Thermal Alterations of Flint Implements and the Conservation of Microwear Polish: Preliminary Experimental Observations

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RESUMEN

En todo yacimiento arqueológico suele aparecer un cierto número de piezas líticas que presentan algún tipo de alteración térmica. Ante estos restos líticos nos planteamos si es factible o no realizar un análisis funcional, si vamos a saber reconocer los rastros de uso, si estos han sido alterados o eliminados por la acción del fuego, etc. En este trabajo se presenta la experimentación llevada a cabo tanto en laboratorio como en fuegos al aire libre, con el fin de observar las alteraciones que se producen en las superficies de los sílex. Describiremos las distintas alteraciones y el grado en que estas afectan al reconocimiento de los microrastros de uso. Las alteraciones observadas en estas experimentaciones son: cambios de coloración y "manchones" negros, fracturas, escamaciones y grietas, levantamientos térmicos, "pátinas" y lustre (o brillo) témnicos.

PALABRAS CLAVE: SILEX, EXPERIMENTACIÓN, ALTERACIONES TÉRMICAS, ANÁLISIS DE MICRODÉSGASTE.

ABSTRACT

The lithic assemblage of most archaeological sites usually shows a certain number of pieces bearing different kinds of alterations due to fire. These thermal alterations are normally referred to as thermal polishes, cracks, black spots or different-coloured zones. In this paper we shall describe different alterations that we have observed on experimental flint pieces. The main objective of this analysis is to determine the extent to which these thermal alterations can affect the recognition of microwear traces, especially of micropolish.

KEYWORDS: FLINT, EXPERIMENTATION, THERMAL ALTERATIONS, MICROWEAR ANALYSIS.

Publications concerning the analysis of thermal alterations on flint or other lithic raw materials are abundant (Ahler 1983, Griffiths et alii 1987, Rick 1978, 1983, Joyce 1985, Schindler et alii 1982, etc.). Some other publications deal with thermal treatments related to knapping techniques (Bordes 1969, Inizan et alii 1976-77, etc.), while others concern microwear formation and identification on thermally treated pieces (Binder and Gassin 1988). However, it has not been possible to find any analysis concerning the conservation of microwear traces after a post-depositional thermal alteration.

EXPERIMENTAL RESEARCH DESIGN

To study the possibilities of the conservation of microwear traces on tools subjected to heat, an experimental program was developed, in which three different kinds of flint were used (i.e. different in source and such characteristics as grain size, colour, etc.). One sample was a black flint from Barrica (Vizcaya, Spain). Another sample was from Sant Quintí de Mediona (Barcelona, Spain), with colour bands ranging from red to grey in the same nodule; it is a very hard material, with internal fracture planes filled with crystallization. The third sample was a brown flint from Dordogne (France).

With these flints, 20 experimental implements were made and then used to work different materials. The motions most frequently used were transverse (scraping-whittling), to produce well-developed micropolishes. These micropolishes, although marginal, were usually not
eliminated when microflakes were detached from the edge, as normally happens with micropolishes produced by longitudinal actions on hard materials.

All flakes used in these experiments were unretouched. Eleven flakes were used in scraping-whittling actions on fresh pine, box and hazel woods. Six flakes were used on fresh cow bone, all six in scraping and two in boring actions. Three flakes were used to cut soft material (meat, fat and sinews) that were still attached to the bone.

All experimental flakes were used for half an hour, after which, by microscopic analysis microwear was located and photographed. Next, to produce thermal alterations on the same tools, the flint implements were placed in open-air hearths or in a laboratory oven, where heating conditions were registered (cf. infra). Afterwards, the microwear traces were again analysed and documented.

Besides the experimentally used tools already described, we also tested the following materials: 50 unused flakes of the same flint types, and 11 flint pieces of an old harrow thrasher (cf. infra).

FIELD EXPERIMENTATION IN OPEN-AIR HEARTHS

Two hearths were built in the field, on humus sediment. Ten used flakes and ten unused flakes were placed in each hearth, on the ground immediately before the fire was started. The distribution of the flakes was as follows: three flakes were buried 3-5 cm in the centre of the hearth and the other seven were distributed on the surface within an area of 1 square meter. All the flakes were placed with the dorsal face up and the ventral face in contact with the soil. These were registered and coordinated, to control both their proximity to the middle of the hearth, where the thermal effects were expected to be most intense, as well as the possibilities of movement during the experiment.

At the end of the experiment, two zones could be defined. The central one, in the middle of the hearth, where the fire action had been direct and stronger. The soil had been more intensely burnt and was darkened by a higher charcoal concentration. The peripheral zone, on the other hand, had a lesser concentration of ashes and charcoal, was lighter in colour and the soil appeared to have been less affected by fire.

The hearths were flat and constructed directly on the ground after the flint tools had been buried, by flattening the surface. The fuel used included local types of wood: pine, box and beech in one of the hearths and pine and other evergreen woods in the other. Both of the hearths burnt about three to four hours. To record the different temperatures, a Crison T-637 thermo-recorder was used, allowing measurements of up to 600°C. Soil temperatures were recorded at depths of 3 to 5 cm, where the flakes had been buried. Just after the lighting of the fire, temperatures reached 10°C, and while the fires were burning, temperatures rose to 60°C and 70°C. Similar measurements had been published for other experiments (i.e. Griffiths et alii 1987).

LABORATORY EXPERIMENTS

In addition to the field experiments, we carried out a series of laboratory tests for precise control of experimental conditions and accurate recording of the variables. These tests helped to resolve certain questions raised by the results of the field analysis. In a Nabertherm oven
(allowing temperatures up to 1200°C) we placed unused flakes of the three varieties of flint, as well as used pieces that had been previously heated in the field hearths.

We also tested 11 grey flint artefacts from an old harrow thrasher, recovered in the Pyrenees region. These pieces had well-developed micropolish, resulting from agricultural use (to thrash the grain). This micropolish was similar in a general way to sickle gloss produced by cutting Gramineae, though sickle gloss is thicker and brighter. Moreover, the thrasher flints have abraded zones, and micropolish shows abundant deep and wide striations, due to the intense contact with the soil.

**ANALYSIS**

The alterations observed after the heating experiments were the following: colouration changes, fractures, thermal extractions, scales and fissures, thermal gloss, patina, and weight loss.

**Colouration changes**

The colouration changes did not appear to follow any systematic pattern, some pieces showing important changes of colouration, while others showing only slight changes. At the moment, it is not possible to relate these colour changes to the position of the flakes inside the hearths. The grey colour of Sant Quintí flint usually turns white, while the red zones lightened to rose tones. Some brown pieces of Dordogne flint turned dark grey and the basque flint from Barrica changed from black to a variety of greys. However, not all the pieces changed colour, and changes were frequently minor. In no case did the changes in the colour of the surface hinder the recognition of microwear traces.

On some of the pieces that had not been buried, microscopic examination showed the presence of black spots on the dorsal face (the face of the flake that had not been in contact with the soil surface). When analysed under high magnification, these spots were bright, thick and rugged, and covered the entire microtopography. Where the spots were more intense, we observed textures resembling craters and ribs (fig. 1). In these cases, something appeared to adhere to the flake surface —perhaps a compound of resin together with other organic materials.

![Figure 1.—“Black spot” on the flint surface (100X).](image-url)
substances. The surface of this substance resembled that of the heated pine resin which we had used for experimental hafting. The same phenomena was observed in archaeological pieces and in another experiment (unpublished) with flakes of rhyolite (an igneous rock altered by metamorphism) from Tierra del Fuego (Argentina).

Flakes showing this alteration were subjected to chemical treatments, to eliminate any surface deposits. Before examination under the light microscope, the pieces were cleaned (like all the others), first with water and soap, and then with acetone. After the preliminary examination, they were put into an ultrasonic tank with a hydrochloric-acid solution (HCl at 10% and 20%) for two hours. The subsequent observation showed no changes. For the third cleaning procedure, the same pieces were placed for an hour in the ultrasonic tank, in a solution of acetic acid (CH₃ COOH at 25%), in view of the possibility that the deposits were organic material; nevertheless, the deposits remained unchanged. Finally, the black spots were removed by placing the flakes in the oven for half an hour with temperatures ranging between 400°C and 500°C.

If this alteration in the form of a black spots appeared on the surface of an active edge of an archaeological tool, it would mask the microwear traces, and thereby make microscopic functional analysis impossible. The flint surface usually changed colour when temperatures reached between 200°C and 300°C. The black basque flint became clearer, as the temperatures increased. With temperatures of above 800°C, the pieces became light grey. The opposite happened to the grey flint from the harrow thrasher, which darkened during the heating process until turning completely black on the surface. However, the negatives of the thermal extractions became lighter, almost white, and the same happened to the interior of the flake. The light brown flint from Dordogne became more opaque and darker, but always within the brown range (brown/grey). Among the San Quintí flints, a grey and a red variant were distinguishable. The grey pieces lightened almost to white, while the red ones turned red-rose or purple during the heating.

When flints heated at temperatures of 800°C left the oven, their surfaces were completely red, and then, during the cooling process, stabilized in the above stated tones.

Fractures

Another common alteration of thermally treated pieces was the occurrence of fractures. Diverse fractures could be observed on six of the flakes placed in the experimental hearths. Four of these flakes were located in the central zone and the other two in the peripheral zone. Most (four) were made with flint from Sant Quintí de Mediona and two were located in the central zone. This flint, as stated previously, has a good quantity of crystallization arranged in bands crossing the entire piece. It is possible that these crystallization planes caused the fractures. However, in the laboratory hearth the Dordogne flint was more fragile. The other two fractured pieces included one made from the basque flint and one from the Dordogne flint.

The fractures usually had smooth surfaces and crossed the pieces vertically, but smooth-surface fractures also crossed the piece in an oblique direction, and rugged surface fractures with feathered edges were visible.

The oven experimentation with the three varieties of flint produced the same variability of fractures, apparently related to the size of the piece. The Dordogne flint started fracturing at a low temperature (the first fragments usually began to detach at 250-300°C), but sometimes thin or small pieces withstood higher temperatures without fracturing.
An important factor in the thermal alteration of the flint was the way of heating the flake. A sudden increase of temperature produced certain phenomena, while a slow and gradual heating produced others. For example, a large piece (15x12x10) of Sant Quintí flint was placed in the oven preheated to a temperature of 400°C, and in ten minutes several fragments of different sizes and shapes had detached. On the other hand, a small flake (4 x 3 x 0.7) of the same flint placed in the oven and gradually heated endured high temperatures (600-700°C) without fracturing (only scales, fissures and thermal extractions occurred).

Fractured pieces are difficult to analyse for microwear. If we can recognize microwear traces on the edges of the fragments and infer which material was worked, or identify the working action, then the interpretation of the entire tool depends on the possibility of refitting all the fragments together, i.e. knowing how the tool was used, how it was handled, whether it was hafted or not, etc.

Thermal extractions

This kind of alteration is frequently observed on thermally altered pieces. Thermal extractions are the negatives of small flakes or fragments which detach during the heating process. These have spherical or oval shapes. The negative surfaces can be both smooth or rough, but are usually bright (thermal gloss) (fig. 2). Sometimes these thermal extractions are shallow and wide with rough, bright surfaces and do not have a definite shape (i.e. not spherical).

In our experimental series, eight thermal extractions of the former type could be observed. Most of these (5) were located on the ventral face, which had been in contact with the soil surface. These alterations could destroy all or part of the microwear traces, if they occurred along the active edge. However, they usually appeared on the central part of the flake surfaces.

Scales and fissures

Other thermal alterations observed in the experimental collection were scales and surface fissures. Scales (fig. 3) are macroscopic alterations with different sizes and shapes and variable deepness, observable on the surfaces of burnt pieces. Curvilinear scales were the
more frequent. When well developed, these scales could be detached from the flake and in these cases constituted thermal extractions.

As the scales did not detach a portion of the flint surface, they did not affect the recognition of microwear traces.

Fissures are fractures located on the flint surface, usually microscopic, produced by thermal action. These may be either thin and shallow or wide and deep (fig. 4). They may be isolated or, when the alteration is more intense, appear in groups of many fissures, thus forming a grid that covers the flint surface (resembling "mud cracks").

Fissures can affect the edge surface where the microwear traces are located. However, it is important to note that fissures appear more easily in zones where micropolish has not developed. It is possible that surfaces with micropolish have a different structure producing a highest resistance to this kind of alterations. Thus, if only fissures are caused by the heating process, a cracked surface will be observed, but maintaining an identifiable micropolish.

**Thermal gloss**

This kind of alteration was first described by F. Bordes in 1969, concerning solutrean pieces. This alteration (typical of flint objects subjected to heat) has a bright gloss with a slightly greasy appearance. The extractions, both due to retouching or fractures, contrasts with the matte texture of the flint surface. We have observed this gloss, or greasy shine, of the thermal extractions, as well in the negatives as in the internal face of detached flakes.

Two flakes from the experimental hearths showed another type of gloss that covers almost the entire surface of the piece. This gloss is bright with a pronounced greasy sheen. When observed under the metallographic microscope, a silica dissolution appeared to have developed on the flint surface, in the form of a structural change —the surface was extremely bright and smooth, with some holes and grooves, and had the pecked appearance of an old mirror (fig. 5). In this case, it was not possible to recognize the microwear traces.

Flakes treated in the laboratory oven showed this alteration only on the negatives of the thermal extractions or on the fractured surfaces. Some pieces of the Sant Quintí flint subjected
to heat were then retouched, and this gloss could be observed on those which had reached temperatures higher than 300°C.

**Patina**

At the moment, for descriptive purposes, we shall use the term “patina” to denote alterations of the flint surface in the form of a thin translucent veil which seem to be caused by chemical action. Two of the three flakes from the central zone of the experimental hearths showed a pronounced patina. This was a brown or white colouration which, under the metallographic microscope, appeared milky white (when well developed) or translucent (when less developed). The patina was brighter and smoother than experimentally induced patinas produced with caustic soda (T. Rodón pers. comm.).

One of the experimental flakes (Dordogne flint) showed a well-developed patina covering the entire surface, with the only exception of a dorsal scar where the patina was almost absent (in some zones we could detect only a change in colour). This scar had been used to scrape wood. When this zone was observed under the light microscope, it became evident that microwear polish had remained on the parts of the microtopography where the patina was absent. Moreover, where the patina was slightly developed, it had just started to cover the micropolish, so that the polish could still be recognized under the patina (fig. 6).

Flakes treated into the laboratory oven showed the same kind of patina as flakes from the experimental open-air hearths. This patina is light brown or white and, when examined under the light microscope, it appears milky white, smooth, compact and bright (when well developed).

From the observation of patinated flakes from the experimental hearths, we have deduced, as previously stated, that surfaces with microwear polishes were more resistant to this kind of alteration than the unused surfaces of the tools. To test this hypothesis, we selected a flake of the Sant Quintí red flint which had already been treated in one of the experimental hearths. It had a well-developed microwear polish and only slight evidence of a patina. This piece was then heated in the laboratory oven, with a slow and gradual temperature. It was removed at intervals, depending on the temperature, in order to observe and document the alteration process.

A patina began to affect the flint surface when temperatures reached 500-550°C. At this point the patina covered 5 to 10% of both faces of the flake, mainly formed on the dorsal ridges and edges. At the active-edge zone, where micropolish was most developed, the patina was absent. At 670°C, the patina had covered up to 40% of the flake surface. A portion of the flake with micropolish had been affected by a thermal extraction; the negative surface of this thermal extraction showed a bright, greasy appearance. The micropolish looked more rugged and had developed a metallic gloss. Portions of the microtopography where micropolish was most developed, began to be covered by the patina.

To test the relationship between presence of micropolish and patina formation, we placed 11 grey flint pieces from the harrow thrasher in the oven. These flakes had well-developed and widely extended microwear polish (fig. 7), and were then exposed to thermal actions at different temperatures up to 800°C. Between 400 and 500°C, the patina began to affect unpolished zones and the colour changed to darker tones, making the polish brighter and clearly visible. At 650°C, the patina covered the entire unpolished surface, and the zone with micropolish was even easier to identify (fig. 8). The flint surface showed different scales and fissures. When the temperature increased to 700-800°C, the micropolish suffered multiple
fissures, showing a cracked appearance (craquelé) (figs. 9 and 10). The patina now affected the polished zone, mainly the lower parts of the microtopography, where the micropolish was less developed.

M. E. Mansur (1983, 1986) was the first to observe and describe the way in which the white patina may affect flint surfaces with different intensity according to the presence or absence of micropolish. She suggested that surfaces with well-developed micropolish are more resistant to chemical attacks, and consequently are altered more slowly than is the natural flint opal. The main reason for this phenomenon is the different structure of these surfaces —more compact and more regular in the case of micropolish and stepped and lobular in the case of cryptocrystalline surfaces. In the first case, the surface area exposed to any kind of attack is less extensive than in the second one.

Weight losses

Parallel to these experiments, thermally altered pieces were checked for weight loss during the heating process. Pieces were weighed before and after thermal treatment.

Figure 6.—White patina produced by thermal alteration, at an early stage of development (100X).

Figure 7.—Micropolish on a thrasher flake (100X).

Figure 8.—Micropolish on the same flake as number 7, after heat treatment up to 600°C (100X).

Figure 9.—Quatered micropolish on a thrasher piece, after heat treatment up to 800°C (100X).
In the case of buried pieces, no weight changes were detected. In surface pieces, when the flakes were fractured or showed thermal extractions, there were obvious weight losses related to losses in mass. Consequently these flakes were not taken into account for the weight-loss study. Weight after treatment was recorded only in cases where all the fragments had been recovered and the original piece could be completely reconstructed. As a result, it was possible to observe minimal weight losses, ranging between 0.01 and 0.03 grs. This is true for both laboratory and field experiments.

**MICROWEAR TRACES IDENTIFICATION**

The six buried pieces (3-5 cm) showed no alterations typical of thermally treated pieces, such as colour changes, fractures, fissures or brightness. Microwear traces did not undergo any alterations either. The nature of the soil where the pieces were buried (in this case compact humus) were possibly a factor in this stability. We assume that the capacity of the sediment to affect thermal process depends on its properties as a heat transmitter. To test this hypothesis, new experiments with different types of soil (i.e. sand, gravel, etc.) will have to be performed. In another experiment (yet unpublished) with a shell and small pebble-soil (shell-midden) rhyolite pieces buried at the same depth suffered a colour change.

After heat treatment, half the other used flakes (14) placed in experimental hearths retained identifiable microwear polishes (figs. 11 and 12). Some of these micropolishes showed minor alterations, such as fissures or small irregular portions. In any case, different micropolishes seemed to be more-or-less resistant to thermal alterations, due perhaps to their structural differences. Thus, bone micropolishes seemed to resist thermal alterations better than did wood micropolish, and both resisted better than polishes produced by contact with soft material (i.e. meat, fat, sinew, etc.). On pieces used to work soft materials, analysis after heating showed micropolishes that were brighter but less extensive than before treatment. Bone micropolish seemed also to show a little change in bright intensity.

**DISCUSSION**

Lithic surfaces are modified in different ways by thermal processes, thus affecting also the results of microwear analysis. Depending on the kind of alteration undergone by the tool surface, microwear evidence can be hidden, making microwear analysis impossible.

The experimental results presented in this paper show that 50% of the flakes which had undergone contact with fire were still suitable for microwear analysis. Micropolish on these flakes, although showing some minor microscopic changes, could still be identified. However, these results allow no generalization on polish survival ratios, as it is possible that these vary in other cases. A new series of experiments is now required, to test the hypothesis raised by the
present analysis. In addition, a SEM, could enable a more accurate examination of the micropolish structures and the nature of thermal alterations (micro-fissures and micro-irregularities).

Most of the alterations observed had no relationship with the position of the lithic pieces in the hearths (central or peripheral zone), given that changes occurred on pieces in both zones. However, the sort of alteration that we call patina is more frequent on pieces placed at the central zone of the hearth, the place where the temperatures reached the highest values. It is probable that the nature of the alteration varies according to the causal agent (fire, live coal, temperature, fuel used, etc.). Further experimental programs, monitoring all these variables are needed to clarify these points.

The fact that certain types of micropolish were more resistant than others to specific alterations, such as patina, may be related to the particular structure of each micropolish. Thus, bone micropolish seems to be stronger than wood or polishes on soft material. It is also possible that the stage of development of micropolish is a relevant factor in determining micropolish resistance: a well developed micropolish has a compact structure, which is more resistant than a less developed micropolish.

The different behaviour of the polished zones, as opposed to unpolished parts of the microsurface, is also evident. This observation is clear in the case of the thrasher pieces, which show an extensive well-developed micropolish. This differential endurance of the various classes of micropolish is also evident when these are affected by chemical agents (Plisson 1985).

As a preliminary conclusion from this experimental analysis, we should state that microwear analysis is possible on thermally altered pieces. Consequently, archaeological materials showing traces of fire action should not be rejected, considering the difficulties inherent to this kind of study. A good example of microwear analysis is that carried out in 1990 by M. E. Mansur (n.d.). In a report concerning the lithic assemblage of the Lapa do Boque (Brazil), she analysed 22 thermally altered flint pieces. In 14 cases it was impossible to determine the accomplished action or the worked material; in six cases it was possible to determine the action and the worked material; and in two cases, only the action or tool kinematics could be determined.
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