



The formation of fire residues associated with hunter-gatherers in humid tropical environments: A geo-ethnoarchaeological perspective



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ABSTRACT

Tropical forests have been an important human habitat and played a significant role in early human dispersal and evolution. Likewise, the use of fire, besides being one of the exceptional characteristics of humans, serves as a marker for human evolution. While the use of fire by prehistoric hunter-gatherers is relatively well documented in arid and temperate environments, the archaeological evidence in humid tropical environment is to date very limited. We first review the archaeological evidence for hunter-gatherer use of fire in humid tropical environments and suggest that better understanding of formation processes is required. We present a geo-ethnoarchaeological study from South India, involving ethnography, excavations and laboratory-based analyses in order to build a new framework to study fire residues in humid tropical forests associated with hunter-gatherer's use of fire. Ethnographic observations point to a dynamic and ephemeral use of hearths. Hearths location were dictated by the social and ever-changing social dynamics of the site. The hearths deposited small amount of residues which were later swept on a daily basis, re-depositing ash and charcoal in waste areas and leaving only a microscopic signal in the original location. Particular acidic conditions and intensive biological activity within tropical sediments result in the complete dissolution of ash and bones while favouring the preservation of charcoal and phytoliths. Consequently, the identification of fire residues in humid tropical forests and the reconstruction of the human use of fire must involve multi-proxy microscopic analysis to detect its micro-signatures.

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1. Introduction

The use of fire is considered one of the exceptional characteristics of humans. The earliest evidence for the use of fire date back to over a million years ago (Bellomo, 1994; Berna et al., 2012; Clark and Harris, 1985) and unequivocal indication for habitual and controlled use of fire c. 300,000–400,000 BP (Bentsen, 2014; Karkanas et al., 2007; Roebroeks and Villa, 2011; Shimelmitz

et al., 2014). The use of fire played a major role in the evolution and development of complex and advanced behaviour of humans (e.g., Brown et al., 2009; Goren-Inbar et al., 2004; Roebroeks and Villa, 2011). Therefore, the study of prehistoric use of fire bears significant implications for research concerning the human past. In order to allow the reliable interpretation of early use fire and reconstruct human pyrogenic behaviour, one must carefully examine the archaeological context and study the formation processes of fire residues (Goldberg et al., 2017; Mallol et al., 2017; Mentzer, 2014).

Studying site formation processes is especially crucial when examining the role tropical environments play as a human habitat during prehistoric times (Mercader, 2003; Morley and Goldberg, 2017), and in particular in the dispersal of humans into South and

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Southeast Asia (Barker, 2013; Barker et al., 2007; Gosden, 2010; Morley, 2017; Perera, 2010; Roberts and Petraglia, 2015; Roberts et al., 2015; Summerhayes et al., 2010). The case of the 'simple' lithic industry abundant in Southeast Asia during the Late Pleistocene had been argued to not be interpreted as a mere reflection of a rather 'simple' behaviour but that a rich and complementary industry was made of degradable plant materials (also termed 'the Bamboo Theory', see Bar-Yosef et al., 2012; Boriskovsky, 1967; Brumm, 2010; Gorman, 1969, 1971; Hutterer, 1976; Lycett and Bae, 2010; Pope, 1989; Reynolds, 2007; Solheim, 1972; White, 1977; Khaufair et al., 2012, 2016). The 'bamboo theory' is based on the assumption that due to the environmental conditions in Southeast Asia and taphonomic processes in humid tropical environments, plant material will not preserve in the archaeological record. Similarly, the scarce archaeological evidence for use of fire in humid tropical forests raise a similar question - whether it is an absence of evidence or an evidence of absence. To date, geoarchaeological studies aiming to understand the formation processes of combustion features largely concentrated on temperate, semi-arid and arid environments (Goldberg and Macphail, 2008; Mentzer, 2014 and references therein) compared to the humid tropics (Mercader, 2003; Morley and Goldberg, 2017).

2. Archaeological evidence of hunter-gatherer use of fire in humid tropical environments

Early human occupation of humid tropical environment is suggested to date back 200,000 years (Mercader, 2002, 2003). However, direct evidence for human adaptation and long-term occupation of tropical forests emerge around 45,000 BP (Roberts and Petraglia, 2015; Roberts et al., 2015). To date, the earliest evidence for fire residues associated with human activity in humid tropical environment was reported from the Niah Caves, Sarawak, Borneo dating to around 45,000 BP (Lewis, 2016; Stephens et al., 2005, 2017). Fire residues dated between c. 20,000–30,000 BP were also reported in other sites in Southeast Asia such as Tham Lang Rongrien (Anderson, 1997) and Tràng An (Rabett et al., 2011, 2017) both in Thailand, Tapon Cave in Palawan, Philippines (Lewis, 2007) and Liang Bua in Flores, Indonesia (Morley et al., 2017). In Africa, charcoal found alongside Late Stone Age lithic in Njuinye, Cameroon, was dated to c. 35,000 BP (Mercader and Martí, 2003). Similar radiocarbon dates were yielded from charcoal reported from layers of 'stone-lines' in Mosumu, Equatorial Guinea, dating back to c. 30,000 BP (Mercader et al., 2002). In South America, evidence of archaeological fire residues were found among the earliest sites of human occupation in humid tropical environment during the Pleistocene-Holocene transition around 12,000 BP (Gnecco and Mora, 1997; Roosevelt et al., 1996; Villagran et al., 2017).

Geoarchaeology is commonly used to directly associate the presence of fire residues with past human behaviour, as it allows a microscopic investigation of the formation and deposition processes of the residues (Goldberg et al., 2017; Mentzer, 2014). While micro-geoarchaeology had become the most common approach to study Palaeolithic fire worldwide (Goldberg et al., 2017), only few geoarchaeological studies were implemented in humid tropical environments (Morley and Goldberg, 2017). Few of them studied fire residues that could be directly associate with hunter gatherer occupation in South and Southeast Asia (Anderson, 1997; Gillieson and Mountain, 1983; Kourampas et al., 2008, 2009; Lewis, 2007; Magee, 1988; Mijares and Lewis, 2009; Morley et al., 2017; Rabett et al., 2011; Simpson et al., 2008; Stephens et al., 2005, 2017), Africa (Mercader et al., 2003) and South America (Araujo et al., 2008; Villagran et al., 2017). The most abundant form of fire residue in humid tropical sites appears in the form of charcoal (e.g., Aceituno

et al., 2013; Anderson, 1997; Araujo et al., 2008; Gillieson and Mountain, 1983; Gnecco and Mora, 1997; Kourampas et al., 2008, 2009; Lewis, 2007, 2016; Magee, 1988; Mercader, 2003; Mercader et al., 2003; Mijares and Lewis, 2009; Morley et al., 2017; Rabett et al., 2011; Roosevelt et al. 1996; Simpson et al., 2008; Stephens et al., 2005, 2017; Villagran et al., 2017). However, the presence of charcoal alone can also derived from natural fire (e.g., Summerhayes et al., 2017). Additional human-related fire residues abundant in archaeological sites around the world include wood ash particles, rubified clay aggregates, fire-related clasts and burnt bones and shells (Mentzer, 2014). The major challenge imposed on the preservation of fire residues in humid tropical environments lays in the acidic conditions of humid tropical soils. Under these conditions carbonates tend to dissolve which archaeologically result in absence of wood ash (calcite), bone (carbonated hydroxyapatite) and shells (aragonite and/or calcite) (Friesem et al., 2016). On the other hand, wood charcoal (structure resembling graphite) and phytoliths (opal) tend to preserve under acidic conditions (Friesem et al., 2016). Consequently, the majority of the archaeological sites where wood ash and burnt bone were preserved are situated on limestone or within karstic systems (Anderson, 1997; Araujo et al., 2008; Gillieson and Mountain, 1983; Lewis, 2007, 2016; Magee, 1988; Mijares and Lewis, 2009; Morley et al., 2017; Rabett et al., 2011; Stephens et al., 2005, 2017; Villagran et al., 2017). The carbonate-rich environment act as a buffer and prevent the reduction in pH levels that allows better preservation of wood ash and bones (Weiner, 2010). Only a handful of studies reported on preservation of intact hearths that can be clearly associated with *in situ* use of fire (Anderson, 1997; Morley et al., 2017; Villagran et al., 2017). Yet, several others had suggested that the presence of wood ash, charcoal, burnt bone and burnt soil substrate and/or clay aggregates, even if reworked and/or disturbed, should be interpreted as reworking of adjacent combustion features, either as a result of post-depositional disturbance or as rake-out and dumping activity (Araujo et al., 2008; Kourampas et al., 2009; Lewis, 2007, 2016; Mercader et al., 2003; Mijares and Lewis, 2009; Rabett et al., 2011; Simpson et al., 2008; Stephens et al., 2017). More than reflecting the entire range of human behaviour, the archaeological record of human use of fire reflects the taphonomic conditions and state of preservation of fire residues (Mentzer, 2014). For this reason, most of the studies that identified Palaeolithic fire residues took place in caves and rock-shelters (Goldberg et al., 2017) as opposed to open-air sites (e.g., Friesem et al., 2014b). This situation is enhanced in humid tropical environments where very few studies reported fire residues in open-air sites associated with hunter-gatherers occupation (e.g., Gnecco and Mora, 1997; Simpson et al., 2008). It was suggested that Pleistocene hunter-gatherers did not use rock-shelters, and perhaps also caves, as long-term dwelling sites, but used them only intermittently as brief campsites (Anderson, 1997; Mercader, 2003).

In contrast to the archaeological image, ethnographic data from contemporary hunter-gatherers living in humid tropical environments suggest that most of their habitation sites and activity take place in open-air sites with routine use of fire (e.g. Bird-David, 2009, 2017; Endicott, 1979; Fisher and Strickland, 1989; Gardner, 2000; Hewlett, 1993; Morris, 1982; Turnbull, 1965 to mention but a few). Although, the analogy between contemporary hunter-gatherers and Pleistocene ones is problematic, to say the least (see below on ethnoarchaeology), the ethnographic data raise an important archaeological question; how can we improve the identification and interpretation of fire residues in humid tropical environments to allow better reconstruction of human behaviour in this important habitat? The first step in this pursuit should therefore be to gain better understanding of the processes that form the insubstantial archaeological record of fire residues in

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