Fire and the Genus *Homo*

An Introduction to Supplement 16

by Dennis M. Sandgathe and Francesco Berna

Employing fire as an adaptive aid represents one of the most important technological developments in the course of hominin evolution, and, not surprisingly, research into the prehistoric use of fire has a long history. Over the last decade or so there has been a notable increase in research. Some people have continued to focus on better understanding of the timing of the beginning of fire use, but some have also been trying to understand something of its role in the evolution of the genus *Homo*. In the fall of 2015 a symposium was held in Portugal that brought together 17 researchers who have contributed significantly in recent years to this subject. These contributions include improving the type and quality of archaeological and ethnoarchaeological data, collecting and interpreting fire residue data from archaeological sites from various time periods and regions, and developing models of fire as an ecological resource and the role of cooking in hominin evolution. A result of the symposium was the recognition of the need to focus less on data from individual sites and more on the broader role of fire in hominin adaptations and to concentrate more on developing the analytical methods and skills to confidently interpret what we see in the archaeological record.

While it may be difficult to identify major events in the evolution of human physiology, we can certainly identify important cultural ones, such as the initial use of stone tools, the development of artificial shelter, or the beginning of food production. Of course, researchers may debate which developments are the most significant, but when it comes to major technological developments over the course of the evolution of the genus *Homo*, almost all would certainly include the use of fire. It is difficult to overemphasize the significance of this development. In whatever manner fire was initially acquired, whatever it was initially used for, whatever its function at various times and places over the course of subsequent prehistory, and however the hominin-fire relationship developed over time, its far-reaching potential is clear. It allowed us to significantly modify our environment and its resources, to survive in extremely cold environments, and to keep dangerous animals at bay. With fire we can see better in the dark, thus effectively extending the period in each day for activities; we can modify raw materials to expand the range of our material culture; and we can cook our food in order to make it easier and safer to consume and at the same time significantly increase its caloric returns. Beyond significantly increasing our adaptive range and potential, the use of fire very likely played a major role in subsequent physiological changes such as our decrease in gut size and increase in encephalization. The papers in this volume, originally presented at a workshop titled "Fire and the Genus *Homo*," bring together a wide range of current perspectives and data on this important topic.

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Early Research

The recognition of the importance of fire in hominin adaptations can be traced back to very early in the history of prehistoric archaeology and human evolution research (e.g., Darwin 1871). Since then questions about early fire use have been evolving, but rather slowly. For much of the earlier history of research, interest was focused heavily on simply determining when and where fire was first used (e.g., Black 1932; Hough 1926; Oakley 1955, 1956). Moreover, much of this research was not necessarily hampered by any concern about the authenticity of potential evidence for fire use at early sites (e.g., Black 1932; Stewart 1956), and there was also a strong presumption that once fire use was "discovered," it subsequently became a universal and ubiquitous component of all hominin populations (e.g., Oakley 1955, 1956; Stewart 1956). Likewise in the early years there was little specific interest in how fire use came to be incorporated into the hominin technological repertoire: it was simply the result of a discovery. And there was also limited interest in exploring what early fire might have been used for, other than general suggestions related to cooking food, providing heat, or scaring off dangerous animals (e.g., Oakley 1955). A

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significant exception to much of this early history is the work of Kenneth Oakley. In the 1950s he published important articles on the (at that point very limited) evidence for Paleolithic use of fire. This included discussions of the nature of this evidence and potential problems with some of it (including the potential for natural fire residues to be mistaken for anthropogenic ones; Oakley 1954, 1955, 1956, 1961). However, there were no real discussions about the "development" of fire use—that is, as a process rather than an event—and there was no discussion about the interaction between fire use and hominin physiological evolution.

In the early decades of Paleolithic research there were limited field methods available for the accurate identification and interpretation of sediments that could represent potential evidence of hominin fire use. At a number of sites this led to the misidentification of the presence of fire based on sediments that were in fact unrelated to burning (Goldberg, Miller, and Mentzer 2017). For example, at the site of Fontechevade in southwestern France patches of manganese dioxide were mistaken for charcoal (Chase et al. 2009), and at Zhoukoudian, China (Goldberg et al. 2001; Weiner et al. 1998), lenses of organic matter and layers of very fine silts from Middle Pleistocene contexts were mistaken for charcoal and ash. A similar mistaken interpretation occurred at South Africa's Cave of Hearths (Oakley 1957), and more recently there is the example of Schöningen in northern Germany (Stahlschmidt et al. 2015). There was also a serious lack of detail in the descriptions of real or potential fire residues in early sites. For example, the term "hearth" was often used rather indiscriminately to refer to what were simply dark or reddish patches in the sediments or a scattering of a few burned bones, charcoal, or burned lithics, and such evidence was rarely quantified (e.g., Bader and Klein 1965; Breuil 1922; de Lumley and Bard 1972; Garrod 1951; Henri-Martin 1965; Klein 1965; Oakley 1954, 1956, 1961; Stewart 1956; Waechter 1951). This meant that other researchers could not properly assess such findings in terms of how accurately they reflected evidence for fire use in the archaeological record. So the recovery of minute traces of what was assumed to be ash or charcoal resulted, in many cases, in those sites being put forward as examples of the frequent use of fire. Over time, such lack of rigor resulted in an overestimation of the frequency of fire residues in Paleolithic sites and, in turn, how common fire use likely had been throughout the Paleolithic (e.g., Roebroeks and Villa 2011; Sandgathe et al. 2011*b*; Stahlschmidt et al. 2015).

However, while the evidence for fire use from Lower and Middle Pleistocene contexts was limited and subject to debate (Barbetti 1986; Bellomo 1993, 1994; Gowlett 2006; James 1989), unmistakable examples of hominin use of fire, including well-preserved combustion features, had been recognized in Late Pleistocene contexts. This was especially the case with sites associated with Neanderthals in Western Eurasia (e.g., Oakley 1956). Fire residues, however variously described, occurred frequently enough in these contexts that, taken at face value, they seemed to indicate that at least by this point in prehistory fire use had become common. In fact, the literature would suggest that currently the majority of researchers believe that by the Middle Paleolithic, if not earlier, hominins were regularly using fire and had developed the technology to create it at will; conversely, in contexts where evidence for fire was lacking, the absence was interpreted simply as being a product of taphonomic processes. However, there was no evidence of any hominin-fire interaction predating the emergence of the genus *Homo*. This continues to be the case today: regardless of the specific timing for when fire came to be used, it is clearly a behavior associated exclusively with species of *Homo* and does not appear to predate the emergence of *Homo ergaster*. We should note, however, that the recognition of a certain degree of passive interaction between chimpanzees and fire (Pruetz and Herzog 2017; Pruetz and LaDuke 2010) as well as some species of monkeys (Herzog et al. 2014) suggests the possibility of similar behaviors extending back into the Pliocene.

Research in Recent Years

While there has long been a general interest in the question of Paleolithic fire use, the last couple of decades—and especially the last several years—have seen a particularly strong uptick in research on this topic. Since 2000 there has been a three- to fourfold increase in the number of journal publications specifically on Paleolithic fire use. This upsurge is the product of a number of factors that include important new discoveries of fire residues associated with various *Homo* species in Africa, southwest Asia, and Europe, the influence of the cooking hypothesis (Alperson-Afil and Goren-Inbar 2006; Alperson-Afil, Richter, and Goren-Inbar 2007; Berna et al. 2012; Goren-Inbar et al. 2004; Gowlett and Wrangham 2013; Karkanas et al. 2007; Preece et al. 2006; Schiegl et al. 1996; Wrangham 2009), and the development of new methods associated with the recovery and interpretation of archaeological deposits (e.g., Goldberg, Miller, and Mentzer 2017; Mentzer 2014). The latter development has put us in a much better position to distinguish actual fire residues and features from deposits that can potentially mimic them (Bellomo 1994; Berna and Goldberg 2008). A small number of researchers have also begun to broaden our understanding of the nature of natural fires, their resulting residues, and their potential effect on archaeological remains (Barbetti et al. 1980; Gowlett et al. 1981, 2017). These two developments have resulted in a more generally critical approach to claims for fire, especially in particularly old contexts (James 1989; Roebroeks and Villa 2011; Sandgathe et al. 2011*b*).

New approaches are now being used that allow us to test the effects of taphonomy on the presence or absence of ephemeral fire residues in site components. Direct fire residues like charcoal, ash, and heat-altered sediments are easily eroded or dissolved by a range of taphonomic processes, and while we recognize that the absence of these residues cannot be taken as evidence for a lack of fire use at a site, neither can we build models or construct hypotheses about prehistoric fire use on contentions that fire could have been used in contexts where there is no positive evidence for it. However, some fire residues such as fat-derived char (e.g., Goldberg et al. 2009; Mallol et al. 2013) and burned lithics (and to a lesser extent burned bones) are far less affected by common taphonomic processes. Several research projects have been investigating how informative these residues are about the apparent frequency of fire use at Paleolithic sites (Aldeias et al. 2012; Dibble et al. 2009, 2017; Goldberg et al. 2012; Sandgathe et al. 2011*a*; Shimelmitz et al. 2014). Others have been looking at spatial patterning in burned lithics (e.g., Alperson-Afil, Richter, and Goren-Inbar 2007; Gowlett 2006), often with the implicit goal to identify criteria by which the results of natural fire can be distinguished from results of anthropogenic fire (e.g., Gowlett et al. 2017; Hlubik et al. 2017). As a result of improvements in the types and quality of data and an increased appreciation for the importance of biocultural evolution, there are some clear and significant shifts from previous decades in how most researchers view the probable complexity of hominin interaction with and use of fire. This change has resulted in changes in the way Paleolithic fire use should be studied and in what constitutes evidence for various fire-related behaviors.

The Symposium "Fire and the Genus *Homo*"

When we first proposed to Leslie Aiello and Laurie Obbink at the Wenner-Gren Foundation that they devote one of their two annual symposia to early fire use, we were quite surprised to find that over the Wenner-Gren symposium history that spans almost 60 years (and over 150 conferences!), this topic had never been covered before. This is unexpected considering how much interest archaeologists and anthropologists have always shown in the subject of early hominin fire use. However, considering the increased emphasis on research on this topic over the last several years, this did seem like a particularly opportune time to finally bring together a significant number of the scholars currently leading research into this area of hominin behavior and adaptation. We only regret not being able to include all those researchers who are currently doing research on Paleolithic fire or who have made major contributions to this topic in the past.

It is becoming increasingly clear that we are now at the point where we can begin developing a more evolutionary approach to the role of fire in hominin (or homininae?!) adaptations, and this symposium was intended to instigate and facilitate discussion and collaboration along those lines. During the discussions in this symposium it became clear that the field needs to move on from treating hominins establishing "control" of fire as a onetime event at some distant time in the ancient past, from debating the timing of this, and from assuming that from that point on, fire was a regular component of all hominins' adaptations. Obviously, we still need to establish an understanding of the timing of the process of hominin development of fire use, and so it is still very important that we identify examples in the archaeological record of early hominin interaction with fire. These are still our primary sources of data. However, we are coming to recognize that the relationship between hominins and fire was likely a long and complex one, possibly following many varied stages of development. Perhaps not at first, but as this relationship became more entangled, fire came to play ever more important roles in hominin adaptations, and eventually the multifaceted use of fire became a necessity for the survival of modern humans: we became obligate fire users.

The Organization of This Volume

This volume follows the general organization of the symposium on which it is based. The topic "Fire and the Genus *Homo*" includes a wide range of distinct but overlapping areas of research, and we have tried to organize the participants' contributions in this manner.

Prehistoric Fire Use: The Data

Regardless of the varied approaches that researchers take to understand the nature of Paleolithic interaction with fire, all interpretation ultimately rests on the nature and quality of our most basic types of data—residues and alterations directly resulting from fire—and researchers have been expanding the types of data that can be brought to bear on our questions. We rely on these data to provide the most basic contexts for our subsequent interpretations: Are sediments in a site actually fire residues? Are these fire residues the result of natural or anthropogenic fire? What type of fuel was used? What temperature did the fire reach? But we are now trying to expand our questions to include investigations into the structure and function of fires, the latter being the most difficult aspect to demonstrate. These questions lead us to consider even more carefully what types of data should be recorded, what types of samples should be taken, and what analyses should be carried out as a normal course of excavation in sites with potential evidence of early hominin interaction with fire. Building on the work of Barbetti (1986), Goldberg, Miller, and Mentzer (2017) formalize three basic questions that should comprise the identification and interpretation of early *Homo* fire use: (1) Are the sediments or objects in question actually burned? (2) If they are burned, what was the nature and context of their deposition? (3) Were they burned by hominins? Currently there is a range of data, analytical techniques, and methodologies that are necessary in trying to answer these questions, and many of these should be considered as minimal standards in the recovery and interpretation of potential evidence of early fire use. Goldberg, Miller, and Mentzer (2017) and Aldeias (2017) summarize the types of data and analyses as well as quantification that can differentiate actual burned residues from sediments that can mimic these. Ultimately, the most effective approach is going to be the integration of high-resolution spatial analysis of the archaeological record and microscopic and chemical-physical characterization of the archaeological deposits (microcontextual approach).

However, our understanding of the relationship between prehistoric fire and the resulting archaeological residues depends heavily on an understanding of the interaction between fire and its immediate environment and the residues and alterations that result from this interaction. This understanding relies very heavily on experimental work (e.g., Aldeias 2017; Aldeias et al. 2016; Bellomo 1993; Berna et al. 2007; Gowlett et al. 2017; Mallol and Henry 2017; Mallol et al. 2007, 2013; March 1992; March et al. 2014; Théry-Parisot 2001; Théry-Parisot and Costamagno 2005). Having an understanding of what residues and alterations of the immediate environment occur under different heat conditions (e.g., the size of the fire, the duration of the fire, what fuel was used, the nature of the substrates upon which the fire was constructed) and under what conditions these residues and alterations can survive in the archaeological record is essential for the further development of methods that can address the three questions laid out by Goldberg, Miller, and Mentzer (2017).

A second source of information about fire in the archaeological context comes from the ethnographic record. We have come to recognize the problems inherent with trying to apply ethnographic data or models wholesale to prehistoric contexts, especially when we are dealing with premodern hominin species. There is no a priori reason to expect exactly the same interactions with the environment and the exact same limits on the range of behaviors between modern humans and extinct species of *Homo*. Indeed ethnographic analogy should not be completely trusted as compelling evidence in prehistory (Wylie 1985). However, we also recognize that ethnographic data can be a powerful source of insight into the potential types and ranges of evidence left behind by behaviors and technologies that hominins may have adopted under certain environmental circumstances (David and Kramer 2001). The ethnoarchaeology of fire use among living small-scale societies provides a wealth of comparative materials for the interpretation of archaeological fire remains. Such studies can provide important insights into how fire creation technologies, fire function, fire structures, the repeated use and duration of use of a single fire, and fires using different fuels are transformed when they enter the archaeological record (Mallol and Henry 2017; Mallol et al. 2007). In this volume, ethnoarchaeological investigations of fire use among two different small-scale society groups—a group of Hadza foragers in Tanzania and Evenk reindeer herders and hunters of southeastern Siberia—included residue analysis of combustion remains (Mallol and Henry 2017). As with other experimental approaches, these types of studies provide data against which archaeological observations can be compared. For example, how do different types of fuels behave in different combustion settings, and what sort of fire functions can they be linked to? Geoarchaeological analysis of ethnographic fire use provides major insights into taphonomy and formation processes: what is the nature of the residues left behind, if any; what sort of alterations occur to substrates with different types of combustion features and different fuel types; and under what conditions will combustion residues be preserved?

Goldberg, Miller, and Mentzer's (2017) third question (whether or not the evidence of burning is a product of hominins) is especially important in many Paleolithic contexts, especially the open-air sites, because fire residues may be a product of natural fires with no relationship to hominin behavior. In many ecosystems, especially in warmer midlatitudes and forested regions, natural fires are very common, which means that for many archaeological sites natural fires are an equally plausible source for fire residues and alterations of sediments, bones, and lithics (for a particular example, see the prelude in Goldberg, Miller, and Mentzer 2017). It has become apparent that we need a much better understanding of the frequency, variability, effects on substrates, and resulting products of natural fire across a range of different environments so that we can begin to distinguish these from the products of anthropogenic fires—in essence, control for the natural fire "background noise" across the landscape. Based on observations and experiments with natural and controlled-burn fires in eastern and southern Africa, Gowlett et al. (2017) call into question some previous assumptions held about the differences between natural fires and anthropogenic ones. For example, they observed that in natural grass fires temperatures can reach up to and beyond the limit typically ascribed to campfires. However, the nature of residues and alterations produced by a fire depend heavily on the duration of the fire and the temperatures reached. There is significant variability in these variables across different types of wildfires and even within individual wildfires, depending on the nature, concentration, and density of the vegetation.

Lower and Middle Pleistocene Use of Fire

It is in African Lower Pleistocene contexts where we get the earliest potential evidence for hominin-fire interaction, and for many researchers this indicates that *Homo ergaster*/*Homo erectus* could have been regularly using fire well before a million years ago (e.g., Alperson-Afil 2017; Bellomo 1994; Brain and Sillen 1988; Clark and Harris 1985; Gowlett and Wrangham 2013; Shimelmitz et al. 2014). However, the number of examples of Lower Pleistocene fire residues associated with hominin sites is very small when compared with the totality of coeval sites, and the evidence (patches of rubefied sediments that may indicate hearth locations, isolated burned bones, and isolated or small concentrations of burned lithics) is unconvincing to many (Chazan 2017; Roebroeks and Villa 2011). As discussed above, many researchers recognize that given the frequencies of natural fires in Africa today, especially in Savannah and Sahel ecosystems, there is a reasonable possibility that such fire residues in archaeological sites are not the products of hominin behavior (e.g., Gowlett et al. 2017; Hlubik et al. 2017; Roebroeks and Villa 2011; Sandgathe et al. 2011*b*). Over the hundreds of thousands of years that these sites lay on the landscape, natural fires must have passed over them many times. For archaeological sites that are not deeply buried, the chances are not insignificant that the later fires could affect artifacts, bones, and sediments (Buenger 2003). In the case of a burning tree or shrub, the result can be a concentration of burned sediments, bones, or lithics that could mimic the remains of a hearth (Bellomo 1994; Gowlett et al. 2017). This means that simply measuring (through methods like magnetic susceptibility and thermoluminescence) the temperatures that altered sediments or heated flints or performing simple spatial analysis of these residues are not enough to distinguish natural from anthropogenic fires. However, we might be able to get at this problem through the careful analysis of patterning in the burning in these early archaeological sites. This is the approach that Hlubik et al. have been taking in their study of burned basalt, bone, and soil aggregates at the site of FxJj20AB at Koobi Fora in Kenya. They attempt to identify patterning in the distribution of burned artifacts that cannot be explained as a result of the passage of natural fires through or over the site and that indicate that the fire and the occupation of the site co-occurred. This would certainly make it much more likely that the hominins were interacting with and perhaps responsible for the fire.

Researchers have identified sites dated to the end of the Lower Pleistocene with potential evidence for hominin interaction with fire. One of these is Wonderwerk Cave in South Africa, which has yielded ash and burned bone fragments deep inside the cave in deposits dated to a million years ago (Berna et al. 2012; Chazan 2017). It is difficult to propose natural fires as a source for these residues as there is no evidence that any of the sediments washed into the cave and it seems very unlikely that natural fire could occur so deeply inside the cave. There are also sites of similar age outside of Africa. Gesher Benot Ya'akov in Israel, where a number of concentrations of burned lithics across the site strongly suggest the locations of hearths dated to approximately 800 kya (Alperson-Afil 2017; Alperson-Afil, Richter, and Goren-Inbar 2007) and Cueva Negra in Spain where, like Wonderwerk Cave, fire residues occur inside a cave (Walker at al. 2016).

The record of fire in archaeological sites changes dramatically in the Middle Pleistocene, with a large increase in the number of sites and site components with fire residues and undeniable examples of hominin use of fire. This includes intact hearths in several sites in Israel—Qesem Cave (Barkai et al. 2017; Karkanas et al. 2007), Hayonim Cave (Goldberg and Bar-Yosef 2002), and Tabun Cave (Schimelmitz et al. 2014)—and hearth structures identified during recent excavations in layer 4 of Zoukoudian in China (Gao et al. 2017). Whereas we have no idea how fire was being obtained, it is clear that the hominins occupying these sites were using fire and often used it repeatedly, in the same locations within the sites (e.g., at Qesem Cave; Shahack-Gross et al. 2014). These sites dating to 300–400 kya are the earliest evidence so far for fire beginning to take on a more important role in *Homo* adaptations. It is very difficult to get a realistic idea of the actual nature of this interaction or the role that fire was playing. To get at this we need more information about, among other things, the actual frequency of use of fire at these sites. Was fire being used every time a group occupied a site? Or was its use intermittent, and if so, how much time passed between uses, and why was it just used at some sites and not others? It would be important to have some understanding of how regular fire use was, how integrated it had become in hominin adaptations, and what function or functions it served before we are able to construct models about the role fire played and its potential impact on hominin biocultural adaptations at this point in prehistory.

Fire Use in Late Pleistocene Europe and Holocene Australia

The current evidence from several Spanish sites in the Atapuerca Hills and Orce Basin indicates that some species of *Homo* (some version of *H. erectus*?) moved into Europe sometime prior to 1.25 Mya (Carbonell et al. 2008; Moyano et al. 2011). However, evidence for any interaction with fire in any European sites older than around 400 kya is almost nonexistent (the one exception, so far, being Cueva Negra in Spain, which has fire residues that date to around 800 kya; Walker et al. 2016). While Lower and Middle Pleistocene occupations of Europe may have correlated strongly with warm climatic periods and warmer Mediterranean latitudes, it is still surprising that these African-adapted hominins were able to colonize European latitudes without the regular use of fire. However, that fire was not a requisite technology for hominins to do this was recognized many years ago (e.g., Perlès 1981). By the end of the Middle Pleistocene, the majority of Eurasian site components still have little or no evidence for fire, but some do, and by the start of the Late Pleistocene a significant number do have very good evidence that Neanderthals regularly used fire (Roebroeks and Villa 2011). Because of this, for several decades now it appears that the general consensus is that regardless of what was going on in previous time periods and with other hominins, Neanderthals were creating and using fire at will and that it was an integral component of their adaptation (e.g., Barkai et al. 2017; Daniau, d'Errico, and Goñi 2010; Gowlett 2016; Pettitt 1997; Rolland 2004). In fact, it is difficult to imagine that even an apparently physiologically cold-adapted species like Neanderthals could survive the extreme colds of Ice Age Eurasia without fire. However, Dibble et al. (2017) present evidence from several French Middle Paleolithic sites that appears to support the idea that while Neanderthals were certainly using fire regularly during some periods, there are sites with evidence for major successive occupations spanning many thousands of years with no evidence that they were using fire over that period. The data from these sites seem to show a pattern of fire use that correlates counterintuitively with climate: Neanderthals were using fire during warm periods and apparently not during cold periods. Dibble et al. suggest a number of potential explanations for this that bring into question whether by the Late Pleistocene all hominins in all regions had the technology to make fire at will.

General perceptions among Paleolithic researchers appear to be that with the arrival of modern humans in Europe and throughout the subsequent Upper Paleolithic period, fire use was ubiquitous and had taken on an even more complex role in human adaptations (e.g., Chazan 2017; White et al. 2017). As presented by White et al., Upper Paleolithic sites in Europe contain a range of different fire structures, some with relatively complex stone arrangements (see also Movius 1966) that make it clear that many of these are not just general-use "hearths" providing heat for warmth and cooking. While the actual functions of these different structures has yet to be determined in most cases, their evidence strongly suggests a much wider range of applications of fire than anything observed in earlier periods. There is also a clear increase in the complexity of the spatial arrangement of occupation sites, with fire structures being major components of this organization.

However, the archaeological record is a product of taphonomic processes as much as—and often more than—the direct result of patterns of behavior (Holdaway, Fanning, and Shiner 2005). This is an important point when it comes to interpreting any aspects of the archaeological record but is especially pertinent when we are dealing with remains that are particularly susceptible to erosion and loss, as is the case with direct fire residues like charcoal and ash. Holdaway, Davies, and Fanning (2017) present an important example of this with Holocene age fire features in Australia. In the presented case, the preservation and visibility of any evidence of fire-related behavior is facilitated by the prehistoric use of stone structures as heat retainers. While the ephemeral residues like charcoal and ash generally disappeared very quickly, these structures survived more or less intact. One might then examine the temporal and spatial distribution of these features as direct sources of information about patterns of prehistoric use of fire. However, the analysis of Holdaway, Davies, and Fanning indicates that the frequency of these hearth structures in the archaeological record is also heavily influenced by taphonomic processes, particularly geomorphic development of landscapes. This serves as one cautionary tale (and a particularly powerful one considering the young age of these hearth structures) for any attempts to infer behavioral patterns directly from the presence or absence and frequency of any archaeological phenomena, not just fires.

Cooking

While fire has undoubtedly served a wide range of functions over the course of prehistory, a century of ethnographic observations from around the world has shown that cooking is universal among human groups. Thus it made sense to have a special section devoted to this.

People cook food for a variety of reasons, for example, making rotting meat safe to eat (e.g., Dibble et al. 2017) or denaturizing meat or plant food to make it easier to chew (e.g., Wrangham and Conklin-Brittain 2003; Zink and Lieberman 2016). For over a decade Wrangham (e.g., Wrangham 2007, 2009; Wrangham et al. 1999; Wrangham and Conklin-Brittain 2003) has made a compelling argument that modern humans need to cook our food in order to obtain the net energy returns required to support such a large brain while also having such a small gut and small teeth. Furthermore, he argues that this obligatory relationship between brain, gut, teeth, and cooking extends back to *H. ergaster/H. erectus* around or shortly after 2 Mya. Wrangham's cooking hypothesis has come to be one of the more influential ideas in paleoanthropology today. However, the cooking hypothesis is arguing that cooking and fire use would have essentially been a daily activity over the last 2 Mya, while the current archaeological evidence for fire use over much of this time is sparse at best. Wrangham (2017) presents further arguments in support of the very early adoption of a cooked diet. He also addresses many of the potential problems the hypothesis faces and goes a long way toward reconciling some of the apparent inconsistencies between the hypothesis and the archaeological data.

Two other symposium contributions represent major data points along the prehistoric development of cooking. Barkai et al. (2017) discuss the significant fire residues at Qesem Cave, Israel, dated between 420 and 200 kya. They interpret these residues as the remains of meat-roasting fires that were used regularly and repeatedly, and they argue that this behavior was an essential component of hominin adaptations in the Levant in this period. What species of archaic *Homo* is represented at the sites is unclear, but presumably it is either *Homo heidelbergensis* or early Neanderthals.

Henry (2010) and Henry, Brooks, and Piperno (2011) have made significant contributions to our understanding of cooking and the role of plant foods in Neanderthal diets. Their analysis of phytoliths and starch grains incorporated into Neanderthal dental calculi strongly suggests that some plants were being integrated into their diet. The morphology of some starch grains in the calculi also suggests that some plants were being cooked before they were consumed (Henry 2015). However, much of the other evidence (stable isotope data and the faunal record) suggests that the Neanderthal diet was heavily meat focused (e.g., Richards and Trinkaus 2009) and that Neanderthals were not cooking their food at all times and in all places (e.g., Dibble et al. 2017; Sandgathe et al. 2011*a*, 2011*b*). Henry (2017) has taken a novel approach to understanding Neanderthal fire use patterns (although the implications are not restricted to any one species of *Homo*). She suggests that unlike recent modern human foraging societies, Neanderthals may have viewed fire as just another potentially exploitable resource among many available in the landscape. Whether or not they chose to exploit each resource depended on a cost-benefit approach, and this, of course, changes depending on the changing circumstances. At times, the cost of collecting fuel and starting and maintaining a fire may outweigh the potential benefits. Under such circumstances they may have chosen not to use it. This idea is complementary to, and may present an alternative explanation for, the observation in Dibble et al. (2017) that at least in some regions Neanderthals were not using fire for very long periods of time.

The Long View of Hominin Fire Use

Ultimately, one of the major goals of the symposium was to instigate discussions about and perhaps reevaluate the role fire played in the evolution of the genus *Homo*. Starting at the level of the analysis of data from individual archaeological sites, we want to be able to start to construct models and hypotheses about how this process might have gone and what stages of increasing complexity might characterize it (e.g., Parker et al. 2016). An important source of data for constructing such models will come from observations of how nonhuman primates interact with natural fires (e.g., Atwell, Kovarovic, and Kendall 2015; Parker et al. 2016). Some work has already been done that indicates that some primates take advantage of natural fires and can organize their behaviors around exploiting food by-products derived by the passage of a fire (e.g., vervet monkeys; Herzog et al. 2014). Pruetz and Herzog (2017) present the results of their observations of chimpanzees in Fongoli, Senegal, interacting with wildfires. This interaction is limited, and the observed chimpanzees did not actively manipulate natural fire, but they developed an understanding of its behavior that allows them to predict its movement. Such an understanding in turn lessens their fear of it and allows them to exploit changes to the fire-altered landscape, such as accessing food resources that were altered or exposed by the fire. With the logical caveat that applying modern examples as direct analogs to the past is problematic, such research is obviously necessary if we want to develop models of early human interaction with fire that, presumably, is a required first step in the development of a more complex relationship with fire that would include active manipulation and maintenance.

Chazan (2017) proposes a model of the prehistory of fire use. He addresses one of the major problems hindering the development of a broader evolutionary view of hominin fire use: our tendency to construct narratives to describe and explain the past. The result of this tendency in the context of this topic is that we continually focus on trying to identify an "origin of fire," looking for an event that can be pinpointed in time, after which everything changes for all hominins. Chazan's model proposes three broad stages that would characterize the process of increasing complexity in hominin-fire interaction. The first stage involves opportunistic interaction with natural fire, and so its use was limited to where and when it was available. This could be compared to or overlaps with the chimpanzee behavior observed by Pruetz and Herzog (2017; see also Pruetz and LaDuke 2010). The second stage involves the development of fire maintenance behaviors. The third stage sees the development of fire containment strategies and presumably includes the development of techniques for creating fire. Chazan then positions these stages within the framework of *Homo* speciation. An attractive component of this model is how readily it can be operationalized—how directly researchers can develop hypotheses that are testable with archaeological data.

Finally, Sandgathe (2017) discusses two major current issues in the development of broader, more process-oriented views of the hominin fire use. The first issue is a practical one of terminology. A number of terms have come into common usage among early fire researchers (e.g., "control" and "habitual"), but there is little common understanding of what individual researchers mean by these terms, with the result that there are undoubtedly some mutual misunderstandings and a certain degree of talking past each other. The second and more important issue is the overarching tendency until recently to see the development of fire use as an event (see also Chazan 2017). In recent years another "event" has been added to this discussion: when fire use becomes "habitual." The addition of a second, later event is a small step forward among researchers in that it starts to hint at the existence of a longer process that likely includes several major stages. However, it still fails to recognize the greater potential complexity that could have, and likely did, underlie the development of fire use. This process was undoubtedly a very long, slow one, and there is no a priori reason to assume that this development was linear, or at least was always so. The prehistory of fire use may have included multiple examples of populations not using fire after long periods of time when they did. And there is no reason to think that the process of development of fire use was the same in all regions. The big picture of the prehistory of hominin fire use was likely very messy.

Results of the Symposium

Over the course of the discussions that characterized the symposium a number of major issues with prehistoric fire use were identified by the discussants. These are issues that seemed to be commonly recognized by the majority if not all of the symposium participants and, presumably, by other researchers whom we were unable to invite.

First, we as a community of researchers interested in the same questions need to shift the emphasis away from discussions and debates about individual sites and what the nature of their fire residues might mean. While most of the basic data are going to continue to come from work carried out at individual sites, we need to focus more on the broader research goal of understanding the role of fire in hominin adaptations, how this evolved over time from an initial simple interaction with fire to its becoming an integral component of hominin adaptations, and the development of the technology to make it at will. This can only come from examining collectively the data from many sites. We also need to recognize the importance of integrating the rest of the archaeological data: the fire data alone will not be enough for us to understand its role in adaptations.

Second, we need to concentrate more on developing the analytical methods and skills to confidently interpret what we see in the archaeological record. Major sticking points in the debate have been identifying in very early sites, with broadly held confidence, actual fire residues and fire residues that are the product of hominin behavior. This is a basic requirement if we are to be able to identify the nature of hominin use of fire at different times and places.

These two broader goals require the acknowledgment of several other important guiding principles and considerations:

- Context is of paramount importance in interpreting the archaeological record. This is particularly important for fire residues, and a number of the papers in this volume address this issue directly (Aldeias 2017; Goldberg, Miller, and Mentzer 2017; Holdaway, Davies, and Fanning 2017; Mallol and Henry 2017). Context involves several levels of resolution as well. For example, what was the nature of vegetation cover of the site at the time it was occupied? How many years are represented by the millimeter-scale gap between two hearths in the same location? What was the substrate beneath a hearth composed of? Are the burned bones associated with a fire feature the result of cooking meat, burning bone as fuel, or simply building a fire on top of previously discarded bone? By what processes was the deposit with the fire evidence formed and altered?
- Since it is logical to assume that no scholar can be determined to have discovered the first use of fire in prehistory, this pursuit is a useless exercise in terms of what it can tell us about fire and hominin adaptations. What is important is understanding the role fire played in hominin adaptations through time and across space. In order to achieve this, the scientific community should focus on frequency of use, intensity of use, and functions of fire and the changes that took place in these aspects through time and by region.
- On their own, individual site records are of limited value, especially single occupation sites. We need to study the evidence for fire use at multiple sites and through multiple occupations to get meaningful temporal and spatial frequency data. Therefore, while some researchers do have access to multiple sites, realistically, we will only make significant progress through broad collaboration.
- We need to tailor questions to investigate available and future data. There are some important questions we would currently very much like to answer that we simply lack the data to realistically address at this point in time. For example, how, when, and where was the technology for making fire developed? Did it have a single origin? Or did it occur independently with different modalities in different areas and at different times? Getting to the point where we can confidently address these questions comes back to focusing on the development of better data-recovery methodologies and incorporating new types of data.
- A certain degree of standardization in the types of data and methods of data collection is necessary for comparability of different researchers' data. How can we compare what different researchers are finding in the archaeological record if they individually are collecting very different types of data or using very different units of measure? How can we determine the weight of interpretations if researchers are not collecting or addressing the lack of all the pertinent data?
- We need more explicit definitions for the terminology we use so that we know what each researcher means when they discuss their data and how they have interpreted it, to eliminate unnecessary ambiguities.

Through the discussions that took place at the symposium and from reading the resulting papers, it is clear that, as with all areas of research, there are some disagreements and potential conflicts between the approaches and data that different researchers are employing in their research into early fire use. However, there is also far more common ground, and what was most obvious coming out of the symposium was the shared goal by all researchers involved to better understand the nature of the evolution of fire use in the genus *Homo*. We hope the symposium represents an important step in that process.

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