CENTRE D'ÉTUDES PRÉHISTOIRE, ANTIQUITÉ, MOYEN ÂGE - UMR 6130
Proceedings of the round table, May 27-29 2008

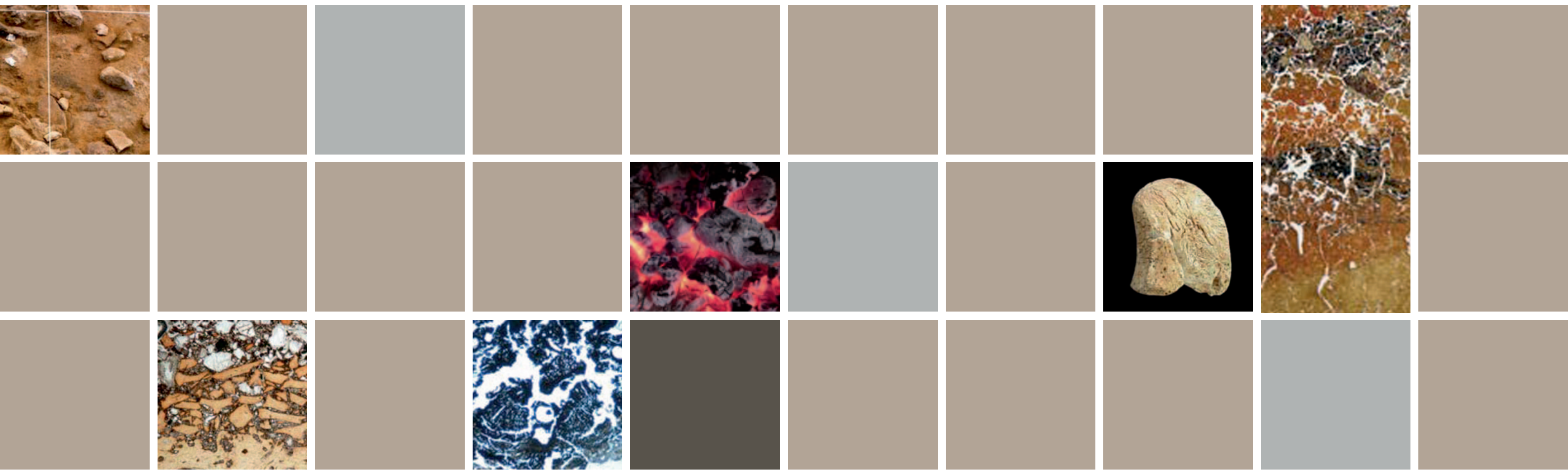
2010 # 2

http://www.palethnologie.org
ISSN 2108-6532

edited by

Isabelle THÉRY-PARISOT
Lucie CHABAL
Sandrine COSTAMAGNO

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



P@LETHNOLOGY
Bilingual review of prehistory

P@LETHNOLOGY
Bilingual review of prehistory

Review published by the P@lethnologie association, created and supported by the TRACES laboratory, the Ethnologie Préhistorique laboratory, the University of Liège and the Ministry of Culture and Communication.

The contributions should be addressed to:

REVUE P@LETHNOLOGIE
Vanessa LEA, Research associates

TRACES - UMR 5608 of the CNRS
Maison de la recherche
5 allées Antonio Machado
31058 Toulouse cedex 9, FRANCE

Phone: +33 (0)5 61 50 36 98
Fax: +33 (0)5 61 50 49 59
Email: vanessa.lea@univ-tlse2.fr

This event and its proceedings received support from

P@lethnologie / 2010.2
bilingual review of Prehistory

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, deducible 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 (Begoňa, 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

Fig. 1 : The Sanctuary of Apollo in Hierapolis (Turkey).

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 (Humpheys, 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_Cα (EXP_Dα in the second cycle) and EXP_Cβ (EXP_Dβ in the second cycle). In EXP_Cα and Dα, five combustions were performed, and in EXP_Cβ and Dβ 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).

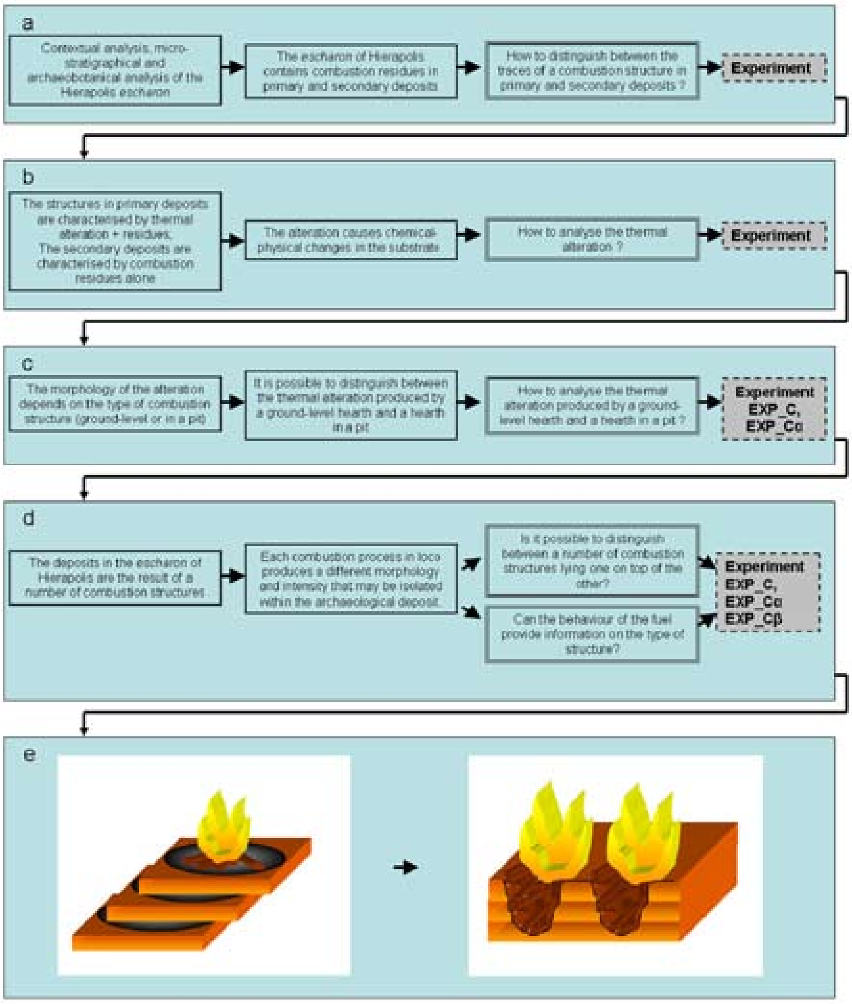


Fig. 2 : Logic model to decoding the deposit of Hierapolis.

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).

Results

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_C*α* and EXP_D*α*, 80 kg of wood was burned, the residues amounting to 2.5% of the total weight, while in EXP_C*β* and EXP_D*β* 16 kg of wood was burned, the residues amounting to

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_C*α* and EXP_D*α*, 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_C*β* and EXP_D*β* 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.

Cycles	*Prunus armeniaca*	*Pinus halepensis*	*Olea europaea*	*Quercus ilex*	*Quercus cerris*
		Ash			
Cycle EXP_C	380 g	637 g	415 g	371 g	336 g
Cycle EXP_D	448 g	429 g	370 g	759 g	410 g

Tab. 1 : Weight of combustion residues in ground hearth structures.

Structures with 5 combustion events: EXP_Cα (charcoal: 62,7 g; Ash: 2036,5 g)										
Weight (g)	US 16	US 17	US 18	US 19	US 20	US 21	US 22	US 23	US 24	US 25
Charcoal	2,4	0,5	0,2	0,5	2,8	0,8	4,6	2,6	13,1	35,2
Ash	0	196,9	93,7	177,6	582,9	146,8	164,5	83,4	520,7	70
Structures with 1 combustion events: EXP_Cβ (charcoal: 247,8 g; Ash: 1746,3 g)										
Weight (g)	US 3	US 4	US 5	US 6	US 7	US 8	US 9	US 10	US 11	US 12
Charcoal	33	1,3	0,5	7,2	8,5	1,6	9,6	117,7	67,2	1,2
Ash	0	141,6	114,6	218,3	0	0	333,8	456,6	58,1	423,3

Tab. 2 : Weight of combustion residues in pits hearth structures (Cycle C).

Structures with 5 combustion events: EXP_Dα: (charcoal 34 g; ash: 2033,5 g)													
Weight (g)	US 57	US 58	US 59	US 60	US 61	US 62	US 63	US 64	US 65	US 66	US 67	US 68	US 69
Charcoal	13,9	0,1	0,5	1,1	1,3	0,3	1,8	0,8	2,4	1,9	3,1	2,9	3,9
Ash	0	99,7	238,1	148,5	200,7	47,1	420	75,4	109,1	211,1	49,4	41,2	393,2
Structures whit 1 combustion events: EXP_Dβ: (charcoal 138,4 g; ash 1530,9 g)													
Weight (g)	US 41	US 42	US 43	US 44	US 45	US 46	US 47	US 48	US 49	US 50	US 51	US 52	US 53
Charcoal	6,9	0,1	0,2	0,1	0,6	0,9	2,1	0,9	1,5	4,7	7,4	6,1	106,9
Ash	0	253,6	202,6	5	27,3	128	97,6	0	93,8	77,8	16,7	0	628,5

Tab. 3 : Weight of combustion residues in pits hearth structures (Cycle D).

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.

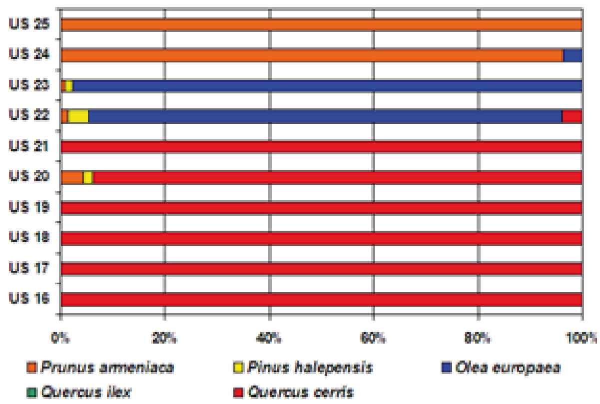


Fig. 3 : Anthracological diagram of EXP_Cα.

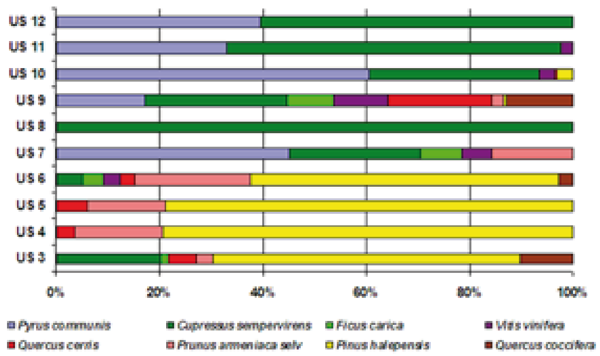


Fig. 4 : Anthracological diagram of EXP_Cβ.

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

Ground level hearth structure	
Hearth structure	Hearth delimitated by stone circle Internal diameter: 50 cm
Five combustion phases	
Wood fuel	Semi-arid wood of : *Prunus armeniaca*, *Pinus halepensis*, *Olea europaea*, *Quercus ilex*, *Quercus cerris* Total weight : 16 kg for every taxon
Parameters	Flame temperature Temperature of soil at four different depths (-2, -7, -12, -18 cm) Atmospheric temperature (near the fire and 4 m away) Humidity (near the fire and 4 m away) Wind speed (at 2 m and 10 m above the ground) Wind direction (at 2 m and 10 m above the ground).
Instruments:	Thermocouple Type K Multichannel T-C 08 Picologger Weather station Anemometer Chronometer
Time for registration	Flame and soil temperatures : 30 s Atmospheric parameters: 5 min
Time for re-loading fuel	2 kg of wood fuel every 15 minutes
Procedures	Load fuel – lighting – charring – reloading fuel. Every 15 minutes the hearth structure was reloaded with another 2 kg of wood. The experiment was monitored for 3 hours, and the ash deposit was excavated after 24 hours.

Tab. 4 : Experimental design for ground hearth structure.

Oval hearth structures	
Hearth structure	Two oval pits 40 X 90 cm, delimitated by stone circles, 30 cm deep
EXP_Cα : Five combustion phases	
Wood fuel	Semi-arid wood of : *Prunus armeniaca*, *Pinus halepensis*, *Olea europaea*, *Quercus coccifera*, *Quercus cerris* Total weight of fuel : 16 kg for every taxon
EXP_Cβ : One combustion phase	
Wood fuel	Semi-arid wood of : *Pyrus communis*, *Cupressus sempervirens*, *Ficus carica*, *Vitis vinifera*, *Quercus cerris*, *Prunus armeniaca*, *Pinus halepensis*, *Quercus coccifera* Weight of each load : 2 kg for every taxon
Parameters	Flame temperature Temperature of soil at four different depths (-2, -7, -12, -18 cm) Atmospheric temperature (near the fire and 4 m away) Humidity (near the fire and 4 m away) Wind speed (at 2 m and 10 m above the ground) Wind direction (at 2 m and 10 m above the ground).
Instruments:	Thermocouple Type K Multichannel T-C 08 Picologger Weather station Anemometer Chronometer
Time for registration	Flame and soil temperatures : 30 s Atmospheric parameters: 5 min
Time for re-loading fuel	2 kg of wood fuel every 15 minutes
Procedures	Load fuel – lighting – charring – reloading fuel. After 15 minutes the hearth structures is reloaded with others 2 kg of wood fuel. The experiment is monitored for 3 hours. After five combustions another oval pit was excavated. In this second pit one combustion was performed. The ash deposit was excavated after 1 month.

Tab. 5 : Experimental design for pit hearth structure.

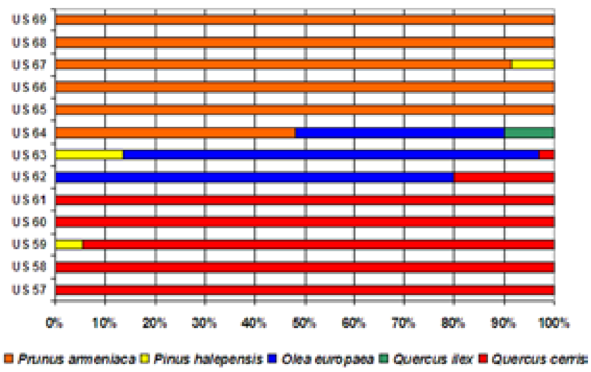


Fig. 5 : Anthracological diagram of EXP_Dα.

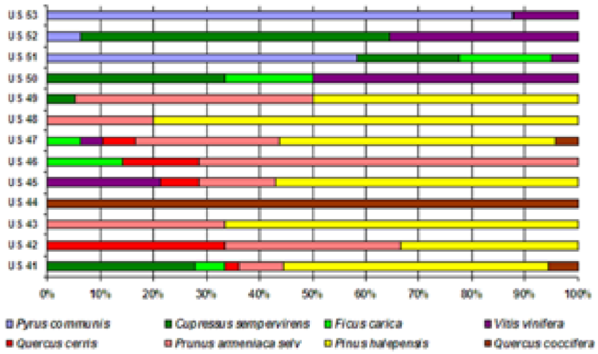


Fig. 6 : Diagramme anthracologique de EXP_Dβ.

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_C*β* and EXP_D*β* 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 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*.

Authors

Girolamo Fiorentino

Laboratory of Archaeobotany and Palaeoecology– Department of Cultural Heritage – University of the Salento – Via D. Birago, 64 – 73100 Lecce - Italy.
girolamo.fiorentino@ateneo.unile.it

Cosimo D'Oronzo

PhD Student - University "Cattolica del Sacro Cuore" - Milano
cosimodoro@alice.it

References

Anderson-Ambrosiani P. 2002 - Man-Fire-Stone. Fire-cracked stones as a cultural expression. *In* : *Fire in Archaeology*, Gheorghiu D. (ed). Papers from a session held at the European Association of Archaeologist Sixth Annual Meeting in Lisbon 2000, British Archaeological Reports, S1089 : 125-131.

Ascher R. 1961 - Experimental archaeology. *American Anthropologist*, 63 : 793-816.

Begoňa S. L. 2003 - Estudio de las estructuras de combustion prehistoricas : una propuesta experimental : Cova Negra (Xàtina, Valencia), Ratlla del Bubo (Crevillent, Alicante) y Marolles-sur-Seine (Bassin Parisien, France), Deputacion de Valencia.

Berna F., Behar A., Shahack-Gross R., John Berg J., Boaretto E., Gilboa A., Sharon I.,Shalev S., Shilstein S., Yahalom-Mack N., Zorn J. R. & Weiner S. 2007 - Sediments exposed to high temperatures: reconstructing pyrotechnological processes in Late Bronze and Iron Age Strata at Tel Dor (Israel). *Journal of Archaeological Science*, 34 : 358-373.

Canti M.G. & Linford N. 2000 - The effects of fire on archaeological soils and sediments: temperature and colour relationships. *Proceedings of the Prehistoric Society*, 66 : 385-395.

Cazzella A. 1989 - *Manuale di Archeologia. Le società della preistoria*. Roma, Editori Laterza.

Çengel Y.A. 2005 - *Termodinamica e trasmissione del calore*. Milano, McGraw-Hill.

Clarke D.L. 1968 - *Analytical Archaeology*. London.

Coles J. 1973 - *Archaeology by Experiment*. London.

Cornell R.M., Schwermann U. 1996 - *The Iron Oxides*. Weinheim : VCH.

De Guio A. 1988 - Unità stratigrafiche come unità operazionali: verso le archeologie possibili degli anni '90. *In* : *Archeologia stratigrafica dell'Italia settentrionale*, Uboldi M. (ed). Como, Edizioni New Press : 9-22.

DeBano L.F. 1991 - *The Effect of Fire on Soil Properties*. United States Department of Agriculture Forest Service General Technical Report, INT-280 : 151-156.

Fiorentino G. & Solinas F. 2009 - Micro-stratigraphical and archaeobotanical approaches to investigating ash deposits in the Apollo Sanctuary in Hierapolis. *In* : *Paper of 1st International Symposium on Oracle in Antiquity and the Cults of Apollo in Asia Minor*, Izmir 17-19 August, 2005, Arkeoloji Dergisi, Special Issue.

Fitzpatrick R.W. 1988 - Iron compounds as indicators of pedogenetic process : examples from the Southern hemisphere. *In* : *Iron in Soil and Clay Minerals,* Stucki J.W., Goodman B.A., Schwermann U. (eds), Dordrecht : Reidel, Nato ASI, 217 : 351-96.

Frandsen W.H. & Ryan K.C. 1986 - Soil moisture reduces belowground hear flux and soil temperatures under a burning fuel pile. *Canadian Journal of Forest Research of Botany*, 14 : 243.

Gascó J. 1985 - *Les installations du quotidien. Structures domestiques en Languedoc du Mésolithique à l'Age du Bronze d'après l'étude des abris de Font-Juvénal et du Roc-de-Dourgne dans l'Aude*. Documents d'Archéologie Française, 1. Paris. Ed. de la Maison des Sciences de l'Homme.

Gose W. 2000 - Paleomagnetic studies of burned rocks. *Journal of Archaeological Science,* 27 : 409-421.

Henry, A., Théry-Parisot, I. & Voronkova, E., 2009. La gestion du bois de feu en forêt boréale: problématique archéo-anthracologique et étude d'un cas ethnographique (Région de l'Amour, Sibérie). *In* : *Gestion des combustibles au Paléolithique et au Mésolithique: nouveaux outils, nouvelles interprétations*, Théry-Parisot I. & Henry A. (Eds). Proceedings of worshop 21, UISPP 13, XV congress, Lisbon, 4-9 septembre 2006. Archaeopress. British Archaeological Reports International, 1914 : 17-37.

Humpheys F.R., Craig F.H. 1981 - Effects of fire on soil chemical, structural and hydrological properties. *In* : *Fire and the Australian Biota,* Gill A.M., Groves R.H., Noble J.R. (eds). Camberra, Australian Academy of Science : 177-200.

Joly D., March R.J., Marguerie D. & Yacobaccio H., sous presse. Gestion des combustibles dans la province de Jujuy (Puna, Argentine) depuis l'Holocène ancien: croisement des résultats ethnologiques et anthracologiques. *In* : *Gestion des combustibles au Paléolithique et au Mésolithique : nouveaux outils, nouvelles interprétations*, Théry-Parisot I., Costamagno S. & Henry A. (eds). Proceedings of worshop 21, UISPP 13, XV congress, Lisbon, 4-9 septembre 2006. Archaeopress. British Archaeological Reports International, 1914 : 39-56.

Leonardi G. 1992 **-** Il deposito archeologico: bacini, processi formativi e trasformativi. *In* : *Atti del Seminario internazionale Formation processes and excavation methods in archaeology: perspectives,* Leonardi G. (ed). Padova 15-27 Luglio 1991. Saltuarie dal laboratorio del Piovego, 3 : 13-47.

Leroi-Gourhan A. 1943 - *L'homme et la matière*. *Evolution et techniques I*. Paris, Ed. Albin Michel.

Leroi-Gourhan A. 1945 - *Milieu et techniques*. *Evolution et techniques*. Paris, Albin Michel.

Leroi-Gourhan A. 1964 - *Le geste et la parole*. *Technique et Langage I*. Paris, Ed. Albin Michel.

Leroi-Gourhan A. 1965 - *Le geste et la parole*. *La mémoire et les rythmes II*. Paris, Ed. Albin Michel.

Leroi-Gourhan A. 1973 - Structures de combustion et structures d'excavation. *In* : *Séminaire sur les structures de combustion*. Collège de France. Ethnologie Préhistorique, CNRS, 52.

Lintz, C. 1989 - Experimental thermal discoloration and heat conductivity studies of caliche from Eastern New Mexico. *Geoarchaeology*, 4 : 319-346.

Malina J. 1980 - *Metody experimentu v archaeologii*. Praha, Accademia.

Malina J. 1983 - Archaeology and Experiment. *Norwegian Archaeological Review*, 16, 2 : 69-85.

March R.J. 1992 - L'utilisation du bois dans les foyers préhistoriques: une approche experimentale. *Bulletin de la Société Botanique de France*, 139, Actualités Botaniques, 2-4 : 245-253.

March R. J. 1996 - L'Etude des structures de combustion préhistoriques: une approche interdisciplinaire. *In* : *The Lower and Middle Palaeolithic,* Bar-Yosef O., Cavalli-Sforza L. L., March R.J., Piperno M. (eds), Colloquium X UISPP. Forlì, A.B.A.C.O. : 251-275.

Marshall A. 1998 - Visualising burnt areas: patterns of magnetic susceptibility at Guiting Power 1 round barrow (Glos., UK). *Archaeological Prospection,* 5 : 59-177.

Moutarde F. 2006 - *L'évolution du couvert ligneux et de son exploitation par l'homme dans la vallée du Lurin (côte centrale du Pérou), de l'Horizon Ancien (900 –100 av. J.-C.) à l'Horizon tardif (1460-1532 ap. J.-C.). Approche anthracologique*. Université de Paris 1, Paris, 2 vol, 317 pp.

Ntinou, M., 2002. *La Paleovegetación en el norte de Grecia desde el Tardiglaciar hasta el Atlántico : formaciones vegetales, recursos y usos*. Oxford, British Archaeological Reports, S XVI. Archaeopress, 268 pp.

Orme B. 1981 - *Anthropology for Archaeologists : an introduction*. London.

Pagoulatos P. 2006. Experimental burned rock studies on the Edwards Plateau : a view from Camp Bullis, Texas. *North American Archaeologist*, 26 : 289-329.

Petraglia M.D. 2002 - The heated and the broken: thermally altered stone, human behaviour, and archaeological site formation. *North American Archaeologist,* 23 : 241-269.

Popper K. 1970 - *Logica della scoperta scientifica*. Torino, Einaudi.

Reynolds P.J. 1978 - *The Experimental Storage of Grain in Underground Silos*. Unpublished PhD thesis, Leicester University.

Reynolds P.J. 1979 - The nature of experiment in archaeology. *In* : *Experiment and Design – Archaeological Studies in Honour of John Coles*, Harding A.F. (ed.). Exter, The Short run Press : 156-162.

Semeraro G. 2005 - Per un approccio contestuale alla lettura delle immagini. Le ceramiche a rilievo di Hierapolis di Frigia. *MEFRA*, 117, 1 : 83-98.

Semeraro G. 2007 - Ricerche archeologiche nel Santuario di Apollo (Regio VII) 2001-2003. *In* : *Hierapolis di Frigia I, Le attività delle Campagne di scavo e restauro 2000-2003,* D'Andria F., Caggia M.P. (eds). İstanbul, Turkey, Ege Yayinlari : 169-209.

Solari, M.-E., 1992. Anthracologie et ethnoarchéologie dans l'archipel du Cap Horn (Chili). *Bulletin de la Société Botanique de France*, 139, 2-4 : 407-420.

Théry-Parisot I. 1993 - *Les déformations anatomiques des charbons de bois : implications archéologiques (sites des Canalettes et des Usclades, Aveyron)*. D.E.A., Université de Paris I.

Théry-Parisot I. 1998 - *Économie du combustible et Paléoécologie en contexte glaciaire et périglaciaire, Paléolithique moyen et supérieur du sud de la France, Anthracologie, Expérimentation, Taphonomie*. Thèse de doctorat, Université de Paris I.

Trabaud L. 1976 - Inflammabilité et combustibilité des principales espèces des garrigues de la région méditerranéenne. *Ecologia Plantarum*, 11, 2 : 117-136.

Wells C.G., Campbell R.E., DeBano L.F., Lewis C.E., Fredriksen R.L., Froelich R.C. & Dunn P.H. 1979 - *The effects of fire on soil : a state of knowledge review*. National fire effects workshop, Denver, Colorado, April 10-14, 1978. United states Forest Service General Technical Report WO-7.

Wood W.R. & Lee Johnson D. 1978 - A Survey of disturbance processes in archaeological site formation. *In* : *Advances in archaeological method and theory,* Schiffer M.B. (ed) : 315-381.

Wright H.A. & Bailey A.W. 1982 - Temperature and heat effects. *In* : *Fire and Ecology: United States and Southern Canada,* Wright H.A., Bailey A.W. (eds). New York : 8-23.

To cite this article

Fiorentino G. & D'Oronzo C. 2010 - An archaeobotanical and experimental approach to identifying successive fire events in hearth structures in the sanctuary of Apollo in Hierapolis (Turkey). *In* : The taphonomy of burned organic residues and combustion features in archaeological contexts, I. Théry-Parisot, L. Chabal & S. Costamagno (eds). Proceedings of the round table, Valbonne, May 27-29 2008. *P@lethnologie*, 2 : 59-68.

P@LETHNOLOGY
Bilingual review of prehistory