THE TAPHONOMY OF BURNED ORGANIC RESIDUES AND
COMBUSTION FEATURES IN ARCHAEOLOGICAL CONTEXTS

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AN ARCHAEOBOTANICAL AND EXPERIMENTAL APPROACH TO IDENTIFYING SUCCESSIVE FIRE EVENTS IN HEARTH STRUCTURES IN THE SANCTUARY OF APOLLO IN HIERAPOLIS (TURKEY)

Girolamo FIORENTINO & Cosimo D’ORONZO

Abstract
We use anthracological and experimental approach for decoding fire refuses and thermal alterations of soil in an area of the Sanctuary of Apollo in Hierapolis (Turkey). Results obtained from experimental hearth structures show that the escharon is the result of a series of ground-level hearths, pit hearths and secondary ash deposits. Important ritual implications derive from the contextual identification of these fire events, that shed new light on the Apollo cult in the region.

Keywords: Apollo Temple, Hierapolis, Turkey, earth structures, cultural function, experimental design, anthracology
Introduction

The study of hearth structures is highly complex since it involves numerous aspects of human behaviour which do not always leave clear traces in archaeological deposits. The traces allowing us to identify the use of fire are combustion residues, thermal alteration of soil and structures. Over the years, the analysis of hearth structures has sought to go beyond the purely descriptive level in an attempt to reconstruct both formal and functional aspects (Clarke, 1968). Studies of activities linked to the use of fire have been borrowed from ethnography – despite the risks linked to the use of analogy in the interpretation of archaeological contexts (Cazzella, 1989; Henry et al., 2009; Joly et al., in press; Moutarde, 2006; Ntinou, 2002; Orme, 1981; Solari, 1992). However, studies of activities have also benefited from the application of multidisciplinary analyses (Leroi-Gourhan, 1943; 1945; 1964; 1965; 1973; March, 1996) and experimental reproduction. In the first case, numerous chemical-physical and pedological analysis techniques have been used to isolate traces and establish the relationships of cause and effect affecting depositional and post-depositional agents (Wood, Lee Johnson, 1978; De Guio, 1988; Leonardi, 1992). The experimental approach entails the reproduction of the structure and the measurement of certain parameters held to be important for understanding various of its aspects. In some cases a combination of both approaches may produce results that are difficult to manage, leading to the loss of the main objective of the study of prehistoric cultures, i.e., an understanding of the behaviour of a group, deductible from a contextual reading of the traces in archaeological deposits. However, a careful assessment of the archaeological context and the nature of the hearth structures currently cannot do without the experimental approach. Experimental archaeology has recently undergone a radical transformation, becoming a sophisticated and rigorous research tool which is entirely compatible with hard science. Experimental archaeology has passed from the concept of imitation (Ascher, 1961) to one of replication (Coles, 1973), developing cyclical formulae (Reynolds, 1978; 1979) and other more sophisticated models based on complex epistemological principles (Malina, 1980; 1983). The combined application of hypothetical deductive and hypothetical inductive logical models can corroborate hypotheses developed in the course of studying a phenomenon (Popper, 1970).

These contributions confirm the importance of the contextualisation of data, experimental control and replicability. Also needed are experimental protocols designed to achieve deeper knowledge of the phenomena (Begoña, 2003; March, 1992; Théry-Parisot, 1998).

In this paper we propose a reading of some aspects of the use of fire in a cult context in South-western Turkey. Since 2002, an area with a high concentration of ash-rich sediment and burnt organic matter, located next to the Temple of Apollo at Hierapolis and interpreted as an *escharon* (Semeraro, 2005; 2007), has been subject to special excavation strategies and archaeobotanical analyses designed to throw light on how these distinctive archaeological deposits were formed in relation to religious practices (Fiorentino, Solinas, 2009).

Archaeological Problems

Traditionally, the *escharon* is a place used for dumping the residues of material burnt in religious structures, although it may itself be the object of particular rituals (fig. 1). Therefore it may contain secondary deposits of combustion residues. In this case, the secondary deposits are made up of a layer of ash covering the area (SU 372), while the primary deposits are contained in two pits (SUs 486, 488, 754, 425, 458, 531). However, the association in this context of combustion residues with a thermally altered substrate indicates combustion activities *in loco*, although the formation dynamics of the primary deposit are hard to read. Specific features of the context and data from the
microstratigraphical and archaeobotanical analyses raise a number of questions concerning the reading of these structures, and have given rise to a series of hypotheses (fig. 2).

Methods and materials

Given the complexity of the archaeological context, we sought to decode the events that may have led to the formation of the deposit by means of an experimental approach. Initially, we identified the elements in the archaeological deposit that could provide clues to a reading of the phenomenon: the combustion residues (ash and charcoal remains) and the thermal alteration of the substrate (a, Fig. 2). Combustion is a chemical process that produces energy in the form of light and heat. The heat energy produced tends to cause a series of transformations in objects that are near the heat source or in direct contact with it. The passage of energy between two objects may induce chemical-physical transformations such as calcination and variations in colour and magnetism (Humphreys, Craig, 1981; Marshall, 1998; Canti, Linford, 2000; Gose, 2000; Çengel, 2005; Berna et al., 2007), or mechanical transformations such as thermoclastic fractures (Lintz, 1989; Petraglia, 2002; Anderson-Ambrosiani, 2002; Pagoulatos, 2006).

The effects of the heat produced by the combustion of a solid (wood) on a substrate have been studied as part of forestry research (Wells et al., 1979; Wright, Bailey, 1982; DeBano, 1991), but these studies have paid little attention to the morphology of thermal alteration of the soil, an aspect fundamental to archaeological research (Gasco, 1985; Canti, Linford, 2000).

Experimental design ought to take account of the variables that the observer believes to be important in the behaviour of a phenomenon (b, fig. 2). In addition, it should ensure experimental control and enable the researcher to reach a higher level of knowledge of the phenomenon being studied.

To verify certain hypotheses (c, d fig. 2), two combustion cycles were conducted in the open air to test the behaviour of a hearth at ground level (EXP_C, EXP_D ). In each cycle, the ground-level hearth was subject to five combustions at intervals of 24 hours. Subsequently two pits were dug in the hearth, called EXP_Ca (EXP_Da in the second cycle) and EXP_Cb (EXP_Db in the second cycle). In EXP_Ca and Da, five combustions were performed, and in EXP_Cb and Db only one. The parameters measured included the flame temperature, the temperature of the soil at four depths (-2, -7, -12 and -18 cm), atmospheric temperature and humidity near the fire and 4 m away, and the wind speed and direction at 2 m and 10 m above the ground.

The temperature of the soil was measured by type k thermocouple every 30 seconds, while the atmospheric parameters were measured every 5 minutes.

Semi-arid wood was used as fuel, a different type being used in each combustion (Olea europaea, Pinus halepensis, Cupressus sempervirens, Quercus ilex, Quercus coccifera, Quercus cerris, Prunus armeniaca, Pyrus communis, Ficus carica, Vitis vinifera). The dimensions of the branches (diameter from 5 mm to 80 mm) and the wood taxa were chosen on the basis of the archaeobotanical evidence found in the context (tabs. 4-5).
The average percentage of ash residues produced by the combustion of 16 kg of fuel used to feed the ground level fires was 2% and 3% for EXP_C and EXP_D respectively. In addition, the two cycles produced 56.4 g and 32 g of charcoal. In the first cycle the species that produced the most residues was *Pinus halepensis*. In other cases, given the small number of replicas, the behaviours observed did not indicate significant tendencies. However, it is interesting that *Quercus ilex* produced little or no charcoal (tab.1).

In contrast, the behaviour of the pit hearths was completely different (tab. 2). In EXP_Cα and EXP_Dα, 80 kg of wood was burned, the residues amounting to 2.5% of the total weight, while in EXP_Cβ and EXP_Dβ 16 kg of wood was burned, the residues amounting to 11% of the total weight (Tabs 1 and 2). This difference is probably related to the different number of combustions in the pits. It cannot be ruled out that the charcoal produced by the initial and intermediate combustions were burned off by subsequent combustions. Indeed, while fresh fuel was being loaded on the fire, this was observed to cause lateral spreading of the deposit, which in some cases exposed charcoal fragments left over from previous combustions, leading to their complete combustion. In contrast, in other cases, the combustion residues near the edge of the hearth were partly covered by material falling on them from the walls of the pit, which seems to have shielded the fragments from subsequent combustions (tab. 3).

The anthracological analyses of the combustion residues again highlight the different behaviour of a hearth structure used just once with respect to a structure used many times. In EXP_Cα and EXP_Dα, unlike the first and the last combustion episode, there was little material left from the second (figs. 3, 5).

The first levels of the ash deposit contain charcoal fragments from the last combustion episode, but few from the fourth and second combustion. This may depend on factors intrinsic to the fuel used. In addition, both pits had a deposit on the bottom composed of charcoal fragments of more than 60 mm in length belonging to the first combustion episode. In contrast, the assemblages in pits EXP_Cβ and EXP_Dβ appear to be more complex, since they are composed of residues of every single load of wood placed on them, which partly follow the order of deposition of the fuel (figs. 4,6). In this case the material at the bottom of the pits had a low fragmentation index.
also result from the way in which the flow of heat is propagated and from the properties of the surrounding atmosphere (oxidant/reductant) during the combustion.

An aspect of this is the survival on the bottom of the first loads of fuel, apparently because the combustion process was interrupted by the reduced circulation of oxygen as a result of subsequent loads of fuel being placed on top and of material falling on to the fire from the walls of the pit.

During the experiment, the extent of the thermal alteration and variation in colour of the sediment was observed by using the soil colour codes table in Cailleux. Before lighting the fires in the ground-level hearths (EXP_C, EXP_D), the sediment was brown (P51). After the first combustion the substrate was dark grey (T73) with some parts of a lighter colour (R31). At the end of the experiment, 80% of the surface was orange (N60), while along the edges, near and below the stone circle it was black (T92).

In cross section, the thermally altered substrate was thinner at the edges (10 mm thick on average) and thicker in the centre (up to 20 mm). The colour at depths of 0 to -0.5 cm was orange (N39), while between -0.5 cm and -2.5 cm the intensity of the orange colour tended to diminish (N59). Below this intensely altered level was a layer of sediment (0.4 cm thick).

The survival of some taxa rather than others could be due to the calibre, age and humidity of the branches (Trabaud, 1976; Théry-Parisot, 1993; 1998), but may also result from the way in which the flow of heat is propagated and from the properties of the surrounding atmosphere (oxidant/reductant) during the combustion. An aspect of this is the survival on the bottom of the first loads of fuel, apparently because the combustion process was interrupted by the reduced circulation of oxygen as a result of subsequent loads of fuel being placed on top and of material falling on to the fire from the walls of the pit.

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### Tab. 4: Experimental design for ground hearth structure.

<table>
<thead>
<tr>
<th>Ground level hearth structure</th>
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<tbody>
<tr>
<td>Hearth structure</td>
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<tr>
<td>Internal diameter</td>
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<tr>
<td><strong>Five combustion phases</strong></td>
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<tr>
<td>Wood fuel</td>
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<tr>
<td>Total weight</td>
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<tr>
<td>Parameters</td>
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<tr>
<td>Temperature of soil at four different depths (-2, -7, -12, -18 cm)</td>
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<tr>
<td>Atmospheric temperature (near the fire and 4 m away)</td>
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<tr>
<td>Wind speed (at 2 m and 10 m above the ground)</td>
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<tr>
<td>Instruments:</td>
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<tr>
<td>Multichannel T-C 08 Picologger</td>
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<td>Weather station</td>
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<td>Time for registration</td>
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<td>Atmospheric parameters:</td>
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<tr>
<td>Time for re-loading fuel</td>
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<tr>
<td>Procedures</td>
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### Tab. 5: Experimental design for pit hearth structure.

<table>
<thead>
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<th>Oval hearth structures</th>
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<tr>
<td>Hearth structure</td>
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<tr>
<td><strong>EXP_Ca : Five combustion phases</strong></td>
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<tr>
<td>Wood fuel</td>
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**Tab. 4**: Experimental design for ground hearth structure.

**Tab. 5**: Experimental design for pit hearth structure.
cm thick) subject to little or no alteration which was dark brown in colour (S91) with shades of black. Below this, the levels had no variations in colour. The colour variations of the substrate of combustion pits EXP_Cβ and EXP_Dβ were similar to those of the ground-level hearths but with different formation times. The colour of the substrate next to the fire after the first loads of fuel was black (N73), due to the gases released by carbonisation. At the end of the first combustion episode, a semicircular variation in colour was seen on the walls of the central part of the pit. The outer edges were dark brown (S50) while the intermediate area was darker (T51), with shades of black (T92). The central part, closest to the fire itself, was orange (N45). After five combustions the central part displayed a more intense degree of alteration, to the point that it was almost red (N17). This was delimited first by a semicircular dark brown band (T30) and then by an outer black band (T92).

Discussion

The studies conducted in the escharon of the sanctuary of Apollo and the experimental reproduction highlight a number of events linked to the use of fire. The experimental reproduction made it possible to separate the outcomes of the use of fire: thermal alteration and combustion residues. Analysis of the former shows a correlation between the morphology of the altered soil and the structure that produced it. In contrast, the relationship between the colour of the soil and the temperature of the hearth is more complex.

The orange-red colour seems to be determined not so much by the exposure of the soil to high temperatures as to the absence of an insulating “deposit” between the source of heat and the substrate (Canti, Linford, 2000). In the experimental cycles the shift from the natural colour of the soil to red was seen in two cases: when there was direct contact between the source of heat and the substrate (especially in the pit hearths) and when the ground-level hearth was reused after being cleaned. However, the variation in colour of the substrate may also depend on its mineral composition and the percentage of organic residues contained in it. It is no coincidence that the sediments rich in ferrous minerals tended to take on a red colour even at low temperatures (Frandsen, Ryan, 1986; Cornell, Schwermann, 1996; Fitzpatrick, 1988; Canti, Linford, 2000).

It is clear that the structure of the escharon in Hierapolis is the result of a series of ground-level hearths, cleaned after the formation of the ash deposit before being re-used each time, in which a series of pits were subsequently dug (e, fig. 2). Lastly, the interaction between the archaeobotanical analyses and the experimental reproduction was shown to be a useful tool for decoding thermally altered deposits. In the case of Hierapolis reference was made to hypotheses based on the simultaneous presence, observed during the excavations, of the archaeological results of a number of separate events or behaviours linked to various religious practices. Although with our current level of knowledge it is not possible to fully interpret their symbolic meaning, it was possible to differentiate between practices.
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which involved the secondary dumping of ashes in an area different from that of the original combustion and other ritual activities demonstrated by thermal alterations in the substrate and by ash and carbon-rich residues resulting from direct combustion in loco.

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