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Learning from blind tests: Determining the function of experimental grinding stones through use-wear and residue analysis

Elspeth H. Hayes [a,*], Dries Cnuts [b], Christian Lepers [b], Veerle Rots [b]

[a] Centre for Archaeological Science, School of Earth and Environmental Science, University of Wollongong, Northfields Avenue, Wollongong 2522, Australia
[b] Service de Préhistoire, University of Liège, Place du 20-Août 7, 4000 Liège, Belgium

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ABSTRACT

Blind tests provide an objective means to evaluate the accuracy of functional interpretations based on the presence of use-wear and residue traces on stone tools. Previous blind tests have highlighted interpretive errors commonly associated with use-wear and residue analyses leading to significant methodological developments in each of the respective fields. While a number of blind tests have been performed on flaked stone tools, only a single blind test has been published for use-wear on grinding tools. We present the results of a two-part blind test performed on 15 experimental grinding implements that were used in a controlled setting, designed to evaluate the relative importance of residue analysis for determining the worked material (1) when contextual information is available and (2) when contextual information is absent. We argue that use-wear and residue analyses are successful procedures to identify the use of grinding stones, and that residue analysis may be a particularly valuable means for determining the worked material on tools that have insufficient use-wear development. We suggest that residues should be sufficiently abundant to infer use, if we are to avoid the potential confusion caused by contamination.

1. Introduction

Reconstructions of past tool use are possible through the microscopic technique of use-wear analysis, where tool use may be inferred by the nature and distribution of specific wear traces on tool surfaces. The characterisation of adhering residues by their visual appearance—both macro and microscopically—and their distribution on the tool surface, can also provide evidence for worked materials. Whilst reconstructions of past tool use have focussed on the examination of flaked stone tools, traces, including use-wear residues (notably starch grains), on grinding stones, have provided evidence for past activities such as food preparation, plant domestication, tool maintenance and craft production (e.g. Adams, 1988, 1999; Attenbrow et al., 1998; Dubreuil, 2004; Dubreuil and Grosman, 2009; Fullagar and Field, 1997; Fullagar et al., 2006, 2008, 2015, 2016; Hamon, 2008, Hayes, 2015; Hayes et al., 2016; Liu et al., 2010a, 2010b, 2011, 2013; Piperno et al., 2004; Revedin et al., 2010; Van Peer et al., 2003; Wright, 1994).

In this paper, we explore the value of wear and residue traces on grinding tools for determining the *worked material* in a multi-staged blind test, with particular focus on the characterisation of residues. Both parts of the test were carried out on the same set of experimental tools ($n = 15$) used in a controlled setting to process a variety of plant, animal and inorganic materials. Part 1 of the blind test was designed to evaluate the relative importance and reliability of approaches for wear and residue analyses in a context where the grinding stones and sample locations are available, to determine whether the worked material may be identified. Part 2 was designed to evaluate the relative importance of wear and residues documented under high magnification, from samples of these traces without access to the grinding stones or other supporting contextual information.

2. Background

2.1. Blind tests

Blind tests have made significant contributions to the methodological developments of use-wear and residue analyses, providing a means for determining the most reliable way traces of use may be identified and interpreted on stone tools. The earliest blind tests were carried out in the 1970s and 80s on flaked stone tools to evaluate the reliability of use-wear interpretations using low magnification (e.g. Odell and Odell-Vereecken, 1980; Shea, 1987, 1988) and high magnification microscopy (e.g. Bamforth et al., 1990; Keeley and Newcomer, 1977; Knutsson and Hope, 1984; Newcomer et al., 1986). More recently, blind tests have included use-wear observations at both low and high magnifications (e.g. Rots et al., 2006) and analyses of adhering residues

* Corresponding author.
E-mail addresses: ehayes@uow.edu.au (E.H. Hayes), dries.cnuts@ulg.ac.be (D. Cnuts), veerle.rots@ulg.ac.be (V. Rots).

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under reflected light microscopy only (e.g. Lombard and Wadley, 2007; Wadley et al., 2004), reflected light and transmitted light microscopy (Rots et al., 2016) and reflected light and Scanning Electron Microscopy (Monnier et al., 2012).

Only one blind test has evaluated the potential of use-wear analysis on grinding stones. Hamon and Plisson (2008) examined the surfaces of 15 experimentally ground sandstones in an attempt to identify the active zones (i.e. the worked regions) of the tools, the object type (whether the stone was used as an upper, lower or abrading stone), the kinematics of use (i.e. the direction of movement and the orientation of the implement during use), and the transformed matter (the material that was ground). Although the analyst was successful at determining the used surfaces on each tool, recognising the transformed matter (hereafter the worked material) was the least reliable parameter. Their approach, however, did not incorporate residue analysis, which we consider to be very useful for the identification of the worked material, particularly for tools made from relatively porous stones, such as sandstone.

Our blind test was designed specifically to evaluate the relative importance of residue analysis for identifying the worked material on sandstone grinding stones, and the ability to recognise worked material from trace samples (e.g. moulds of use-wear and residue extractions) without any supporting contextual information. Our tools were used for short durations (10–25 min) but for long enough to allow the build-up of diagnostic residue traces. Although expedient use is likely to result in the formation use-wear diagnostic of grinding or pounding activities, use-wear on expedient tools is unlikely to be diagnostic of specific worked material (see Hayes, 2015). Although the experimental tools were washed prior to analysis (to reduce residue abundance), our tests did not investigate the effects of long or short-term residue degradation. How degradation may affect the identification of particular residues requires further investigation.

2.2. Residues on grinding stones

Although residue and wear analyses are now usually well-integrated in studies of grinding stone function, we recognise three issues associated with the documentation and characterisation of residues. First is the problem of *residue deposition*: residues may accumulate on artefacts as a consequence of many cultural and non-cultural processes, including manufacture, use, discard, handling, storage and post-depositional contact with sediment (Rots et al. 2016, pp. 11). The porous nature of most grinding stones, in contrast with flaked stone tools, may cause a relatively higher accumulation of residues from origins unrelated to use (e.g. transfer via taphonomic processes).

Second is the problem of *residue ambiguity* (see Monnier et al., 2012). "Ambiguous" residues are those that lack qualities and distinctive physical characteristics that allow them to be identified optically. Some types of residues (mostly plant residues) can be identified optically by their distinct tissues, cells and films and other structures (Evert, 2006), but other residues, such as lipids and biomolecules (e.g., proteins, carbohydrates) are very difficult to observe under light microscopy, and require other means of identification (e.g., chemical characterisation and spectroscopy). Animal residues (e.g., blood, bone, muscle, fat, collagen, hair and shell) sometimes have distinctive cell structures but often require staining for visibility and other chemical characterisation. Tool residues with an inorganic origin (e.g., haematite, ochre, pigment, and calcite) can be observed microscopically but may require further chemical characterisation. Often, the actions of grinding and pounding involve high pressure and forces that alter the structure of the residues.

One approach to distinguish the origin of ambiguous residues is through *histological staining* (also referred to as 'biochemical staining', see Stephenson, 2015), a method of residue characterisation that enables the visual identification of amorphous or damaged residues that have been altered by processing or diagenesis. The method involves the application of various solutions (staining agents) to a residue mixture and observing any subsequent changes in appearance, typically under microscopic conditions. Particular staining agents will react with a certain component of the residue, causing a distinctive colour change that is not observed in other constituent materials. Staining methods were first applied to archaeological residues by Bruier (1976) to reliably isolate plant and animal tissues on a selection of stone artefacts. More recently, stains have been used to evaluate archaeological material to confirm the presence of both damaged and undamaged starch (e.g., Balme et al., 2001, pp. 4; Barton and White, 1993, pp. 174; Fullagar et al., 2015; Lamb and Loy, 2005, pp. 1433; Loy et al., 1992, pp. 904; Revedin et al., 2010, pp. 11819; Smith, 2004, pp. 178); collagen and other animal tissues (Barton and White, 1993, pp. 174; Fullagar et al., 2015; Stephenson, 2015; Wright et al., 2014, pp. 96); lipids (Stephenson, 2011, pp. 33) and plant fibres including cellulose, lignin and tannin (Barton and White, 1993, pp. 174; Fullagar, 1986; Fullagar et al., 2015; Stephenson, 2011, pp. 34). The ability of many of these stains to highlight very degraded materials, however, is yet to be fully explored. Some stains highlight multiple materials, so selection and sequence of appropriate staining agents is required to answer specific research questions.

Third, *various protocols* are currently applied to residues when analysing grinding stone function. In some studies, analysts look only at extracted residues under transmitted light microscopes (Fullagar et al., 2015; García-Granero et al., 2016; Liu et al., 2010a) while others combine this with initial on-tool observations under reflected light (Fullagar et al., 2006). It is unknown how these different protocols may affect interpretations of the residues and tool function.

2.3. Use-wear on grinding stones

Like residues, wear on grinding stones can be acquired through a number of means, including manufacture, use, curation, transport, discard and other post-depositional processes such as weathering and sediments friction in the burial environment (Dubreuil et al., 2015). Adams (1988, 1993, 2002a, 2002b, 2014) distinguishes four mechanisms responsible for the formation of wear on ground surfaces: (1) adhesive wear; (2) abrasive wear; (3) fatigue wear and (4) tribochemical wear (see Adams, 2014 for detailed descriptions). These mechanisms result in surface modifications of the macro- and micro-topography (microscopic elevational relief) of the ground surface resulting from the rounding, levelling or removal of grains, as well as other features such as polish, striations and conchoidal fracturing of individual quartz grains (e.g., Adams, 1988, pp. 311–312; Adams et al., 2009, pp. 28, 47–53; Dubreuil, 2004; Hamon, 2008; pp. 1506). These modifications will vary depending on the intensity and duration of use, the properties of the material being worked (e.g., texture, hardness, moisture content, etc.) and the mineralogy of the grinding stone surface (i.e., the properties of the stone material, including hardness, durability, asperity, texture and cementation) (Adams, 1993, pp. 61–2, 2014, p. 130; Adams et al., 2009, p. 53; Delgado-Raack and Risch, 2009, p. 9; Hamon, 2008, 1504).

Use-wear (i.e., the wear generated from use) is best documented using a range of magnifications and lighting arrangements. Examination of the tool surface at a macroscopic level, i.e. with the naked eye, using a low angled light, is useful for identifying the *location of the worked surface* and generally requires little or no analyst experience. The use of an external point-source of light creates a shadow when the light source is at right angles to the striation orientations, making large surface furrows (a distinctive and diagnostic grinding wear feature) easily distinguished on the stone surface. The degree of surface levelling and grain rounding is best observed at lower magnifications, where multiple grains could be viewed in context. The *kinetics* of use—i.e., whether the tool was used to process a material through direct contact, or "filing" (cf. "abrading" or "polishing" as described by Adams, 1993, p. 64; and Hamon, 2008, p. 1504), or whether the tool was used in conjunction with another stone to process an intermediate material by pounding,