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Ground stone use-wear analysis: a review of terminology and experimental methods

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ABSTRACT

Methods, terms, and experimental results are presented as standardized concepts for the analysis of ground stone tools. Recent experimental and microscopic research techniques applied to the study of ground stone tools have broadened the recognition of use-wear patterns. Building on the research of tribologists who study wear in order to prevent it, wear mechanisms have been identified that are distinctive to the relative nature of contact between two stone surfaces in addition to the nature of substances worked between contacting surfaces. Tribological wear mechanisms identifiable on stone surfaces include surface fatigue, adhesion, abrasion, and tribochemical interactions, each of which are continuously in play, so that what we see depends on when the wear process was interrupted. Other important factors influencing surface wear are the durability and texture of the rock type selected for tool use.

1. Introduction

The most basic research questions addressed by ground stone analyses are about the specific attributes that allow archaeologists to recognize tool manufacture, use, maintenance, and discard. Flaked lithic technologists began addressing these questions decades ago with use-wear research, evaluation of wear rates, and studies of kinetics (Amick and Mauldin, 1989; Bamforth, 2010; Carr and Bradbury, 2010; Hayden, 1979; Hayden and Kamminga, 1979; Keeley, 1980; Unger-Hamilton, 1984; Mathieu, 2002; Odell and Odell-Vereecken, 1980; Tringham et al., 1974; Vaughan, 1985), and they quickly realized the need for standardizing terms and analysis techniques (see for example, Hayden, 1979). Terms such as striations, abrasions, gouges, crushing, comet-shaped pits, micropolish, and edge rounding are now commonly used in flaked stone use-wear studies. Additionally, the relative usefulness of high power and low power magnification techniques, ethnographic analogy, and experimental replication have been evaluated by flaked lithic analysts.

Less attention has been paid to the standardization of terms and analysis techniques for stone tools used in percussion tasks, commonly referred to as hammerstones or pecking tools, as well as for tools used in or modified by grinding and crushing, commonly referred to as ground stone (but see Hayden, 1987:8–119; Semenov 1973; Woodbury, 1954). The pace, quantity, and quality of research on ground stone tools gained momentum during the 1990s and early 2000s with attempts to bring some level of standardization to the study of these tools (Adams, 1988, 1989, 2002; Mills, 1993; Wright, 1992, 1994; Wright, 1993). Now ground stone analysts world-wide have incorporated use-wear, experimental, and ethnographic concepts into their analysis techniques (Burton, 2007; Burton and Adams in press; Clemente et al., 2002; Dubreuil, 2001, 2004; Hamon, 2008; Procopiou et al., 2011; Vargiolu et al., 2007) with six researchers contributing to an international publication intent on standardizing techniques and terms for ground stone analysis (Adams et al., 2009).

The purpose of this paper is to make more accessible an analytical and terminological strategy for ground stone analysis that builds on the work of ground stone analysts with influence from tribologists who study wear for the express purpose of preventing it. Tribology, a sub discipline of engineering, is the science of interacting surfaces in relative motion specific to the study of friction, lubrication, and wear. Although the tribologists cited here have mainly worked with metal (Blau, 1989; Czichos, 1978; Dowson, 1979; Kato, 2002; Kragelsky et al., 1982; Quinn, 1971; Szeri, 1980), their classification of wear mechanisms is directly applicable to ground stone tools and their terms have meanings that warrant their adoption to facilitate communication about use-wear patterns on stone surfaces.

Tribologists define *wear* as the progressive loss of substance from the surface as a result of the relative motion between it and another contact surface (Czichos, 1978:98; Szeri, 1980:35; Teer and

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Arnell, 1975:94). Such progressive loss is clearly discernible in the wearing of grinding and abrading tools. As used by archaeologists studying ground stone, use-wear analysis is the examination of an item for macroscopic and microscopic evidence that allows us to understand how it was altered, separating damage patterns caused by manufacturing techniques and post-depositional activities from those caused by use (Adams, 1988, 1989, 1993, 2002; Adams et al., 2009; Dubreuil, 2001, 2004; Dubreuil and Grosman, 2009; Hamon, 2008). Building on tribological definitions, four wear mechanisms are helpful in describing and understanding the formation of specific damage patterns on stone surfaces: *adhesive wear*, *abrasive wear*, *fatigue wear*, and *tribochemical wear*. These mechanisms are not mutually exclusive, nor independent in how they change surfaces. The four mechanisms interact, and one becomes dominant over the others depending on the characteristics of the contacting surfaces and the nature of any *intermediate substances* (Adams, 1988, 1989, 1993, 2002; Adams et al., 2009). These are important concepts for ground stone use-wear analysis because they provide a means for evaluating wear patterns without having to create an experimental example of every possible use situation.

Fig. 1. Macrotopography: (a) naturally rough and angular surface on a vesicular rock; (b) flat surface on a granular rock that is asperite enough to abrade a contact surface.

2. Surface analysis

The microscopic analysis of worn surfaces differs from that of flaked edges, mainly in depth and breadth of worn area, but also in the ability to place the larger tools under a microscope. Variations in ground-stone tool sizes require the use of microscopes with adjustable stands. Relatively low-power, binocular magnifications ranging from 20× to 100× have been most commonly used to scan for wear patterns across broad surfaces. The use of magnifications greater than 100× require the same due diligence by focusing on more than one tiny area to evaluate the extent of use and the differential interactions of wear mechanisms across the entire worn surface. Recent exploratory studies have evaluated casts of surfaces for use with Scanning Electron Microscopes or other systems that cannot accommodate large artifacts (Dubreuil, 2004:1617). Dubreuil comments that casts made of silicone provided the best results, but even these could not reach the deepest interstices of granular stone surfaces (Adams et al., 2009:54).

Surface analysis begins with an evaluation of *surface topography* (Adams, 2002:28–29; Adams et al., 2009). Topography can be described without magnification at a *macrotopographic* level and with magnification at a *microtopographic* level. The natural roughness, lamina, and angles in a stone surface are features of *macrotopography* (Fig. 1a). The surface of a stone with no macrotopographic relief appears flat (Fig. 1b), but this is not meant to imply that it is smooth. The surface of a tool made from granular rock might have no macrotopographic relief and still not be smooth because of the natural texture of the rock. In this sense the stone surface has *microtopography* that plays an important role in the formation of use-wear (Fig. 2). Surface topography at all levels is important when two surfaces come into contact. Between two hard or rigid contact surfaces only the higher elevations make initial contact, and this is where use-wear patterns first form. Softer contact surfaces engage the features of topographic relief in ways that are identifiable and classifiable as subsequently discussed.

How use-wear is recognized and described is influenced by the nature of the tool rock which must be understood before wear traces can be accurately distinguished. For example – is the natural granularity or texture of the stone rounded or angular? Are the grains cemented with a durable silica-based cement or a soft calcium carbonate? Are the vesicle margins sharp or rounded? Rock surfaces have natural topographic variability at both macroscopic and microscopic scales (Delgado-Raack et al., 2009). Use-wear on specific items should be evaluated against an area on the stone that is unused or broken so that the unmodified nature of the stone is known (Adams, 2002; Adams et al., 2009:45).

For analytical purposes, ground stone surfaces can be assessed in terms of durability and asperity (Adams, 2002:27–42; Adams et al., 2009). These concepts are relevant to the performance characteristics of rocks chosen for tools and to the alterations needed to make surfaces functional. Asperity is an important concept for understanding how use-wear patterns are created on ground stone surfaces (Adams, 1993, 2002:27–42). *An asperity* can be a single grain or a single projection from a surface, the spaces between asperities are *interstices*. *Asperity* is a combination of rock granularity and surface texture, and is influenced by rock durability. The surfaces of tools made from coarse-grain rock naturally have the potential to be more asperite than the surfaces of tools made from fine-grain rock (Fig. 3). The surface of a fine-grain rock or a water-worn cobble of any texture can be made more asperite by pecking it to sharpen the surface texture. If a smooth surface texture is desirable, a coarse-grain rock can be smoothed by leveling the grains. Thus, the term asperity is not necessarily related to the natural rock texture, but to the texture of the manufactured tool surface.

Through manufacture techniques or by use, the asperity of both fine-grain and coarse-grain rocks can be reduced to equally smooth surface textures. The asperite surface of a tool made from durable rock (some metamorphic and volcanic rocks) may not cause as

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