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The use of sequential experiments and SEM in documenting stone tool microwear

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ABSTRACT

This paper focuses on a methodological proposal for documenting and describing the wear processes on lithic artefacts based on two main aspects: sequential experiments and systematic SEM (scanning electron microscope) analysis.

The procedures followed during experimentation, sample preparation and microscopic observation are presented, and a selection of our experimental results is described in detail and discussed.

We argue that sequential experiments allow stone tool wear to be closely monitored during use, and that this information is crucial in understanding microwear formation processes as well as in interpreting the traces observed on archaeological materials.

1. Introduction

Use-wear analysis is an interpretive discipline that still retains a considerable dose of subjectivity in the inferences drawn, and is strongly dependent on the experience and expertise of the analysts (Grace, 1996; Yamada, 1993, 2000; Stevens et al., 2010). Several approaches to checking for and reducing this subjectivity have been described and assessed, notably blind testing (Bamforth, 1988; Bamforth et al., 1990; Gendel and Pirnay, 1982; Grace et al., 1988; Hurcombe, 1988; Keeley and Newcomer, 1977; Moss, 1987; Newcomer and Keeley, 1979; Newcomer et al., 1986, 1988; Odell and Odell-Vereecken, 1980; Rots et al., 2006; Shea, 1987; Shea and Klenck, 1993; Unrath et al., 1986) and the quantification of use-wear based on different image analyses and surface metrology (among others, Bamforth, 1988; Evans and Donahue, 2008; Fullagar, 1991; González and Ibáñez, 2003; Grace, 1989; Lerner, 2007a,b; Rees et al., 1991; Stemp and Stemp, 2001, 2003; Stemp et al., 2013; Stevens et al., 2010).

Like these proposals and others offered in this volume, we argue that an improved understanding of the processes under study (wear mechanisms) and of the procedures and methods for observing those processes is crucial to the advancement of functional analyses. In this respect, we believe that the close monitoring of experiments is essential.

In archaeology, experiments are useful for validating or rejecting hypotheses resulting from the study of archaeological materials, and are a way of exploring processes and building reference patterns. All experiments undertaken must respond appropriately to the hypothesis being tested, and the control of variables and the analysis of results are crucial components of their design. Use-wear studies have traditionally been based on wide-sweeping experimental programmes, including replicative (reproducing activities hypothetically analogous to those in the past; e.g. Keeley, 1980; Semenov, 1964), analytic (studying in detail how dependent and independent variables are related; e.g. González and Ibáñez, 1994; Gutiérrez, 1996; Tringham et al., 1974; Vaughan, 1985) and problem-oriented experiments (focussing on very specific activities, on interferences between production and use traces, on postdepositional surface modifications, etc.; e.g. Anderson et al., 2006; Burroni et al., 2002; Knutsson and Lindé, 1990; Levi Sala, 1986, 1996: Plisson and Mauger, 1988; Rots, 2010; Shea and Klenck, 1993; Vergès and Ollé, 2011). The traditional procedure for recording the results in use-wear studies has been to analyse the surfaces after the experiment and try to infer the phenomena that produced the modifications and the role played by each variable in the final result. In some cases an indirect control process has been employed, in which worn surfaces were compared with fresh fragments of rock taken from the same nodule as the experimental tool. This is a valid method for obtaining reference collections with which to identify use-wear traces by analogy. However, it has clear

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limitations for studying the mechanisms of wear origin because it provides no direct data on the different phases of the process, on the appearance of the used edge at specific points in time, and any modifications during the process must be deduced from the final appearance of the surface.

The processual documentation of wear processes has been proposed by many authors (e.g. Brink, 1978; González and Ibáñez, 1994; Gutiérrez, 1996; Tringham et al., 1974; Vaughan, 1985), and others have suggested its suitability for the progressive development of polish for different purposes (Fullagar, 1991; Lerner, 2007a,b; Stemp and Stemp, 2003), but the idea of including detailed imaging has only occasionally been addressed in the literature, most notably by Yamada (1993, 2000). Following up on these existing works, we propose studying the mechanism of polish formation from the progressive development of a worn surface. In other words, we have carried out sequential experiments that allow us to observe, in detail, the modification processes at work on the contact surface of lithic tools during their use. In these experiments, a series of points on the edge were monitored by means of SEM images both before the work process began and at intervals throughout the study (Márquez et al., 2001; Ollé, 2003; Ollé and Vergès, 2008; Vergès, 2003).

In this paper we describe what we call 'sequential experiments' — a means of tracing the progressive modification of a tool's surface at single points throughout the use process. We illustrate the standard procedures for recording use modifications with the aim of providing a basis for further improvements in description, understanding and quantification of use-wear traces necessary for making more explicit inferences. Some of the results of our experimental programme have been chosen to illustrate the outcomes of the sequential control of processes using SEM analysis.

2. Materials and method

2.1. The experiments

The experimental samples used in this study come from an extensive, ongoing programme (Ollé, 2003; Vergès, 2003), which includes: a) traditional, b) controlled and c) sequential experiments. In the first group, the implements are microscopically analysed after being exposed to the studied phenomenon (use, production technique, post-depositional process, etc.), which allows us to describe its effects on the tool's surface but not to unequivocally correlate those effects with the action performed. This is achieved only with a designated control, which allows a direct comparison of the points of interest on the tool's surface before and after the experiment. Finally, sequential experiments allow the process to be documented at desired intervals. When studying wear processes, this sequential monitoring allows the subsequent phases of surface modification to be monitored and the evolution of the micro-relief to be precisely tracked throughout the course of the activity performed. So, in addition to yielding data on the basis of which hypotheses can be posed, these sequences represent a means of validating or rejecting hypotheses related to use-wear evidence.

The experiments considered in this article are conducted with tools made of various raw materials and actions on different worked materials in order to illustrate the feasibility and adaptability of the procedures we have established (Table 1). As shown, the use-time in these experiments only occasionally exceeds 30 min, as the guiding goal of our experiments is not to produce really well developed traces, but rather to determine the useful life of the object (the period during which the tool is effective) and the time usually required to complete the activities tested.

2.2. Sequential control

In the sequential experiments, we systematically recorded the development of use-wear traces at several points in order to document the variability of the effects of a given action on the active edge of a tool as closely as possible.

The experimental tools were analysed before use and then at specific intervals during their use. Although initially we programmed five-minute intervals, in some cases these were subsequently modified according to the pace of use-wear development, which depends on the lithic raw materials, the actions performed and the worked materials. That is, we adapted the rhythm of control depending on how wear was developing, reducing the intervals in experiments when the edges showed rapid change and increasing them when modifications were slower.

To document the initial state of the surface of the tools, the initial observation of a selection of points of interest is generally considered sufficient. But this method has several drawbacks: firstly, use-wear does not always develop on the previously selected points along the active edge; secondly, and more importantly, microscopic edge damage occurs as the action is performed, effectively removing many of the control points during the first minutes of work. To overcome these constraints, we used high definition casts of the fresh edges. We therefore selected our control points after the first interval of work had been completed and then compared their appearance with the cast of the fresh edge. In this way we managed to increase the number of sequences that survived over the course of several stages.

Furthermore, in case of a total loss of the control points due to severe edge microflaking, the casts allow the original appearance of any point on the active edge being modified to be checked after use.

Table 1
Main variables of the experiments illustrated in this paper: experiment reference; raw material (SB: Boxgrove flint; SH: Ain Hanech flint; SI: Isernia Flint; SMP: Monte Poggiolo flint; OL; Lipari obsidian; QTA. Atapuerca quartzite); worked material; horizontal delineation (convex: cx; concave: cc; sinuous: sin; uniangular: 1a); profile delineation (straight: str; incurved: inc); edge shaping (shaped: shp; not shaped: nshp); edge angle; angle of work; motion (longitudinal: long; transverse: trans; unidirectional: unid; bidirectional: bid); generic action; time of use (minutes).

Exp. ref.	Raw material	Worked material	Active edge				Action			
			Horiz. del.	Prof. del.	Edge shap.	Edge α	α of work	Motion	Action	Time
SBMG1-BP1	SB	Flesh and bone; *Cervus elpahus*	cc	str	nshap	45	75–90	Long/unid	Cutting/defleshing	15
SHC03	SH	Fresh skin, flesh; *Vulpes vulpes*	cx	inc	nshap	40	90	Long/unid	Cutting/skinning & deflesging	10 × 3
SIE06-2	SI	Dry wood; *Buxus sempervirens*	cx	str	nshap	55	75	Trans/unidir	Scraping (negative)	10 × 3
SMP28 (H)	SMP	Green and dry grass; *Brachypodium phoenicoides*	1a (str)	str (inc)	nshap	40	75–90	Long/unid	Cutting	10 × 3
OLCE01	OL	Dry grass; *Brachypodium phoenicoides*	cx	str	nshap	30	75–90	Long/unid	Cutting	5 × 3
QTAF02-1	QTA	Green wood; *Pinus halepensis*	cx	inc	nshap	50	75–90	Long/bid	Sawing	10 × 3

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