, and working of pigment ores.

As far as the evidence of fire is concerned, Peter Beaumont claimed that Stratum 12 (Oldowan) contained burnt bones and white deposits with dark gray inclusions that were to be considered the remains of the oldest combustion features. When Paul Goldberg and I analyzed the sediments of the putative combustion features and the bones with the FTIR microscope, we found that indeed some of the bones were unequivocally burned but the putative combustion features were instead composed of dolostone and limestone, indicating that these white layers were derived by disintegration of blocks collapsed from the roof of the cave and/or flowstone. So there is no association between the two lines of evidence, and the location of the fire that burned the Oldowan bones remains unknown.

Upon systematic microscopic and FTIR analysis of the petrographic thin sections of the complete archaeological sequence of Excavation 1, we found that a significant number of bone fragments from the Acheulean layers were also unequivocally burnt. Finally, we found that some of these bones were actually resting on a series of microscopic paleosurfaces that also hosted microscopic remains of ashed plant materials. This dataset can only be interpreted as resulting from small fires burning repeatedly inside the cave and indicates that their remains were preserved by its protective environment.

We then went back to reanalyze the materials from previous excavations and found a large quantity of unequivocally burnt bones and heated lithic tools. These burnt objects support the hypothesis of fire burning in situ inside the cave penecontemporaneously with human occupation. And that is all we would like to say today. I can argue that if we were dealing with LSA or MSA lithic assemblages, no one would doubt that such a data set indicated the anthropogenic origin of the fire. But we are dealing with an extreme case and caution has to be used.

In summary, to address the questions of our dialogues, I consider *H. erectus* as being the first Prometheus a hypothesis worthy of testing. Wonderwerk Cave is the ideal place to find out if humans indeed managed fire and cooked their food as early as the Oldowan.

Stay tuned!

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