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Modeling the costs and benefits of manufacturing expedient milling tools

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A R T I C L E I N F O

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A B S T R A C T

It is often assumed that use-surfaces on informal or expedient milling tools were formed strictly through use. Informal or expedient milling tools lack clear evidence of exterior shaping and are often associated with short-term occupations or temporary, task-specific sites. Here, a simple model of technological intensification outlined in Bettinger et al. (2006) is adapted to predict minimum use times necessary to profit from time spent improving the use-surface of milling tools. The costs and benefits of making and using improved milling surfaces for two types of raw material (sandstone and granite) are compared using experimentally derived estimates of grinding rates and manufacturing costs. Experiments indicate that shaping a milling surface increases seed-grinding efficiency. Modeling these data along with manufacturing costs predicts that manufacturing effort should be expected sooner than often assumed—in fact, little more than one and a half hours of seed grinding are necessary to profit from time spent manufacturing a shallow basin in sandstone. It also predicts that sandstone should be selected over granite for short-term seed grinding due to its ease of shaping. These results imply that there are many cases where mobile hunter–gatherers who processed seed resources could have reduced their overall handling time by selecting certain materials and investing time in shaping milling surfaces. This highlights the need for greater attention to physical evidence of manufacturing among expedient milling tools. Documenting raw material selection and degree of manufacturing effort expended on such tools can increase the visibility of gendered economic decisions among prehistoric hunter–gatherers.

1. Introduction

Little theoretical inquiry has been directed to the manufacture of milling tools lacking exterior formalization – tools that are often referred to as expedient or “unshaped”. Reasons for this lack of investigation may include the apparent simplicity of such tools as well as tendencies to view women (arguably, the primary users of these tools) as passive actors in prehistory. Though a number of optimality models have been applied to decisions affecting flaked lithic technology (Bettinger et al., 2006; Brantingham and Kuhn, 2001; Kuhn, 1994; Metcalfe and Barlow, 1992; Surovell, 2003, 2015; Torrence, 1989; Ugan et al., 2003), similar models have rarely been applied to ground stone tools (Buonasera, 2013a; Stevens and McElreath, 2015). Here, I discuss a simple optimality model designed for procurement related technologies (Bettinger et al., 2006) and show how it could be used to predict raw material preference and manufacturing effort for ground stone milling tools in mobile settings. These settings are envisioned to include a range of short-term residential sites, as well as temporary, task-specific sites.

Applying optimality models to technology assumes that people seek to minimize their work efforts and/or maximize energy gain. Although social and ideological factors also affect choices, optimizing assumptions provide a rational starting place from which to build and improve investigations. A benefit of using formal models is that “constraints, currencies and goals” are explicitly defined, allowing logically derived predictions to follow (Surovell, 2003:14). Although the assumptions of optimality models over-simplify the bases of human decision-making, the interplay between a simple predictive model and experimental or empirical evidence can sometimes reveal relationships that were previously overlooked, and thereby provide additional hypotheses for testing.

The costs and benefits of manufacturing grinding tools in mobile settings are often considered to be self-evident and have received little formal consideration by archaeologists. Along these lines, it is commonly assumed that mobile foragers should expend little or no

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effort manufacturing food grinding tools. Yet, people engaged in seed grinding should spend time improving milling tools when it will reduce the total handling time for those resources. Even in mobile settings, time spent manufacturing a better grinding surface could decrease overall processing times for resources like seeds.

Though little ethnographic detail exists about the manufacture and use of grinding tools among hunter–gatherers, some information indicates that users of informal milling tools took time to manufacture desirable attributes. Among historically Pintubi and Kukatja speaking people in the Western Desert of Australia, Cane (1989:99, 112) recorded that "a great deal of work" went into manufacturing seed grinding dishes out of sandstone slabs. Walsh (2003:265–266), also working in the Western Desert of Australia, noted that among the Mantjiltljarra a "husband or a son would shape milling stones by removing lumps and shaping edges under the direction of the mother/wife."

In the southern Sierras of California, Native women are credited with the manufacture of bedrock mortars (Jackson, 1991:307; McCarthy et al., 1985). "Mono consultants said that new mortars were made [by relatives who used the mortars] with steel chisels in historic times, but thought they had probably been made with a hard rock in pre-contact times" (McCarthy et al., 1985:325). Bennett and Zing (1935) reported that among the Tarahumara of the Sierra Madre Occidental, traditional farmers and pastoralists who practiced seasonal transhumance, women were known to spend a few hours manufacturing a simple basin metate and mano when it was necessary.

> Nothing is more important in the household routine of a Tarahumara woman than the metate, which she calls *matáka*... Since it is too heavy for her to carry about in the numerous journeys she takes to pasture the animals, she learns how to make a *matáka* in short order. First, she finds a large, smooth, flat rock that she knows is very hard. She chips it with a much harder piece of volcanic *piedra lumbrosa* to form the groove for the mano, or handpiece (*matásola*). This is similarly chipped with a piece of flat, hard stone. [pp.79–80]

Grinding efficiency of simple milling tools can be increased in several ways. Shaping stone surfaces using pecking or other percussive techniques to remove high points increases the contact between upper and lower stones. Pecking also creates an abrasive surface. Additionally, creating even a very shallow depression can help to retain material on the surface and reduce grinding time over an unmodified surface. Finally, increasing the size of grinding surfaces has been shown to increase grinding efficiency (Hard et al., 1996; Mauldin, 1993). To better assess when an individual should invest time in shaping a milling surface, costs and benefits of manufacturing improved milling surfaces are modeled here using experimentally derived estimates of grinding rates and manufacturing costs.

Throughout the following paper, the term "metate" is used synonymously with "grinding slab" or "milling slab" to indicate the lower stone of a pair of processing tools used predominantly for grinding. Likewise, the terms "handstone" and "mano" are used interchangeably to indicate the upper stone of this pair. Where it is necessary, particular shapes are indicated by appropriate modifiers (e.g., basin, flat, troughed, shaped or unshaped).

1.1. Evaluating technological investment with the point-estimate model

Several models of technological intensification, or "techmodels", have been proposed for evaluating changes in procurement and processing technology (Bright et al., 2002; Ugan et al., 2003; Bettinger et al., 2006). These models predict the minimum amount of use time required for one technology to provide an advantage in time or energy over another. If gains in efficiency can be realized with increased investment in manufacturing time, but more efficient tools are costlier to produce (especially if manufacturing time competes with total use time), then the decision to use the costlier or cheaper version of a technology can be viewed as an optimization problem that depends on the amount of time a particular technology will be used.

Here, a simple model of technological intensification proposed by Bettinger et al. (2006)—the point-estimate model—is adapted to predict threshold use times that make investment in improving milling surfaces on different raw materials worthwhile. The point-estimate model is a variation of a widely applicable optimality model that compares rates of return with additional investments of time (Bettinger et al., 1997; Charnov, 1976; Metcalfe and Barlow, 1992). The point-estimate model assumes each category of technology has its own cost-benefit curve and plots returns associated with each specific technology as discrete points rather than as part of the same function. This allows comparisons to be made between alternative categories of technologies within a class of subsistence technology (e.g., fishing hooks versus fishing nets) as well as among variations within a particular category of technology (e.g., larger or smaller fishing nets). Bettinger et al. (2006) define a *category* of technology as "a structurally related set of forms which can be envisioned as modifications of one another occupying a single, continuous gain function", whereas a *class* of technology is made up of alternate categories of a technology "applied to a particular subsistence pursuit" (p. 540). Given enough data, a continuous curve might be constructed to describe changes in the rate of gain for versions of a particular category of technology. Bettinger et al. (2006:541) note that the point-estimate approach may work better for many archaeological cases because it requires fewer assumptions and less extensive data sets than are necessary to derive accurate cost-benefit curves.

The point-estimate model requires that a cheaper alternative be compared with a more productive, but costlier version of the same technology. A graphical representation is shown in Fig. 1, with the X-axis representing time. The portion of the X-axis to the right of the Y-axis is manufacturing time, while the portion to the left of the

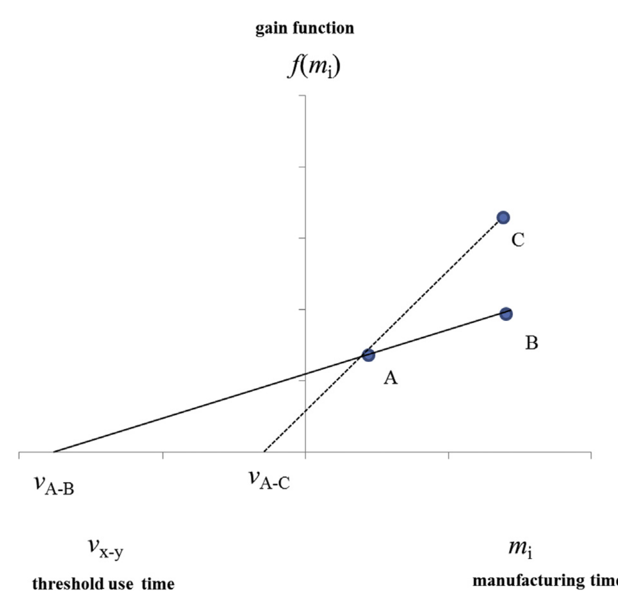

Fig. 1. After the point-estimate model (*Journal of Archaeological Science* 33, Bettinger et al., 2006, p. 542).