Journal of Archaeological Science xxx (2013) 1–14

Contents lists available at SciVerse ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Scanning Electron and Optical Light Microscopy: two complementary approaches for the understanding and interpretation of usewear and residues on stone tools

Antony Borel[a,b,*], Andreu Ollé[c,d], Josep Maria Vergès[c,d], Robert Sala[d,c]

[a] Département de Préhistoire, Muséum national d'Histoire naturelle, UMR 7194-CNRS, 1 rue René Panhard, 75013 Paris, France
[b] Institute of Archaeological Sciences, Eötvös Loránd University, Múzeum krt. 4/b, H-1088 Budapest, Hungary
[c] Institut de Paleoecologia Humana i Evolució Social, C/ Marcel·lí Domingo s/n (Edifici W3), Campus Sescelades, 43007 Tarragona, Spain
[d] Àrea de Prehistòria, Universitat Rovira i Virgili, Fac. de Lletres, Av. Catalunya 35, 43002 Tarragona, Spain

ARTICLE INFO

Article history:
Received 11 December 2012
Received in revised form
18 June 2013
Accepted 18 June 2013

Keywords:
Scanning Electron Microscope
Optical Light Microscope
Usewear
Residues
Tool use
Function

ABSTRACT

Usewear analysis is now well established as a powerful means by which to identify the function of stone tools excavated from archaeological sites. However, one of the main issues for usewear analysts is still to provide quantified analyses and interpretations. Several attempts have yielded promising results but have not, as of yet, been widely applied and usewear analyses are still mainly performed using either Scanning Electron Microscopy (SEM) or Optical Light Microscopy (OLM). The systematic comparison of micrographs from both types of microscope presented here enables us to discuss the advantages and disadvantages of each system. Furthermore, it shows beginners or experts using only one type of microscope that these techniques are complementary and should be considered as such. It also represents a significant basis for developing the implementation of quantitative methods for usewear analysis with SEM and OLM.

1. Introduction

Since the translation of Semenov's book (1964), usewear analysis has been extensively and internationally developed and applied in order to determine prehistoric tool functions. However, numerous controversies and debates arose concerning the reliability and repeatability of the method (e.g. Bamforth, 1988; Evans, 2013; Hurcombe, 1988; Moss, 1987; Newcomer et al., 1986; Odell and Odell-Vereecken, 1980; Rots et al., 2006) and the technique to be used to observe traces (e.g. Keeley, 1980; Mansur-Franchomme, 1983; Odell, 2004; Odell and Odell-Vereecken, 1980; Serizawa et al., 1982; Tringham et al., 1974; Young and Bamforth, 1990). The formation process of the traces was also extensively debated (Anderson-Gerfaud, 1981, 1982; Dauvois, 1976; Del Bene, 1979; Diamond, 1979; Fullagar, 1991; Kamminga, 1979; Mansur-Franchomme, 1983; Meeks et al., 1982; Ollé and Vergès, 2008; Unger-Hamilton, 1983, 1984; Witthoft, 1955, 1967; Yamada, 1993). Usewear analysis is now well established as a powerful technique for gaining a better understanding of how tools were used in the past but the main difficulty for usewear analysts is still to propose quantified usewear analyses and interpretations. Several attempts to do so are promising but these are still far from being generalized or generalizable (Álvarez et al., 2012; Anderson et al., 2006; Evans and Donahue, 2005, 2008; Evans and Macdonald, 2011; Faulks et al., 2011; González-Urquijo and Ibáñez-Estévez, 2003; Ibáñez et al., 2013; Kimball et al., 1995, 2013; Lerner, 2007a, b; 2009; Lerner et al., 2007, 2010; Macdonald, 2013; Nunziante Cesaro and Lemorini, 2011; Stemp, 2013; Stemp and Chung, 2011; Stemp and Stemp, 2001, 2003; Stemp et al., 2009, 2010, 2013; Stevens et al., 2010). Optical light and scanning electron microscopes are still the main techniques used for usewear interpretation among analysts (e.g. Borel, 2012; Hardy and Moncel, 2011; Márquez et al., 2001; Pawlik and Thissen, 2011; Peretto et al., 1998; Sahnouni et al., 2013; Vergès and Ollé, 2011). Moreover, they are often necessary for quantitative studies as they provide the basis for image analysis systems illustrations or visual documentation for EDX/EDS (Energy-dispersive X-ray spectroscopy) map or profilometry, for example. So far, no systematic comparisons of micrographs issued from these two

* Corresponding author. Institute of Archaeological Sciences, Eötvös Loránd University, Múzeumkrt. 4/b, H-1088 Budapest, Hungary. Tel.: +36 70 581 8415.
E-mail address: antony.borel@gmail.com (A. Borel).

0305-4403/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jas.2013.06.031

techniques have been published concerning usewear and residue analysis, despite the fact that the interpretation of these images requires different approaches.

1.1. Usewear interpretation

The identification of the action carried out with a tool (i.e. worked material and movement) requires the description of the nature, direction and distribution of striations, micro-fractures and micropolish on every face of the artefact (Keeley, 1980; Semenov, 1964; Vaughan, 1985; Yamada and Sawada, 1993). The history of the artefact since it was unearthed at the excavation until the moment of usewear analysis should also be taken into account. This indicates whether traces are due to use or to natural factors and allows for the detailed interpretation of use when traces are sufficiently developed.

For each assemblage, several specific traces can be due to the history of the site and excavations. Various other variables are difficult to control or test and can have a direct or indirect influence on the development of microwear: type of raw material and raw material grain size, hardness of the worked material, presence of abrasive particles, duration of effective contact, movement, direction of the cutting edge in relation to the internal structure of the worked material, etc. (e.g. Lerner et al., 2007; Vaughan, 1985). Furthermore, the experience of the analyst is an important factor because it remains the only way to limit the subjectivity of the traces identification as, as stated above, one of the main problems of usewear analysis is the quantification of traces (Grace, 1996). In order to understand the images obtained from Scanning Electron Microscopy (SEM) and from Optical Light Microscopy (OLM) and to develop a quantitative analytical method based on them, it is important to have an accurate comprehension of what can be observed on both types of micrographs.

1.2. Residue identification

Residues are also suitable elements for inferring past tool use. These are fragments of the worked material which remained stuck to the surface of the tool (Fullagar, 2006; Haslam et al., 2006). Residue morphology can be observed at different magnifications depending on their size and nature. The chemical elemental analysis of these residues can be essential for their identification (Jahren et al., 1997). They are useful for identifying worked materials (Crowther and Haslam, 2007; Hardy and Garufi, 1998; Hardy and Moncel, 2011; Lombard and Wadley, 2007; Wadley and Lombard, 2007; Wadley et al., 2004) but also for the documentation of hafted artefacts (Barton et al., 2009; Boëda et al., 1996; Dinnis et al., 2009; Holdaway, 1996; Rots, 2010; Rots and Williamson, 2004). Therefore, it is essential to describe their aspect with SEM and OLM (Monnier et al., 2012).

1.3. How to observe and interpret these use traces

Usewear and residue analyses are complementary and, when combined, lead to a more accurate interpretation of tool use (Hardy, 2010; Lombard, 2005; Rots and Williamson, 2004; Sobolik, 1996). These interpretations are largely dependent on the experience of the observer and particularly on his/her ability to understand the images portrayed through the microscope. The images from SEM and OLM represent two different worlds and training and practice are required in order to become familiar with both techniques. The aim of this paper is to demonstrate to beginners in use-wear analysis the differences between these approaches using a comparison of SEM and OLM micrographs. This comparison will also be useful for analysts who are proficient in one of these techniques, but not the other. Apart from Yamada and Sawada (1993; see also Yamada, 2000) who compared both techniques from the point of view of polish formation and Sussman (1985) for quartz, no such systematic comparison had been carried out before. This comparison also aims to help researchers who wish to develop an image analysis system compatible with both types of images (Álvarez et al., 2012; Lerner, 2007a, b; Lerner et al., 2007). To attain these goals, we do not just present micrographs using the commonly used extended focus system (i.e. a system which stitches together the in-focus area of several pictures of the same point of interest in a single image). We focus rather on the analysis of images which have not been modified by these systems. This is essential to gain an insight into the observation process and not to limit this study to a mere comparison between final images. Therefore, this work focuses on the advantages and disadvantages of each system and assesses the complementarity of both types of microscope for usewear and residue studies.

2. Material and methods

2.1. Samples and observation context

Observations were carried out in the framework of a larger project related to the study of the form and function of the early Holocene stone pieces from the Song Terus cave (Java, Indonesia) dated from 11,200 $\pm$ 600 to 5770 $\pm$ 60 years BP (Sémah et al., 2004). This project integrated the morphological description of the artefacts, usewear and residue analysis and geometric morphometrics (for full details see Borel, 2012; see also Borel et al., 2013, in press). The experimental artefacts presented here were manufactured during this project to create a reference set for usewear analysis using local materials (bamboo, coconut, coconut trunk, acacia, pandanus, shell, skin, meat, bone, sinews) from the surrounding areas of Song Terus cave and potentially available during the early Holocene. Thirty four actions (involving sawing, scraping, drilling, cutting or striking) were performed with flakes made of local chert and each action was conducted with two different flakes. One hundred and four archaeological artefacts were selected for usewear and residue analysis in this project. Residues and usewear traces were observed on each experimental and archaeological artefact before and after cleaning. The cleaning procedure consisted of an ultrasonic bath with neutral phosphate-free detergent (Derquim® LM 02) for ten minutes followed by an ultrasonic bath with acetone for two minutes following the protocol of Ollé and Vergès (2008) and Vergès and Ollé (2011). Sample size was minimized for the study presented in this paper due to limited access to the SEM and the cost and amount of time involved in such detailed and rigorous observation and comparison of both SEM and OLM. Therefore, 14 chert artefacts were observed with SEM and OLM: 9 archaeological artefacts from Song Terus cave and 5 experimental artefacts made by the authors (Borel, 2012). This sample proved to be sufficient to present a comparison of most of the fundamental features of usewear analysis (i.e. fractures, scars, polishes, striations and residues).

The compared micrographs were taken with equivalent magnifications with both types of microscope. The correlation between the magnification values used with each microscope was based on previous calibration conducted with samples of known size and takes account of the field of view (or horizontal field width) observed on the acquisition systems. As magnification can vary with the type of screen and system used to capture the pictures the number indicated for the magnification of one sample point of interest can vary between SEM and OLM. Where both scale and