archaeometry

Archaeometry **58**, 6 (2016) 1038–1046 doi: 10.1111/arcm.12210

QUANTIFYING CEREAL-REAPING MICROWEAR ON FLINT TOOLS: AN EXPERIMENTAL APPROACH*

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From the earliest Neolithic in the Near East to the last Chalcolithic cultures in Western Europe, certain flint tools have been used as sickles to harvest cereals. Such harvesting tools can be identified through use-wear analyses, because the cutting of herbaceous plants produces specific wear-traces on the working edge of flint blades. The aim of this work is to explore harvesting-driven microwear variability and, more particularly, intensity of use as a governing factor. To achieve this objective, an experiment was designed consisting in the production of flint replicas to be used as harvesting tools, in various controlled conditions. A simple, cost-effective method of quantifying wear-traces by measuring polish extent is developed, requiring only classical use-wear observation equipment. The polish extent shows monotonic correlation with the amount of work, expressed either in terms of time or as the quantity of cereals harvested. Polish extent measurement is therefore proposed as a reliable and powerful descriptor of use intensity.

KEYWORDS: MICROWEAR ANALYSIS, EXPERIMENTAL DESIGN, CEREAL HARVESTING, FLINT SICKLES, MICROWEAR QUANTIFICATION

INTRODUCTION

It is now well established that harvesting cereals with flint sickles produces specific wear-traces on the working edge of blades. This specific use-wear is often visible to the naked eye as a gloss along the cutting edge, so that prehistoric harvesting tools have long been identified (Curwen 1930). Later, in the mid-20th century, use-wear analysis pioneer Sergei Semenov conducted experiments on cereal-harvesting and made the first microscopic observations of this glossy polish (Semenov 1964). Analysis focusing on herbaceous plant microwear traces developed in the 1980s (Korobkova 1981; Anderson-Gerfaud 1983, 1988; Anderson 1992; Unger-Hamilton 1985, 1988; van Gijn 1989; Juel Jensen 1995; Gassin 1996; Clemente and Gibaja 1998; Gibaja Bao 2002). These experimental studies attempt to differentiate cereal microwear traces from other herbaceous plants, on the basis of criteria such as brightness, microtopography or striation types and quantity.

Time and intensity of use are consensually identified as important factors impacting microwear traces (e.g., Vaughan 1985; van Gijn 1989; Clemente and Gibaja 1995; Yamada 2000; Gibaja Bao 2002), but there is still vigorous debate about plant harvesting use-wear quantification (Goodale *et al*. 2010, 2012; Vardi *et al*. 2010, 2012; Stemp *et al*. 2012). The dimension of microwear trace coverage and its transversal extent from the working edge of the sickle blade have been considered to provide evidence of tool use intensity (Rosen and Shugar 2007), but use-wear coverage

*Received 24 December 2013; accepted 16 June 2015

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morphology is also described as the result of different hafting solutions (Cauvin 1973, 1983; Stordeur 1987; Olzewski 1994; Copeland and Verhoeven 1996; Yamada 2000, 2003).

Previous studies have quantified stone-tool microwear by using various state-of-the-art methods, including interferometry (Dumont 1982), atomic force microscopy (Kimball *et al*. 1995), confocal microscopy (Evans and Donahue 2008) or laser profilometry (Stemp and Stemp 2001; Stemp *et al*. 2009). Although these methods have led to better knowledge of lithic use-wear, they all require specific equipment rarely available in archaeological laboratories, and not easily transportable for field missions.

The purpose of this work is to explore variability in the microwear produced by harvesting, and the impact of intensity of use on the polish extent. To achieve this objective, an experiment is designed using flint replicas as harvesting tools, in various controlled conditions. The goal is to identify a simple descriptor of microwear intensity, the validity of which can be statistically checked. Although numerous studies have focused on use-wear quantification, none of them have provided a simple quantification method. Moreover, even if a causal link between the extent of the polish and the cereals harvesting intensity has been suggested for long time, it still required to be demonstrated with an appropriate quantification method.

MATERIALS AND METHODS

Experimental flint tools and experimental harvest design

During the Late Neolithic of north-western Europe, long blades were produced in large numbers by specialized craftsmen and generally distributed as 'daggers' (Pelegrin 2006). Microwear analyses have shown that these blades and daggers were used as daily task tools, often as sickles (Beugnier and Plisson 2004; Linton 2012). In North Alpine lake-dwelling collections, exceptional taphonomic conditions have allowed the preservation of Late Neolithic flint daggers still hafted in their organic matter handle (Bocquet 1974). The experimental tools are handmade replicas of Late Neolithic blades, and were all made from Upper Turonian flint from Grand-Pressigny, in the Loire Basin (France), known to have been used as source material for the production of long blades during the Late Neolithic. The purpose-built experimental tools were used as harvesting knives: some were hafted in a proximal wooden handle (Blades 5 and 25), but the majority of the blades were hand-held in a piece of leather (Blades 3, 20pc, 21pc, 22 and 24). The tools were always mounted with a single flint blade. Some of the blades were retouched before being used (Blades 3, 5, 20pc and 21pc) and others were used unretouched (Blades 25, 22 and 24). Over three seasons, an average of 10 participants took part in the experimental harvesting of fields of modern barley (*Hordeum vulgare*) and wheat (*Triticum æstivum*) in Burgundy (France). There was, of course, some variation in temperature and weather during this 3-year experiment, but the harvesting always took place when the cereals had reached maturity. To eliminate the effect of participant efficiency, each tool was used by at least three different participants. All the participants harvested the cereals stems at low level, near the ground, and the reaping motion was always longitudinal. The amount of cereal harvested was measured for each of the seven blades, used for different lengths of working time.

Analysing experimental use-wear from quantitative data

Prior to any measurement, experimental flints were gently cleaned to eliminate any remaining debris and micro-deposits resulting from the manipulation. Blades were washed with a very soft brush, using a mixture of soap and water, then rinsed and patted dry. When necessary, acetone was also used with cotton-tipped applicators.

Microwear is present on both faces of the blades but, as the upper face is marked by imprints of previous removals, retouch scars or edge damage, only the lower, more regular face was measured. Observations were made using a Leica® Mz16 stereomicroscope and a Leica® DM1000 reflected-light microscope. The stereomicroscope was equipped with coaxial illumination directly through the objective and mounted with a Leica® DFC320 camera. Sections of 2 mm in width were photographed at 5 mm intervals along the cutting edge (Fig. 1). The sum of the sections studied represents 40% of the total surface of interest. Microwear is measured as the maximum and minimum extent from the cutting edge reached by the compact pattern of polish, using the Leica® Application Suite with the Interactive Measurement Module, an image capture and analysis program (Fig. 2). The minimum extent may be equal to zero when the microwear has a loose, open pattern.

RESULTS

General microwear observations

Microwear traces observed on experimental tools are consistent with previous studies. The cutting edge becomes rounded during use and may be scarred (Fig. 3). These scars are

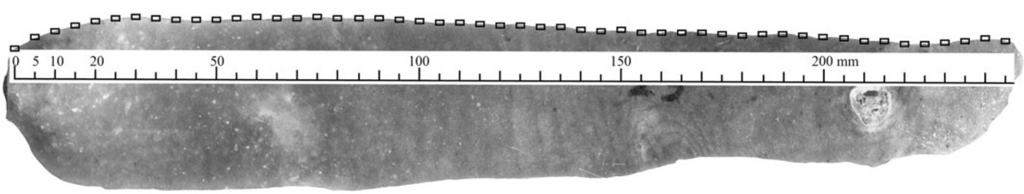

Figure 1 *The frame sampling strategy along the cutting edge of an experimental blade.*

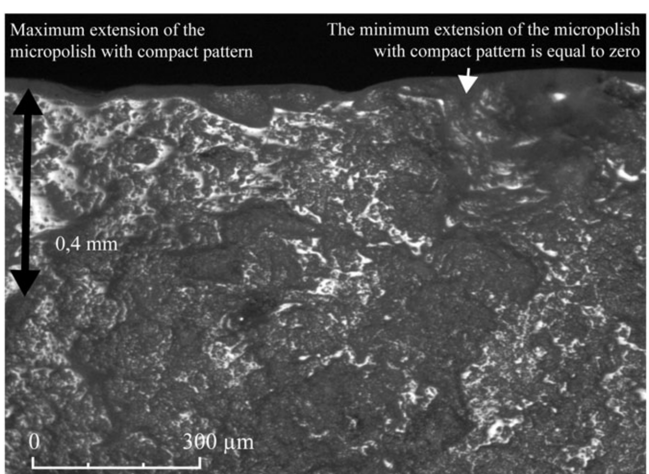

Figure 2 *The quantification method for minimum and maximum extent of polish with a compact pattern (Blade 25, 165 mm along the edge).*

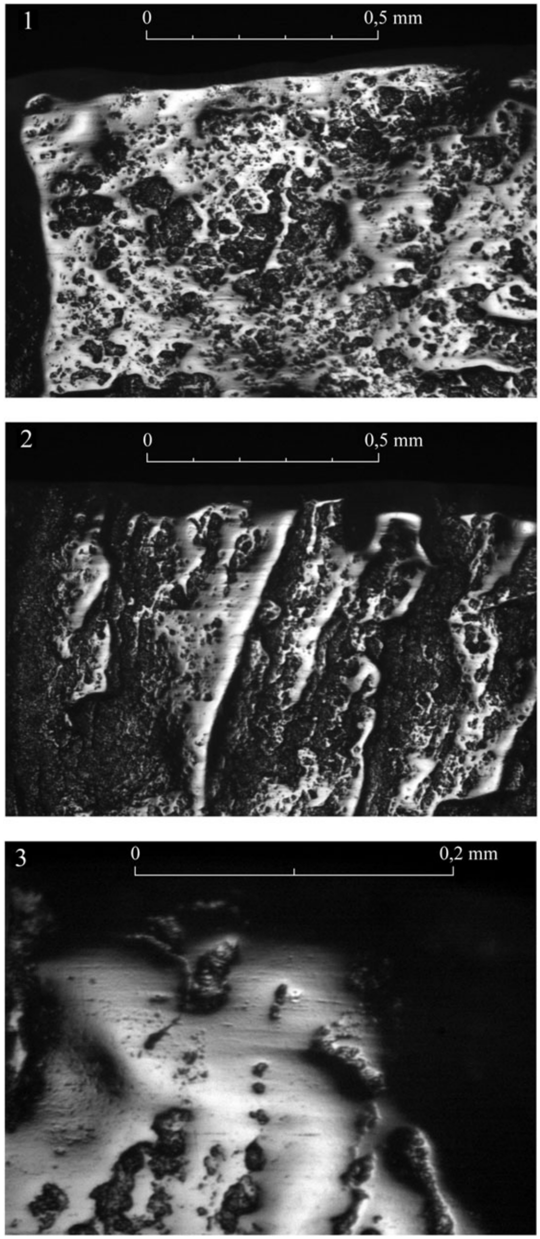

Figure 3 *An example of cereal-harvesting microwear on the cutting edge of an experimental blade after 265 min of use (Blade 3).*

usually bifacial or alternating, small and semi-circular, with feather termination, and their distribution is continuous along the cutting edge. Scars appear very early, at the beginning of the use process. The polish is domed, smooth and glossy, but also spotted, with many micropits. Both the glossy polish and the striations are parallel to the cutting edge or the direction of the cut.

Representing microwear distribution along the edge

The maximum and minimum polish extents along the cutting edge are examined as new quantitative attributes to describe microwear intensity. Micropolish is not distributed evenly along the edge (Fig. 4). At least for five (blades 3, 24, 20pc, 22 and 25) out of the seven specimens, pronounced wear-traces are mostly concentrated in the mesial section, probably as a result of the strong and frequent interaction of this part of the cutting edge with plant stems. This observation is particularly highlighted by the minimum extent of the polish. Wear-traces decrease or are absent towards the extremities of the blades. Several factors are expected to play a role in microwear distribution variability close to extremities; hafting technique is such a factor. The absence of polish on the proximal part of blades 20pc, 22 and 24 can easily be explained, as these areas must have been covered by the haft, the adhesive, or by the user's hand, if the blades were hand-held without protection.

Examining the blade with the longest working time, and the largest amount of cereal harvested (Fig. 4, blade 3), we can see empirically that it also has the greatest extent of polished area. By

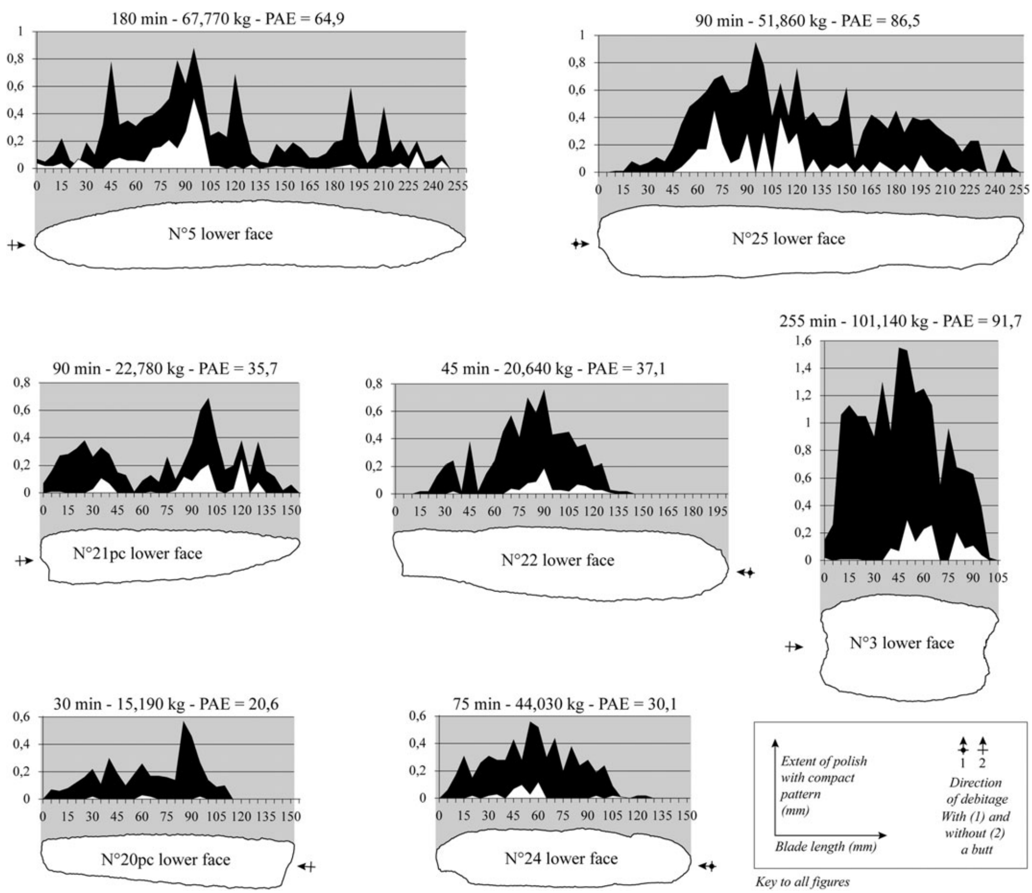

Figure 4 *The microwear distribution expressed as the maximum (in black) and minimum (in white) polish extent along the cutting edge. All graphs are at the same scale.*

contrast, the smallest extent of polished area can be seen on the blade with the shortest working time and the smallest number of cereal stems cut (Fig. 4, blade 20pc). Thus, the graphic representation in Figure 4 provides empirical evidence pointing to a link between use-wear extent, working time and number of cereal stems harvested.

Maximum polish extent distribution as a quantifiable descriptor of use intensity

The maximum polish extent is now aligned with the other experimental parameters, such as the total amount of cereal harvested and the working time. In order to test possible correlations, a new variable—the polish extent area, *PEA*—is defined as follows:

$$PEA = \sum_{i=1}^{n} ME_i \cdot SI,$$

where ME_i is the maximum extent of the section i, and *SI* is the interval between the sampled sections. *PEA* is equivalent to the average maximum extension multiplied by the length of the

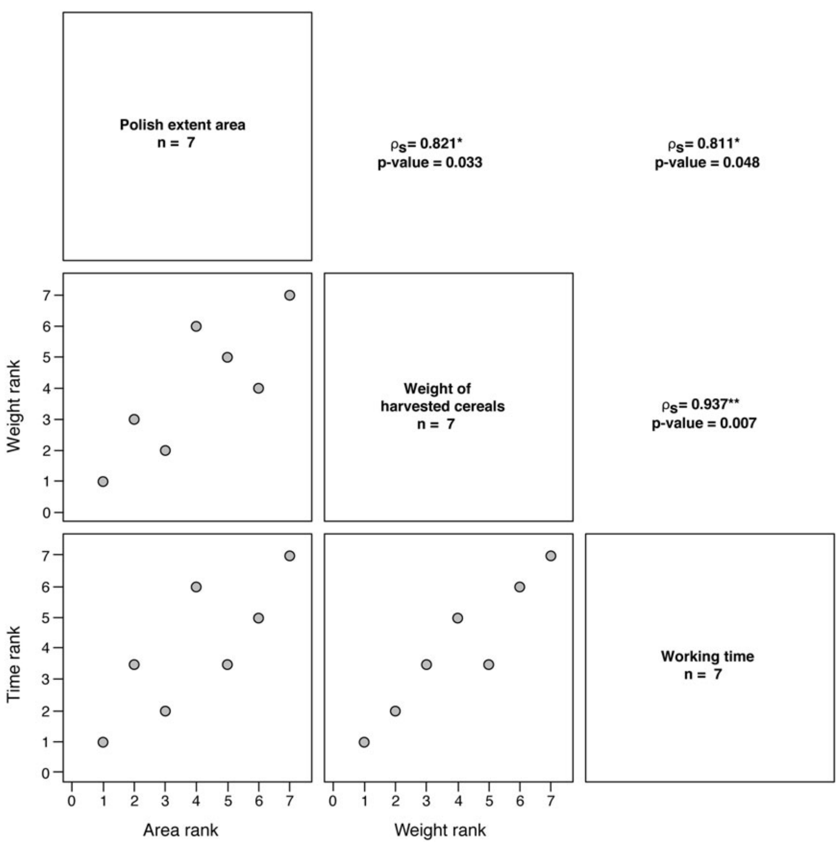

Figure 5 *The Spearman correlation plot, with the distribution of points according to the rank of the variables (polish extent area, weight of harvested cereals and working time) in the lower triangle of the square matrix. Spearman correlation coefficient values (ρ_s) and corresponding p-values are given in the upper triangle of the square matrix: *, $p < 0.05$; **, $p < 0.01$.*

cutting edge. The statistical dependence between *PEA*, the working time and the total amount of cereal harvested is then investigated using Spearman's rank correlation coefficients, a robust non-parametric approach. Note that such a statistical procedure does not test the linear relationships between variables, but the monotonicity. The three variables appear to be monotonically and positively correlated to each other (p-values < 0.05; Fig. 5).

DISCUSSION AND CONCLUSIONS

Even if correlation does not necessarily imply causality, it is reasonable to suppose, from the above-mentioned results, that the maximum polish extent on the experimental tools is largely governed by the amount of work, in terms of time and the amount of cereal harvested. However, when applying this method to archaeological tools, potential drawbacks must be taken into account, as with any other quantitative microwear analysis. If long-term management of archaeological tools has involved the resharpening of edges, then the only information that can be collected will concern the final state of the blades; that is, after resharpening. In the case of sickle blades recycled into other types of tools, the quantification of harvesting microwear is not possible because the cutting edge is no longer complete. The results obtained here do not apply to compound sickle blades, hafted with several flint inserts, since in archaeological collections it is impossible to know which blades were used together on the same haft. Despite these typical restrictions, this study has statistically determined that maximum polish extent can be seen as a useful new quantitative descriptor of archaeological sickle blade use intensity. The low number of blades used to establish this significant correlation strongly suggests that time of use is a preponderant factor in explaining polish extent. The impact of secondary factors, such as tool raw materials, cereal stems diameter and rigidity, flint surface texture, blade shape, cutting-edge angle and hafting arrangements might also warrant further study.

This new statistical descriptor should facilitate new investigations, as the polish extent can easily be measured, using classic microwear analysis equipment. The method can be used in the field, or in museum reserve collections, or as a screening tool for the comparison of flint sickle blades, in terms of polish distribution along the cutting edge. A reflected-light microscope and a camera are used to observe the polish and to measure its extent. This statistical descriptor can be useful to evaluate and compare harvesting use intensity in lithic assemblages. Thus, quantitative data about blade sickle use intensity could help to estimate the relative importance of agricultural activities at archaeological sites, within the same region as the experimental site. Such estimations of agricultural activity, based on flint sickle use intensity, could allow archaeological assemblages to be compared at different spatial or chronological scales; that is, between buildings, at site level, or between sites, at the regional scale. These comparisons should, of course, be limited to comparable flint tools and experimental contexts.

ACKNOWLEDGEMENTS

The experimental harvesting design was led by the late Claude Sestier, as a part of the research program TEPA NEO 'Territoires, Environnements et pratiques agricoles au Néolithique'. We wish to thank all the experimental harvesting participants. We also gratefully acknowledge Carmela Chateau-Smith (University of Burgundy) and Frances Linton for English proofreading.

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