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IRENE ORTIZ NIETO-MÁRQUEZ, JAVIER BAENA PREYSLER

EXPERIMENTS AROUND THE FIRE. DISCOVERING HUMAN AND NATURAL PROCESSES IN MIDDLE PALEOLITHIC HEARTHS

ABSTRACT: The use of fire technology in prehistoric societies is very well known. However, research is still being carried out into its production and control during the middle Paleolithic period. The study of hearths has illustrated the social aspects of human groups through studies of their typology and morphology, the study of the combustible materials and the spatial distribution of remains. In the latter case it is important to differentiate that which has occurred naturally or as a result of human activity. Another factor which must also be considered is the influence of the location of the materials used to make the fire, as well as the temperatures.
In this paper we present a comparative study of experimental fire places with archaeological examples from the El Cañaveral middle Paleolithic site. This study analyzes the relationship between temperature, location inside the fireplace, and the spatial distribution of heated elements in order to consider the "fire spatial displacements". By controlling variations in the distribution of elements, due to fire fragmentations, and with the assistance of refits, we will discuss the existence of other post sedimentary agents, as well as knapping methods. Using these approaches we will attempt to determine some patterns of Neanderthal activities around hearths, and show some dynamic aspects of lithic tools life.

KEY WORDS: Hearth – Spatial analysis – GIS – Refits – Middle Paleolithic

OBJECTIVES

The objective of this research was to study the evidence of a hearth found in a Middle Paleolithic site, El Cañaveral, Madrid (Spain). We constructed an experimental hearth in order to compare data and to study the thermal alteration on surface and buried flint pieces. In addition, we performed a spatial analysis on both hearths to compare the thermal alteration movement.

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GEOLOGICAL CONTEXT

El Cañaveral is located in Madrid, on the central plateau of the Iberian Peninsula. The geological context is the Madrid basin, which is part of a bigger morpho-structural unit called the Tajo Basin. It is triangular in shape and is bounded by the Central System and the Gredos mountains in the North West, by the Iberian Range in the North East, and by the mountains of Toledo in the South.

During the Miocene period the basins underwent an evolution caused by various factors which led to three large stratigraphic units: the Lower Unit, the Middle Unit and the Upper Unit (Baena Preysler *et al.* 2011).

With regard to its geomorphology, this area has characteristic features which have been controlled mainly by lithology and climatic factors. It has two clearly distinct domains, the Jarama Valley in the East, and the erosive-structural plains in the West. The wide Jarama Valley presents a high asymmetry with many stepped terraces on the left bank and a strong erosive character on the right bank. The western boundary of the valley is characterized by cliffs formed from gypsum. On the top of the cliffs, from the right bank of Jarama to the left cliffs of Manzanares, there is a plateau which forms part of the great dividing platform situated between these two rivers. It is a structural-erosive origin relief conditioned by the presence of flint layers and carbonated clays (Baena Preysler *et al.* 2008). It is situated on a platform that defines the watershed between the Manzanares and Jarama rivers where many silica rocks come to the surface, for example: flint, opal etc. The unusual abundance of theses rocks explains the presence of a large number of archaeological sites linked to the supply/catchment patterns of raw materials.

The preservation of a large number of these archaeological sites has been made possible by different sedimentary stages, the eolian and colluvian types, which occurred during the quaternary period. These lacked high energy and almost any transport capacity that covered and buried the anthropological activities protecting them from external erosive agents. The numerical dating series obtained by OSL (still under study) in all areas have registered human activities in OIS 3 and latter (Baena Preysler *et al.* 2011).

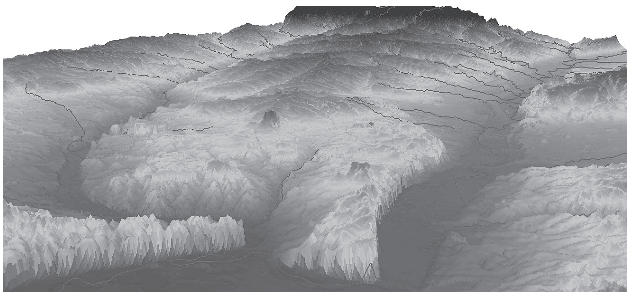


FIGURE 1. General view of the emplacement of El Cañaveral (red point), between Manzanares and Jarama rivers.

AREA 3, EL CAÑAVERAL

The *El Cañaveral* archaeological site (Madrid, Spain) is an open air raw material quarrying site occupied during the middle Palaeolithic period. This site was discovered as a consequence of some research projects supported by the Consejería de Cultura of the region of Madrid. Later excavations conducted by Arquex SL, an archaeological company, and the Universidad Autónoma de Madrid research team, determined different aspects of the site formation and a study of human occupation (Baena Preysler *et al.* 2008). As a result of the discovery of a large number of lithic industries associated with raw material blanks, open excavation commenced in several different areas. One of the main excavations was Area 3, which has total surface area of 164 m^2. Its sequence included at least one clay layer containing large assemblages of lithic industry represented by numerous core flakes and hammer stones (Baena Preysler *et al.* 2011).

The distribution of the materials alternates between concentrations with predominantly horizontal layouts and sets of raw materials located along vertical slopes, which are a result of the edaphic processes that took place later. At the same time, it is likely that the coluvionary deposits were the principal source of raw materials and the basis upon which the well-preserved traces of knapping activity were superimposed. New coluvionar-eolic episodes differentially affected the distribution of various knapping zones with the partial dragging of some pieces and the intrusion of new boulder materials.

During the excavation the distribution of oval or circular concentrations of fresh material was recovered, corresponding to particular *debitage* areas as well as hearth remains indicating a temporary occupation of this area.

The first stages of the operative chain in El Cañaveral have been documented. Procurement, reduction and blank production aimed at the exploitation of the materials, together with steps to full production, took

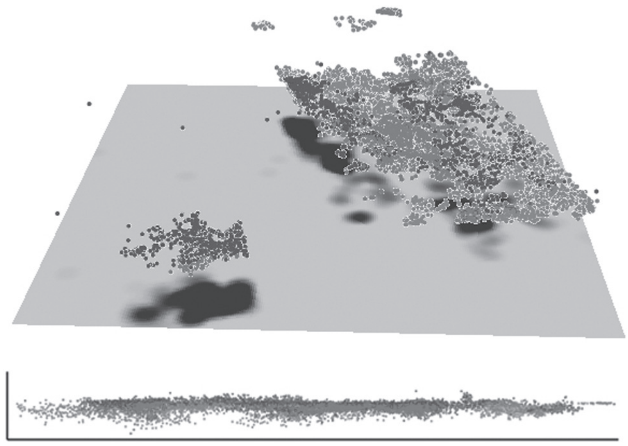


FIGURE 2. 3D projection of Area 3, El Cañaveral. Blue points are level II, pink points are level II–III and green ones are level III.

place within the same space. Traces of consumption activities, the final stages of the operative chain were very limited or non-existent, indicating that human occupation was of a short duration (Baena Preysler *et al.* 2011).

Prior to experimentation, we studied most of the 3 levels determined in the field. We performed spatial analysis -intra-site-, by GIS applications, refits and technological research.

This posed some questions related to this site. Firstly, we needed to discriminate between the different knapping areas in the whole excavation area, and to determine whether this place was a palimpsest as a result of a continuous occupation, or whether discrete layers occurred. Another objective was to discover the post-depositional agents which could affect the original lithic distribution both in the x and y axis and also in the z values. The spatial dimensions of refits could offer basic elements to the interpretation of the site formation processes.

Georeferencing lithic pieces was used to obtain a distribution map of the area, three different levels, II, II–III and III could be distinguished, the most important concentrations were selected using the raster application (Ortiz Nieto-Márquez 2013).

The differences in lithic distribution between levels are shown on the map below. The blue points represent level II, the pink represents level II–III and the green points level III. The whole of the area excavated, and the hearth isolated in the south are shown in the figure below.

Using spatial analysis, density maps, and refit information it was possible to observe that in level II the majority of refits are positioned inside the areas where the density is higher. Some refitting lines follow the same direction, NW-SE. This refit originates from a reduction sequence.

In levels II–III, the higher density areas are situated in different places, but the refits are still well inside them. Theses refits have shorter union lines, because they were very concentrated, and the direction of the lines follow

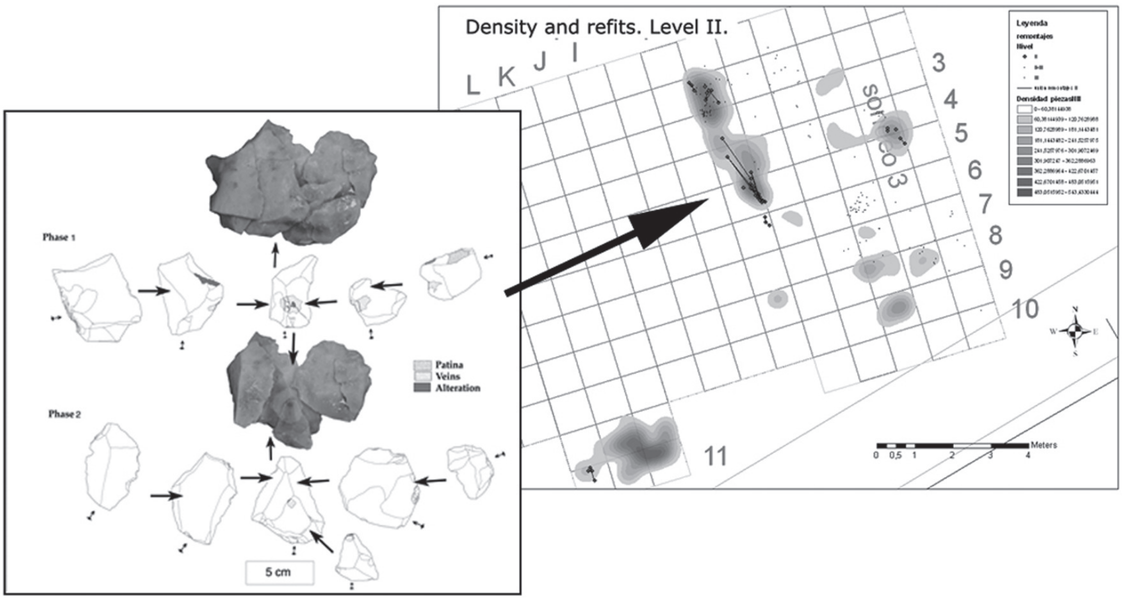


FIGURE 3. Level II, join lines refits and a refit example.

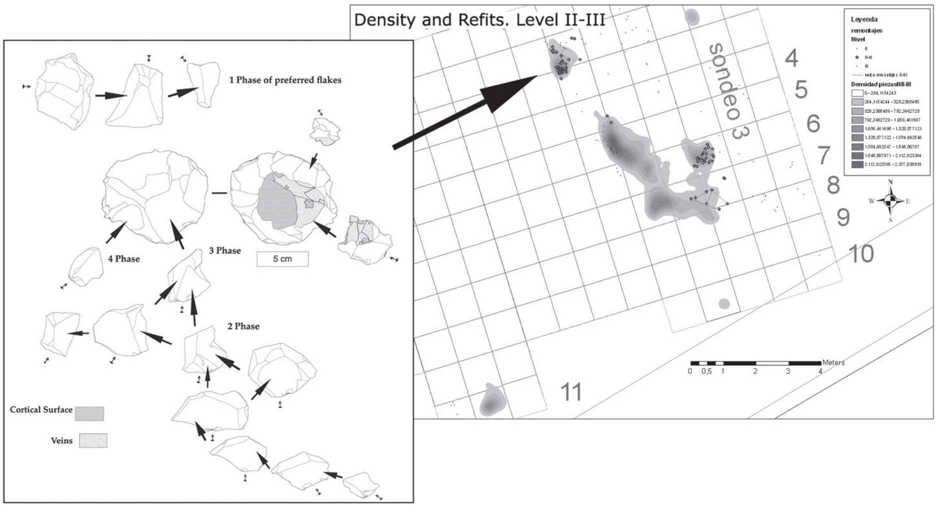


FIGURE 4. Level II–III, join lines refits and an example of a Levallois core refit.

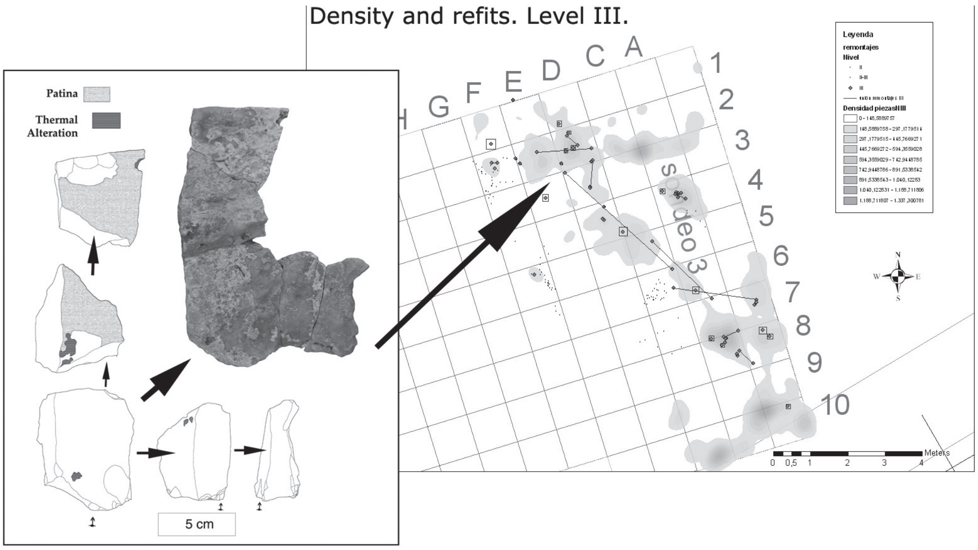


FIGURE 5. Level III join lines refits and an example.

the same NW-SE direction. This following refit image originates from a reduction sequence of a Levallois core.

Finally, at the third level the density areas are also in different positions. However, using refitting lines it was possible to show the main movement of pieces in this site. Pieces from this level were much more bounded and with carbonate alterations, which probably follow the same direction as the refit lines. This could indicate the existence of low energy water flows.

It was possible to combine level II and II–III, because the refits between both levels had the same technological and visual characteristics.

HEARTH

The hearth in Area 3 was discovered as a result of some expansions undertaken during the field work period. Firstly, some lithic elements with evidence of thermal alteration were discovered on the edge of section, during the process of some construction work. We found half of the original fire place and consequently this area was excavated.

The perimeter of the hearth was marked, it was 2.99 m in length, with an area of 0.58 m^2. The depth of the hearth was 30 cm. A cuvette was also excavated inside the perimeter, which had an area of 0.08 m^2. Level

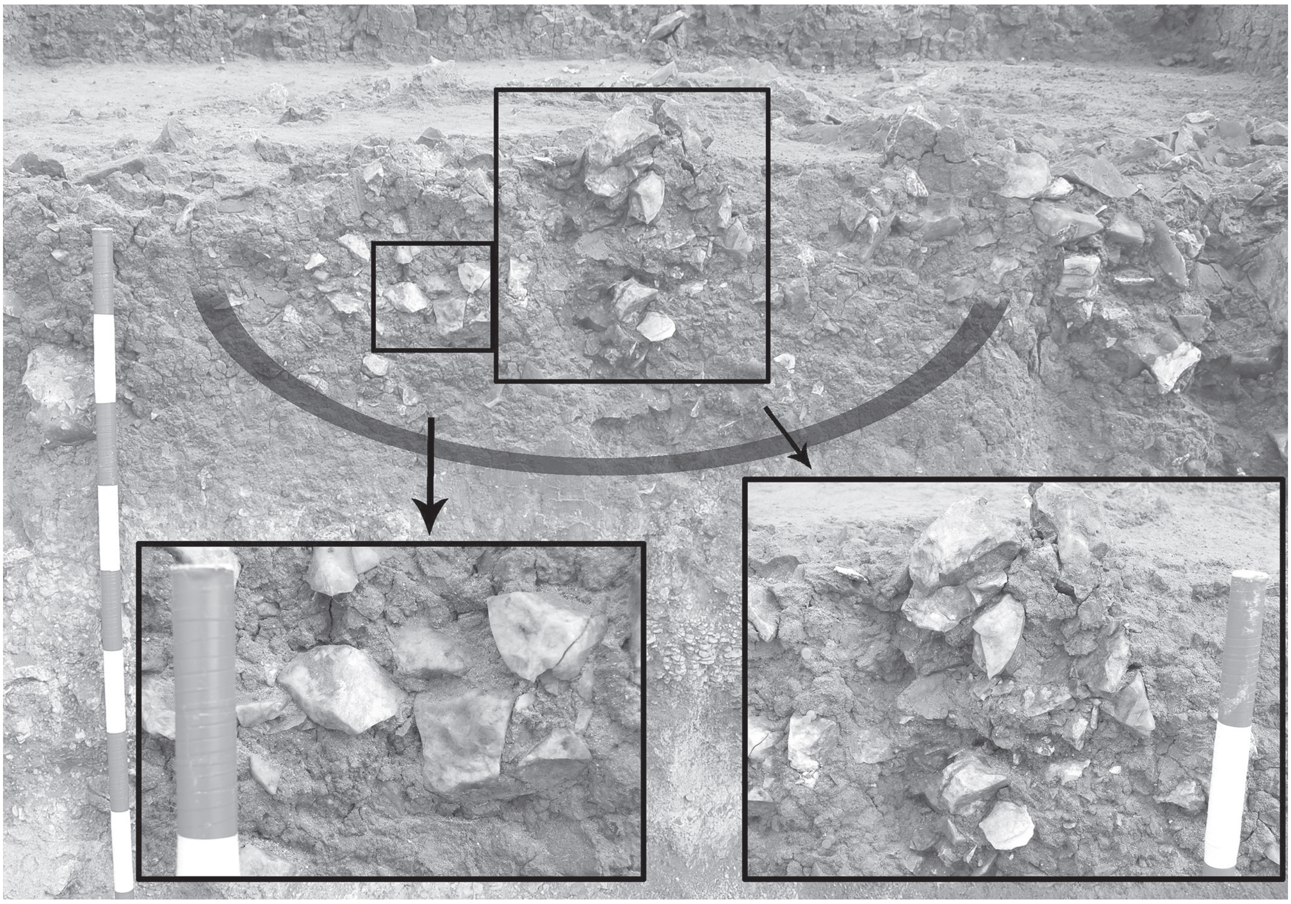


FIGURE 6. Section edge of the hearth with thermal altered pieces.

TABLE 1. Lithic categories of Área 3 hearth.

Categories	Number
Cores	65
Flakes	494
Scrapers	6
Denticulates	2
Fragments	468
Nodules	14
Hammers	2
Sirets	7
Pebbles	3
Total	1061

II and II–III were distinguished in the fireplace, but in this study it has been considered to be the same level.

As spatial analysis was performed on Area 3 which provided density and dispersion maps, which show the positions of the lithic categories, the distribution of the thermally altered fragments and refit movements.

The image of technological dispersion (*Figure 7*) shows the concentrations around the hearth. Fragments were found in the most represented category, in the middle of the fireplace. Flakes and cores, some nodules, two hammers stones and some denticulate and scrapers were identified.

All lithic pieces were analyzed to find some thermal alterations. As Petraglia says, there are typical alterations because of fire action; they are color change, cracked pieces or broken pieces (Petraglia 2002). There are 3 levels of thermal alteration. On level 1 there are almost any external alteration, only reddish patina and some cracked. On level 2 there are more visible changes, such as thermal jumps, cracked pieces and color changes. Finally on level 3 there is color change, becoming grey pieces because of dehydration (Sergant *et al.* 2006).

The map of the thermal alteration distribution shows that the largest number of pieces with high alterations accumulated inside the cuvette. Although some pieces with alterations were also found outside.

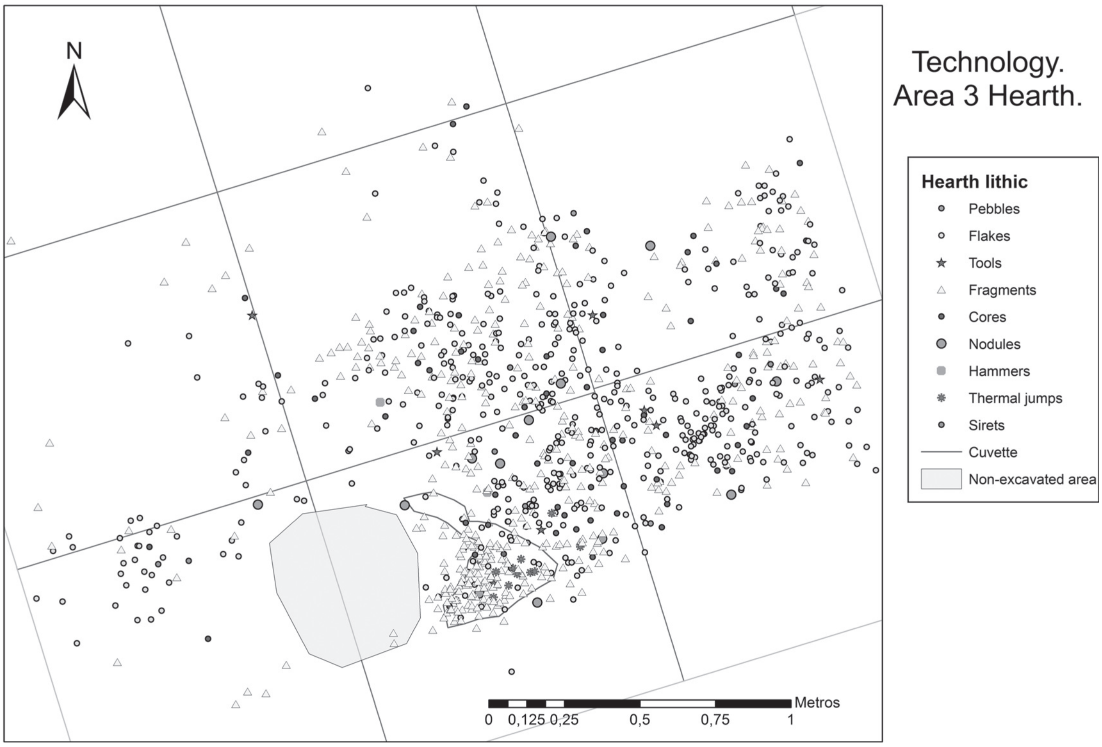


FIGURE 7. Map of technology categories in Área 3 hearth.

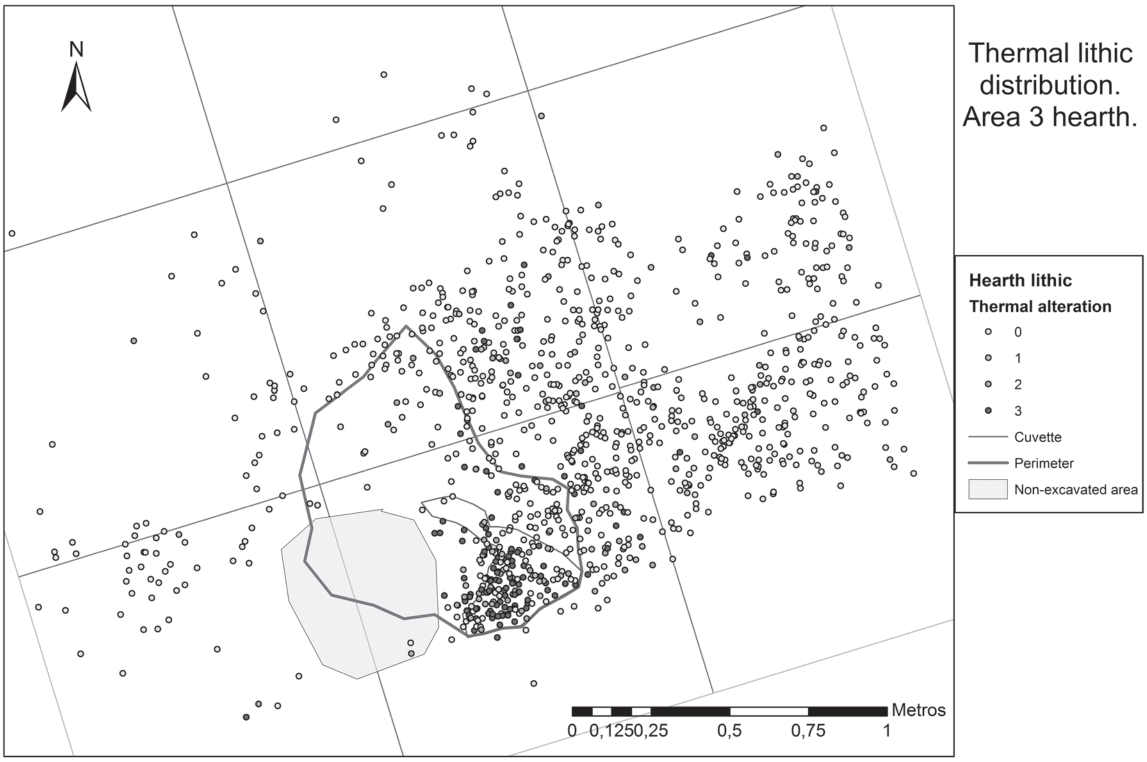


FIGURE 8. Map of thermal lithic distribution in Área 3 hearth.

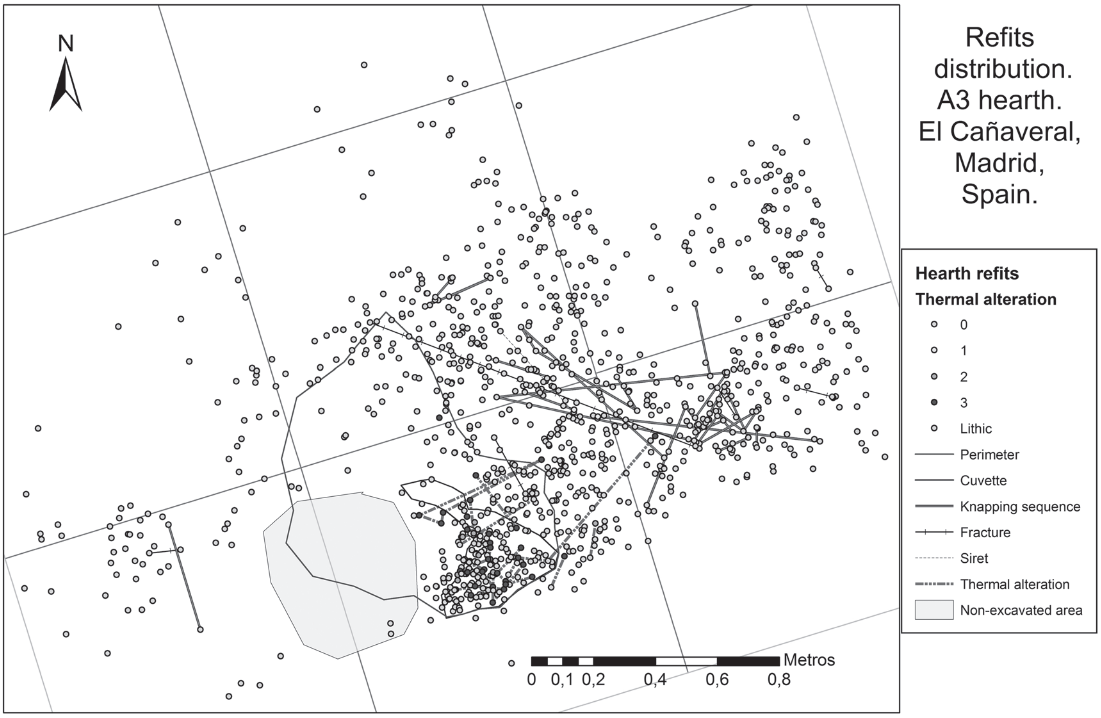


FIGURE 9. Map of refits distribution in Área 3 hearth.

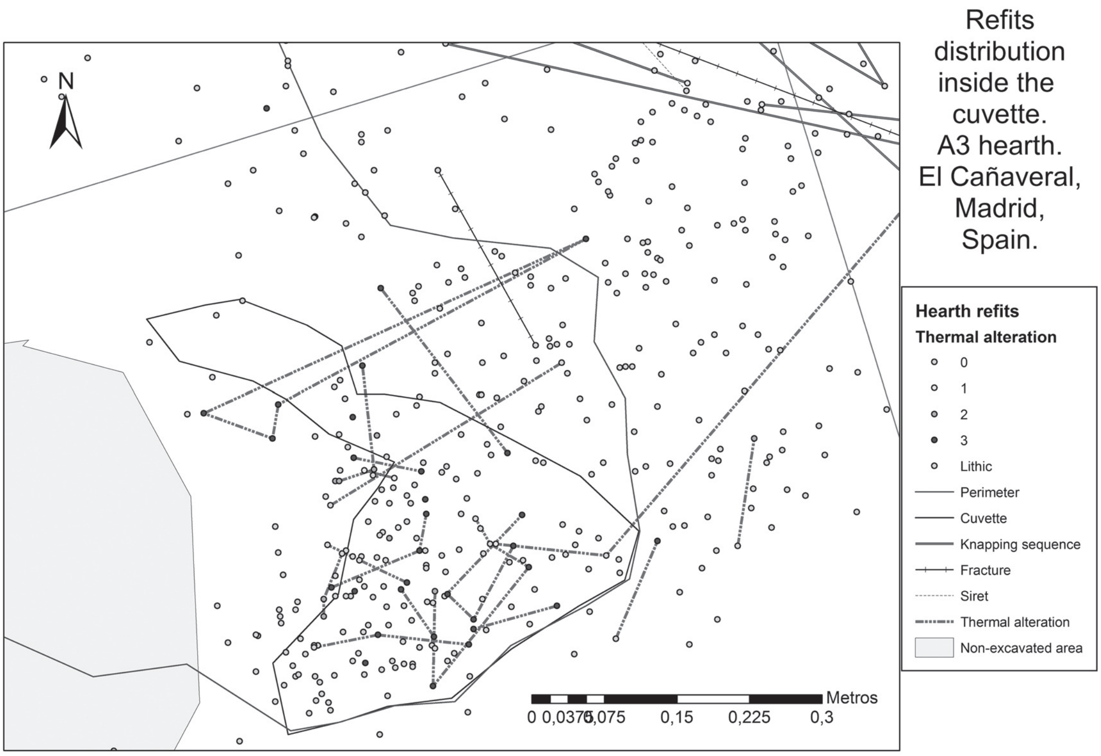


FIGURE 10. More detailed map of refits distribution inside the cuvette.

Finally, we found some refits in the fire place. It was possible to distinguish between core reduction sequences refits; thermal fractures and trampling ones.

This detailed map of the hearth refits shows how thermal jumps move inside the cuvette as well as others which appeared outside the perimeter.

Taking into account the distance between refitted pieces, the mean distance between core reduction sequences was 54.2 cm, and the maximum 221 cm. However, one of the longest distances found in a refit was a thermally altered fragment, with a distance of 90 cm. This suggests that this movement may have been caused either by anthropological agents or natural processes such as thermal jumps.

EXPERIMENTAL HEARTH

After the archaeological hearth had been studied, the main aims of the research using the experimental hearth were:

– To analyze the external modifications to the flint caused by thermal action, depending on:
– The distance from heat focus.
– The depth from surface layer.
– A spatial analysis of lithic movements caused by thermal action.
– A comparison of the data from archaeological and experimental fireplace.

PHASES AND METHODOLOGY

Firstly, it was necessary to obtain original raw material, namely flint nodules, from the archaeological site. Two large nodules discovered during the field work were used, and by reduction sequences we obtained some flakes, cores and fragments.

A Data Base was set up to record information about the raw material, e.g quality, size, weight, colour (using a colorimeter), photographs and an observations option for all the experimental pieces.

Original sediment from Area 3 was obtained for the lithic burial. It was winnowed to avoid any exogenous flake appearing in the experiment. A brief explanation of the composition of this sediment follows:

On the stratigraphic column is it possible to see that level II originates from reddish clayed sand. On Level II–III there are some blanks and pebbles, a maximum of 60 cm in length. It also has a clayed matrix with abundant lithic industry, which in some cases are bounded, and in others the lithic is very fresh. Finally, on level III there are clay pebbles, flint clusters and lithic industry (Baena Preysler *et al.* 2007.).

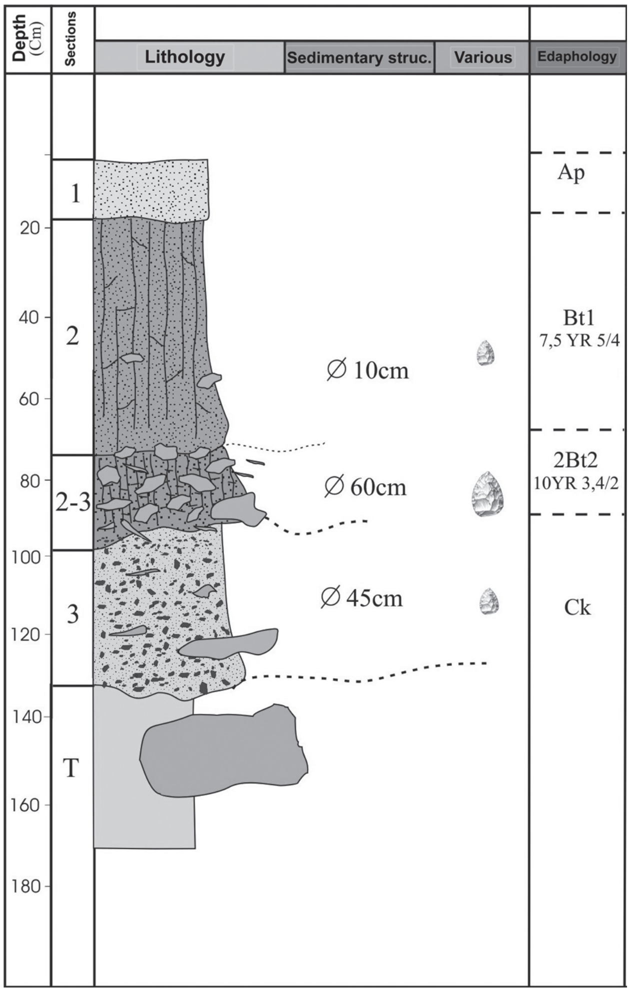


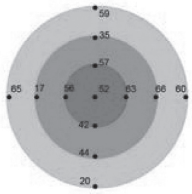
FIGURE 11. Stratigraphic column of Área 3.

In order to reproduce the original fireplace as accurately as possible, a small cuvette, 1×1 m was dug at a depth 30 cm. Lithic pieces were buried at three different layers and a fourth layer was positioned on the surface. The pieces were placed in a cross formation with a distance of 5 cm between them. All the pieces were geo-referenced.

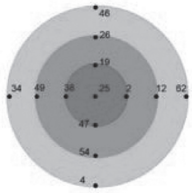
Fire was started using only combustible material of vegetable origin. The fire was kept burning for two hours, adding more fuel. The temperature was measured, in the centre of the fire, every 15 minutes, and finally the fire was extinguished. The maximum temperature recorded was 915 °C.

TABLE 2. Explanation of distribution and position of lithic buried for the experimental hearth.

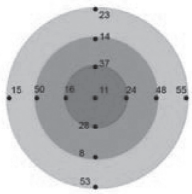
Schema | Pieces position | Photography



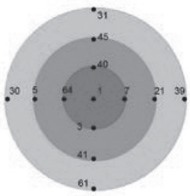
Level III		
Nº Coord.	Nº Piece	Observations
10	20	Downwards bulb
11	44	Upwards cortex, Downwards bulb
12	42	Downwards bulb
13	52	Cortical, Downwards bulb
14	57	Downwards bulb
15	35	Upwards cortex
16	59	Upwards bulb
17	60	Downwards bulb
18	66	Upwards bulb
19	63	Upwards bulb
20	56	Upwards bulb
21	17	Downwards bulb
22	65	Upwards bulb



Level II		
Nº Coord.	Nº Piece	Observations
23	4	Upwards cortex
24	54	Downwards cortex
25	47	Upwardscortex, Downwards bulb
26	25	Downwards bulb
27	19	Downwards bulb
28	26	Upwards bulb
29	46	Upwards bulb
30	62	Downwards bulb
31	12	Downwards bulb
32	2	Nodule
33	38	Downwards bulb
34	49	Downwards bulb
35	34	Downwards cortex



Level I		
Nº Coord.	Nº Piece	Observations
36	53	Downwards bulb
37	8	Downwards cortex
38	28	Upwards bulb
39	11	Upwards bulb
40	37	Upwards cortex
41	14	Upwards bulb
42	23	Downwards bulb
43	55	Downwards bulb
44	48	Upwards bulb
45	24	Downwards bulb
46	16	Upwards bulb
47	50	Downwards bulb
48	15	Upwards bulb



Surface		
Nº Coord.	Nº Piece	Observations
49	61	Downwards bulb
50	41	Upwards bulb
51	3	Downwards bulb
52	1	Upwards cortex
53	40	Downwards bulb
54	45	Upwards bulb
55	31	Upwards cortex
56	39	Downwards cortex
57	21	Downwards bulb
58	7	Upwards cortex
59	64	Downwards bulb
60	5	Downwards bulb
61	30	Upwards cortex

TABLE 3. Experimental hearth temperature.

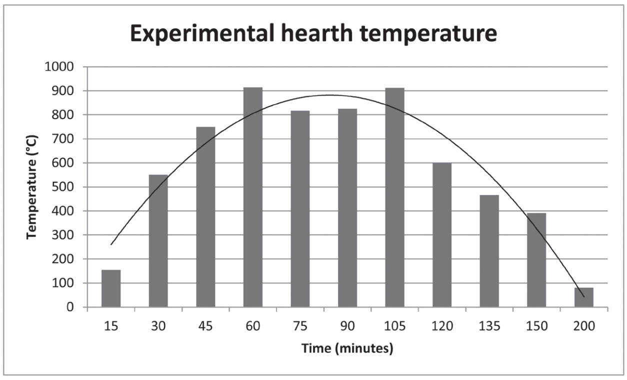
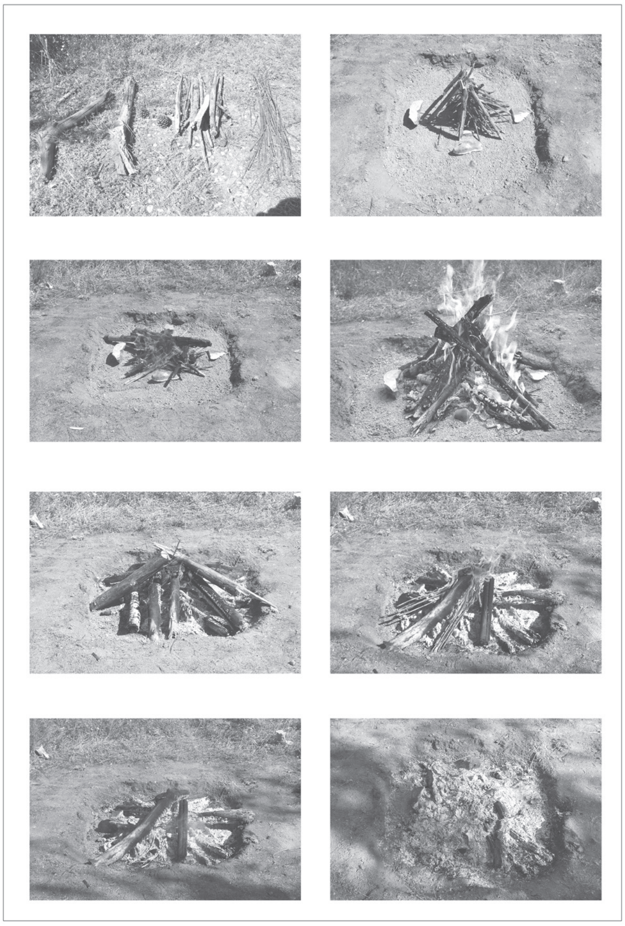


TABLE 4. Different phases of fire action.



DATA

At the end of the experiment the data obtained from both fire places were compared.

These images show the experimental fireplace before and after the fire. The distribution of the central pieces has changed. This is the result of thermal jumps, thermal fractures and to a lesser extent combustible weight.

The pieces placed at the north and the west periphery of the fireplace have not suffered much thermal alteration. They have only changed their colour and some thermal jumps have occurred. These thermal jumps occur on the face directed towards the heat focus.

However, the remaining pieces, in particular the ones in the centre, exhibit thermal fractures, colour changes,

FIGURE 12. First picture shows the experimental hearth before burning activity, the second one shows the hearth after fire action.

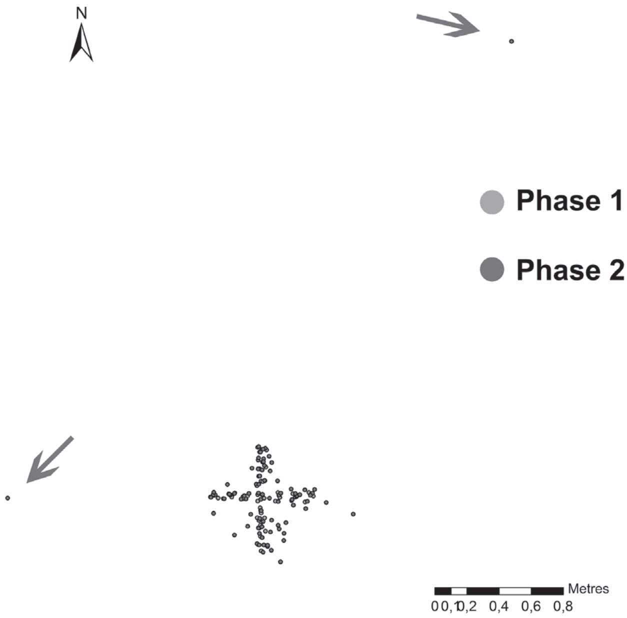


FIGURE 13. Map of thermal altered pieces distribution. Blue points show the original lithic position, red ones shows lithic pieces after fire action.

crackling, long thermal jumps, and a loss in weight resulting from dehydration. The mean weight loss was 2 g per piece. As a result of geo-referencing each piece it was possible to produce a distribution map, from phase 1, before the fire, and phase 2, after the fire. The *figure 13* shows that most of the pieces remained inside the cuvette, except for 2 thermal jumps.

TABLE 5. Fracture index of lithic.

Fracture Index		
Layers	N^{o} of pieces before	N^{o} of pieces after
Surface	13	314
Level I	13	14
Level II	13	13
Level III	13	13

TABLE 6. Displacement index of lithic.

Displacement Index			
Layers	Max (cm)	Min (cm)	Mean (cm)
Surface	342	0.8	37.6
Level I	1.6	0.2	0.8
Level II	1.8	0.3	1.2
Level III	2.2	0.3	1

The Fracture Index shows that there were large differences between the pieces in the buried levels and those on the surface. Levels III and II did not show any increase in the Index on a number of the pieces. Level I had only one additional piece due to thermal fracture, and finally, on the surface level the number of lithic pieces increased by 240 %. These pieces were crackled and had thermal jumps and fractures.

With regard to the Displacement Index, there is a variance between the displacement of those in the buried levels and those on the surface. On levels I, II and III the mean movement distance was 1 cm, probably as a result of sediment weight. However, the mean

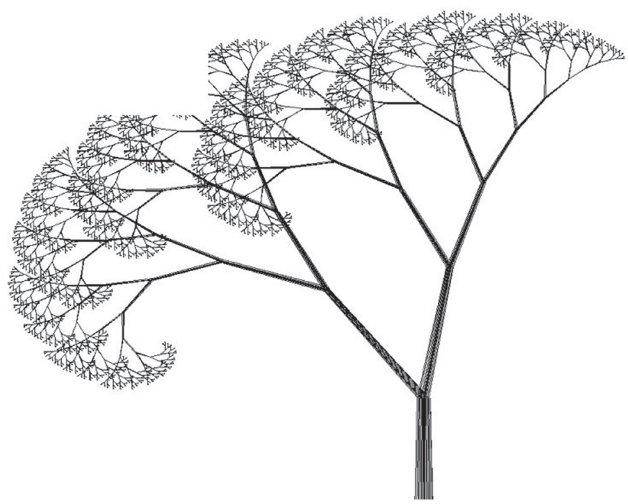


FIGURE 14. First picture shows an example of a fractal model and the second one shows the central piece of the experimental hearth.

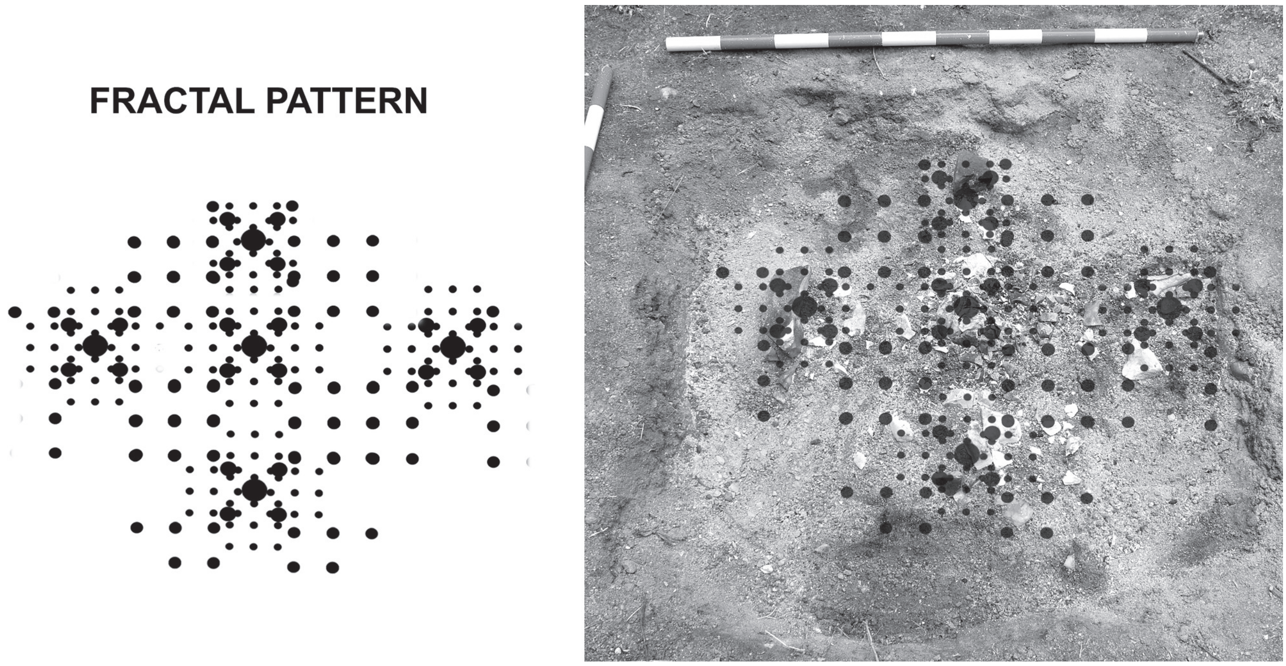


FIGURE 15. Fractal pattern proposed for the experimental hearth.

movement distance on the surface level was 37.6 cm, and the maximum distance moved was 342 cm. This suggests that the lithic pieces which were in direct contact with fire suffered more thermal alteration which caused longer thermal jumps.

A study of the Fracture and Displacement Index indicated a pattern in the thermal fragmentation. A fractal pattern was discovered when the lithic had been fractured by the action of heat. Benoît Maldelbrot said that a fractal is a geometric object which has a basic structure, irregular or fragmented, which is repeated on different scales. Copies are similar to the whole, and they tend to have a similar morphology, but they have different size (Mandelbrot 1997).

The *Figure 15* is an example of a fractal pattern, where the same geometric object comes from a larger one, which has the same structure but a different scale. The second figure shows lots of thermal fractures originating from the same central lithic piece in the experimental hearth.

It is possible to explain the thermal fractures on those pieces that have been in direct contact with the fire. Each piece becomes fragmented, and from these fragments others appear, with a similar morphology and so on and so forth. It could be possible to make a pattern of the fractal action that occurs in the experimental hearth. From a whole piece different thermal fragments will appear, and from these fragments, more fragments will appear. This could continue until the heat focus, that causes the fragmentation, is too far away to have any effect. The fractal model has two determining factors: the temperature and the gradient distance from the position with the highest temperature. If any of these factors changes, the whole model will changes. If the

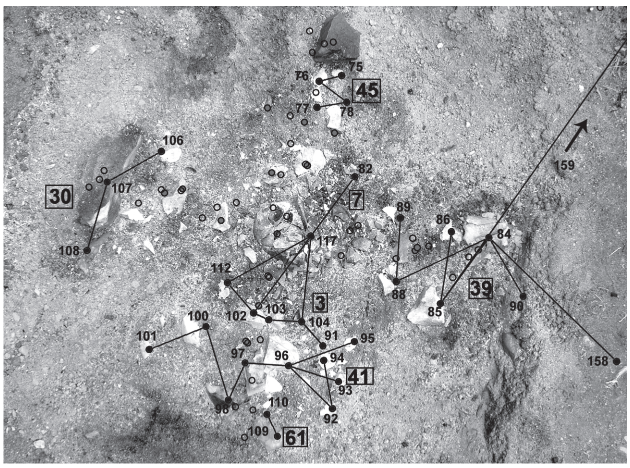


FIGURE 16. Experimental hearth refits lines. Numbers with a frame are the number of the piece, and smaller numbers are coordinates ones.

temperature decreases, only the closest pieces will be affected by thermal alteration; and if the distance of some lithic pieces increases from the focus of highest temperature, the level of thermal alteration will decreases.

On the surface layer map it is possible to see different refit lines which occurred during the burning process. As a result of geo-referencing each piece it was possible to determine the movement of each lithic piece inside the fireplace, the distance of thermal jumps, and to check the fractal pattern *Figure 16*.

Looking at piece No. 45, it is possible to see that it has cracked into 4 fragments. The fractal pattern is illustrated clearly. Piece No. 78, that was in its original position has also produced different fragments. The change in colour is also due to thermal action, and the cloudy tone is probably the result of dehydration. The cortex area has also changed colour although this surface faced the sand. Refitting lines are on the general figure of experimental hearth refittings, but there is a schematic image of fractal movements of thermal fractures. The refit line for this piece has a length of 13.8 cm.

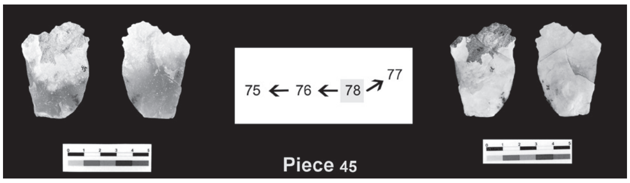


FIGURE 17. Piece 45 before and after the thermal action. In the middle is a schematic model of fractal pattern.

The piece illustrated in figure 18 was situated on the western periphery of the fireplace. It has less thermal alteration due to its distance from the heat focus, but has alterations such as two thermal jumps and a colour change, resulting in a reddish tendency. One of these thermal jumps has a totally different colour and is cloudy because the jump placed it closer to the heat focus and it

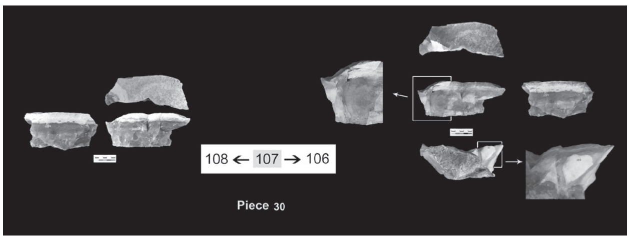


FIGURE 18. Piece 30 before and after the thermal action.

suffered from dehydration. The cortex has also changed colour, probably as a result of the action of the smoke. The refit of this piece has a length of 22.4 cm.

Piece No. 3 was 10 cm from the focus of the heat. This piece was broken into 10 fragments. The figure below shows that this fragmentation followed a fractal pattern, because from pieces Nos. 102 and 103 that are in their original position more fragments have been produced. The colour of the piece has also changed, and some pieces have totally different colours as a result of the thermal jump distance. The refit line for this piece has a length of 21 cm.

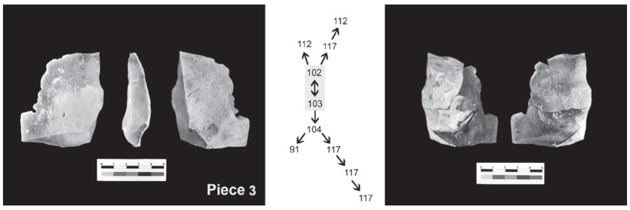


FIGURE 19. Piece 3 before and after the thermal action.

Piece No. 39 was situated on eastern periphery. It was highly altered by thermal action because the combustible material was on top of it. It cracked into 9 fragments which were originally part of the pieces numbered 102 and 103, from which the remaining fragments appear. Fragment No. 157 is worthy of note because of the length of its thermal jump, it moved 3 meters away from its original position. This piece also exhibited color change and dehydration. The refit line of this piece, 3.42 m, is very long as a result of the long distance of the thermal jump.

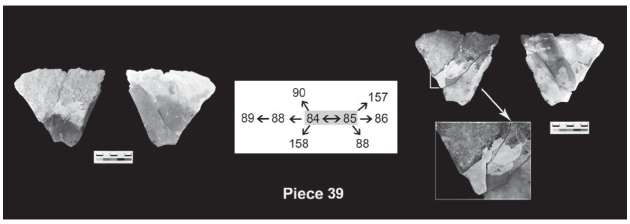


FIGURE 20. Piece 39, before and after the thermal action.

Piece No. 41 was 20 cm from the heat focus, but it was exposed to very high temperatures. It was divided into 9 fragments that were displaced over the whole surface following a fractal pattern. The original position of this piece were fragments Nos. 96 and 97, and from them other thermal fragments appeared. Their colour had also changed, tending towards cloudy except for a fragment that was totally black. It is noteworthy that this piece lost 15 g, and is totally refitted. This refitting line has a length of 58 cm.

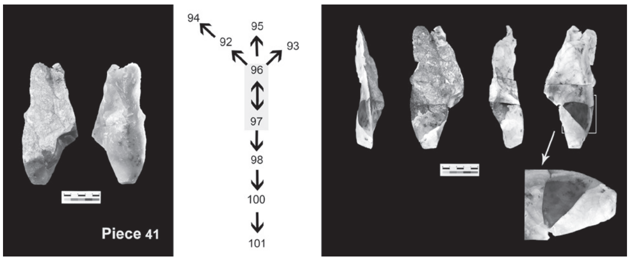


FIGURE 21. Piece 41 before and after the thermal action.

Finally, piece No. 61 was placed at the south of the fireplace and 30 cm from the heat focus. In this piece there was only one thermal jump, but it was crackled and had changed colour. This thermal jump displacement had a length of 4 cm.

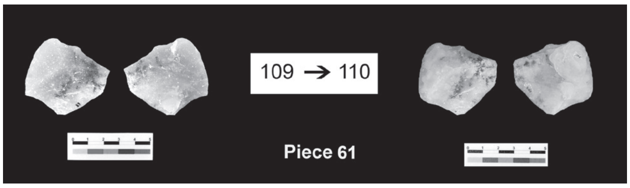


FIGURE 22. Piece 61 before and after the thermal action.

DISCUSION

Although it was not the main aim of this paper, we have noted the difficulties surrounding the discussion concerning the different aspects of fire use in middle Paleolithic societies, their functionality and specific technology. However, the existence of the use of fire during the European upper Pleistocene is a general constant related to human occupation in this period.

The earliest evidence of the use of fire in Europe appeared around 300–400 KY at Beeches Pit, in England and in Shöningen, in Germany (Roebroeks, Villa 2011). However, there are also other archaeological sites that have provided additional evidence of the use of fire and these include: Grotte XVI (Karkanas *et al.* 2002), Lazaret in France (Boyle 2000, Jrad *et al.* 2014, Valensi *et al.* 2013), Bolomor Cave in Spain (Sañudo Die 2008) and some caves in Israel, such as Qesem Cave (Karkanas *et al.* 2007, Shahack, Gross *et al.* 2014), Tabun (Verri *et al.* 2005), Kebara (Speth 2006, Albert *et al.* 2012, Speth *et al.* 2012), stressing Gesher Benot with a chronology of 780 ky (Alperson-Afil 2008), and Koobi Fora in Africa with a chronology of 1.6 million years (Bellomo 1994).

There are middle Paleolithic sites inside caves as well as in open air caves, that show evidence of fire, such as Abric Romaní and San Quirce (Chacón *et al.* 2007, Rúa, Martín 2009, Courty *et al.* 2012, Vallverdú *et al.* 2012), El Salt (J. Dorta Pérez *et al.* 2010, Mallol *et al.* 2013b), and El Esquilleu in Spain (Yravedra, Uzquiano 2013). Notable are: St. Marcel, Peyrards, LaCombette, La Quina, Sant Cesair (Yar, Dubois 1999, Roebroeks, Villa 2011). There are also important sites such as Roca dels Bous (de la Torre *et al.* 2004), Pech de l'Aze IV and Roc de Marsal in France (Sandgathe *et al.* 2011, Aldeias *et al.* 2012) among others.

With the evidence obtained from these studies we can confirm that Neanderthals as well as pre-Neanderthals, had the ability to produce, conserve and transport fire during successive occupations. However, we should also stress that the use of fire was not confined to residential areas.

As a result of the data obtained from the fires in both sites, it was possible to compare them and to elucidate the thermal alteration of flint, the recognition of fireplaces and the possible settlement and behavioural patterns around the fireplaces. Finally, we have tried to distinguish anthropic and post-depositional activities in the archaeological hearth in Area 3.

With regard to the thermal alteration of flint, we defined most of them in the experimental hearth according to their distance from the heat focus, and the depth from the surface layer. The typical alterations resulting from thermal action were colour change, cracked pieces or broken pieces (Petraglia 2002). There are intrinsic and extrinsic variables affecting thermal alteration. The intrinsic variables relate to the internal composition and structure of the flint, while the extrinsic variables are those such as the effect of temperature on the flint, the position of the flint with respect to the focus of the heat and the cooling of the stone (J. Dorta Pérez *et al.* 2010).

The results of our experiments showed changes to the surface of the flint occurred where they had been in direct contact with the fire, whereas those pieces of flint which had been buried did not exhibit any change. Furthermore, those pieces that were closest to the focus of the heat showed more alterations to their surface structure. Likewise, regarding the hearth in Area 3, we also found that those pieces which had been closer to the focus of the heat, i.e. the cuvette, were more thermally altered than those pieces which were further away.

Macroscopic analyses were also carried out on the flint pieces to determine colour changes, shininess, fissures, crackle, micro fractures and thermal jumps. Mechanical changes include a loss of elasticity and fracture resistance. Microstructural changes include re-crystallization, dehydration and micro-fractures (J. Dorta Pérez *et al.* 2010). Weight loss has also been recorded in thermally altered pieces (Clemente-Conte 1997).

Visual changes were recorded both at experimental hearth and archaeological hearth. The pieces changed colour, becoming reddish and darker. Fissures appeared, and the pieces became fragmented by these internal fissures. Crackled pieces and thermal jumps also appeared in both fire places. The thermal jumps in experimental hearth were notable in that they could jump a distance of approx. 3 m. This was also significant in Area 3 because they produced one of the longest refits. Pieces in the experimental fireplace suffered dehydration which was confirmed by their cloudy colour and loss in weight.

The recognition and identification of a hearth in archaeological sites necessitates a detailed spatial analysis of burnt fragments and the determination of their concentration (Sergant *et al.* 2006). The data from Area 3 shows that burnt pieces were concentrated inside the cuvette, and the sediment was rubefacted. Thermal alteration increased the closer the fragments were to the cuvette concentration.

According to Nina Alperson (Alperson-Afil 2008), hearth indicators are knapping fragment concentrations, micro-artefacts that only appear with direct fire contact and clusters. Burnt lithic concentrations should not coincide with non-burnt lithic concentrations. This could be demonstrated in the hearth in Area 3 by spatial analysis and distribution maps, where it is possible to observe the burnt pieces inside the cuvette, and in the fireplace surrounds where there were concentrations of pieces which had not been thermally altered. In this case we have a cluster with a high density of burnt pieces which confirms the existence of a combustion structure.

The best analysis of fireplaces can be made by the study of burnt objects. We have to reiterate that the natural distribution and thermal alteration of pieces is the result of the influence of the temperature and the heat focus distance (Sergant *et al.* 2006). Thermal jumps could appear at distance of 2.5 or 3 m from the origin which was proved in the experimental hearth, where one of the pieces jumped a distance of 3 m from its original position.

This movement generates spatial dispersion, and although it follows random patterns, in general it conforms to arithmetic fractal structures. In some cases there are very long jumps where the fractal expansion decreases strongly, because this movement displaces the materials from the fractal source, the temperature.

Regarding the post-depositional processes, these tend to modify two dimension distribution. The first is a bi-spatial dimension that represents clusters caused by fireplace activity and spatial thermal alteration.

Fireplaces were originally flat structures, with only one combustion and with a specific stratigraphy: a white-yellowish first layer, a brown-black second layer comprising fuel waste, and finally a brown-reddish layer which is the base of the hearth (Mallol *et al.* 2013a, March *et al.* 2014). On the Area 3 hearth it was only possible to see the last brown-reddish layer of the rubefacted base. However, on the experimental hearth we could observe all the three layers. This means that the experimental hearth was not stirred because it retained the original stratigraphy.

However, on the hearth in Area 3 it was only possible to find the last rubefacted layer, indicating that it had probably been stirred or cleaned up. Those data are documented by refit lines, which have the same directional tendency as in the rest of Area 3, this could suggest the action of a small water stream. Of course, there is also the possibility of hearth re-ignition in Area 3 and this is currently being investigated.

We should also discuss the movements of the thermal jumps that appeared inside the hearth and its surroundings. The fractal patterns of the thermal jumps recorded in the experimental hearth confirm the Area 3 hearth refits, and explain the presence of some thermal alteration pieces outside the hearth. It may be possible that these pieces have appeared outside the hearth by a thermal jump, or by some natural action, but we should not dismiss the idea that they may have been transported by anthropic action.

It is possible to determine some settlement patterns around fireplaces by spatial analysis. As Binford said (Binford 2009:159): "*people who work around a fire place do their activities following an universal pattern*". A !Kung, an Australian indigenous bush woman from the central desert and a Navajo woman from southwest of UUEE position themselves in the same place in front of the fireplace. They seat themselves around the hearth, creating a right angle with it at a distance of 1 m. Even when a person is knapping, these pieces and the waste pieces will not fall into the hearth, because the action ratio of a knapper is 0.5 meters. So if they are seated 1 m from the fireplace, the pieces that appear inside the hearth would have been intentionality discarded. On the distribution maps of the hearth in Area 3 it is possible to see that there was knapping activity around the hearth, at a distance of about 1 m away. Regarding the second dimension affected by post-depositional processes, this is the three-dimensional one. This depends on the structure and paleo-edaphic processes, which cause alterations to the Z axis distribution.

In this case we connect anthropic activities, such as knapping, around the fire place. Refits that join in different depths reveal that these pieces were fragmented by the action of the fire, and later they were stirred, which is why refits are on a different Z axis. The experimental hearth was not stirred and consequently the refits appear on the same Z axis. In addition, the action of biologic agents should also be considered which might explain the displacement of some pieces at different depths.

CONCLUSIONS

Using experimental archaeology, and appropriate methodology and refits, it has been possible to answer some questions and defray the lack of archaeological information about the hearth in Area 3 in El Cañaveral.

There is a cluster structure in the Area 3 fireplace where there is a fractal model distribution caused by thermal action, although it is blurred because of post-depositional processes.

Following the study of the archaeological remains, their spatial analysis and refits, it was possible to confirm that these were the vestiges of fireplaces. Thermally altered pieces were concentrated inside the documented cuvette, which confirms the existence of fire. Refits have justified the presence of knapping activity around the fire, but there is not any evidence of the use of fire to improve the quality of raw material, in this case flint. Finally, it is possible to confirm that this hearth has suffered from post-depositional processes, because it had been cleaned up and did not have any charcoal remains.

From the study of the archaeological hearth it is possible to conclude that its relation with Area 3 was that of a temporal settlement, where the main activity was raw material sourcing and knapping. The presence of a hearth proves that fire activity was not only limited to residential settlements. There is no evidence to suggest that fire was used to improve the quality of flint, because there were no burnt knapped pieces.

Regarding the experimental hearth, as a result of this study it was possible to establish a fractal fracture pattern for thermal jumps which could explain the distribution of these pieces. In addition, it was possible to prove that not all the thermally altered pieces that appeared outside the fire place were moved by anthropic action, but in some cases this movement was caused by natural events. Thermal jumps could reach a distance of 3 m.

Finally, it was possible to ascertain that in fireplaces with very high thermal peaks, of around 1000 degrees, and a burning duration of 3 hours, thermal alterations did not affect the pieces that were buried, only surface pieces were affected.

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Irene Ortiz Nieto-Márquez
Javier Baena Preyler
Universidad Autómoma of Madrid
Ciudad Universitaria de Cantoblanco
28049 Madrid
Spain
E-mail: irene.ortiz@uam.es
E-mail: javier.baena@uam.es