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Modeling the influences of raw material availability and functional efficiency on obsidian projectile point curation: A Great Basin example

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ABSTRACT

Prehistoric hunters weighed various factors when manufacturing, using, and maintaining projectile points. I use a model based on the Marginal Value Theorem to generate predictions about the conditions under which hunters should have rejuvenated broken obsidian points or replaced them with new ones. The model predicts that distance to obsidian sources was a major influence on hunters' decisions. I test the model using robust samples of obsidian points from the central and northwestern Great Basin, which I compare for quantitative and qualitative differences in size and evidence of resharpening. The results indicate that broken points in the obsidian-poor central Great Basin were commonly rejuvenated while broken points in the obsidian-rich northwestern Great Basin were simply replaced. These results build on recent studies of stone tool curation and Great Basin prehistory and help explain how and why lithic technological organization varied across time and space.

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1. Introduction

Archeologists are sometimes accused of placing undue emphasis on projectile points (Gero, 1991); however, such attention is warranted for several reasons (Nelson, 1997). First, projectile points may be assigned to particular morphological types, which often serve as index fossils (e.g., Thomas, 1981). Second, projectile points provide indirect evidence of prehistoric subsistence strategies, even when faunal remains are absent (e.g., Hockett and Murphy, 2009). Third, because they are made on materials that may be linked to particular geologic sources, projectile points can be used to reconstruct foraging ranges or exchange networks (e.g., Smith, 2010). Studies of projectile points have led to a recognition that they were part of a complex technology whose design and maintenance were influenced by many factors including cultural norms (Knecht, 1997), provisioning strategies (Thomas, 2012), the need for reliable or maintainable tools (Bleed, 1986), functional efficiency (Musil, 1988), and raw material quality and availability (MacDonald, 2008).

In this paper, I focus on how two factors – functional efficiency, defined here as a tool's effectiveness for a given task, and raw material quality and availability – influenced hunters' decisions to maintain or discard obsidian points. I develop predictions about those decisions drawing upon a field processing model (FPM) (Metcalfe and Barlow, 1992) and the marginal value theorem (MVT) (Charnov, 1976). I use samples of obsidian points from obsidian-rich and obsidian-poor contexts in North America's Great Basin to test the hypothesis that hunters in obsidian-poor contexts curated points to a greater degree than hunters in obsidian-rich contexts, despite the fact that resharpening points may have reduced their functional efficiency. Differences in projectile point size and qualitative evidence of resharpening suggest that whereas hunters with limited access to obsidian curated points to a greater degree, hunters near obsidian sources simply replaced broken points with new ones possessing better performance characteristics.

2. Projectile points and the concept of curation

Binford (1973, 1979) introduced the concept of curation to technological organization studies. While adopted by many researchers, some (e.g., Bamforth, 1986; Nash, 1996; Odell, 1996; Shott, 1996) questioned exactly what curation was: (1) a strategy employed by toolmakers (e.g., tools produced in advance of use and transported between locations)?; (2) a condition exhibited by artifacts (e.g., curated tools are extensively retouched)?; (3) or a relationship between many variables (e.g., strategies, processes, and artifact condition)? Andrefsky (2009:70) suggests that this discussion arose because Binford "did not provide a strict definition and instead used the term in association with a number of interesting ideas". In terms of behavior, these ideas included mobility strategies (e.g., Bamforth, 1990; Kelly, 1988; Shott, 1986) and tool conservation practiced in response to raw material shortages (e.g., Andrefsky, 1994; Bamforth, 1986; Odell, 1996). Because curation was initially linked to a variety of ideas – some of them vague or conflicting – several researchers questioned the utility of the concept to lithic technological organization studies. Nash (1996) suggested that the term be abandoned altogether while Odell (1996) argued that it should be refocused to emphasize behaviors related to settlement systems and not tool conservation.

Recently, Andrefsky (2009:71; also see Shott, 1996; Shott and Ballenger, 2007, and Shott and Sillitoe, 2005) recast curation as "a

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process reflecting a tool's actual use relative to its maximum potential use". When viewed that way, tools are the products of the behaviors (e.g., mobility and settlement) we seek to understand and thus become the focus of curation studies. In the case of stone tools, reduction measures curation; therefore, the degree to which a tool is retouched reflects the degree to which it was curated (Shott and Sillitoe, 2005). Andrefsky (2009:71) suggests that stone tools are "in various phases of being curated from very low use relative to maximum potential use to very high use relative to maximum potential use". But how does one measure "maximum potential use"? In some cases, it may be easy. For example, unifacial flake tools may be continuously resharpened until they are no longer effective for the task at hand (Clarkson et al., 2015). Researchers have developed ways to measure and compare the degree to which unifaces were retouched, and in turn, curated, using experimental assemblages and the recognition that some variables related to original size (e.g., maximum thickness) do not change with increased retouch (e.g., Blades, 2003; Kuhn, 1990).

The function and performance of other tool types make it less clear as to what constitutes maximum potential use. Although projectile points were sometimes used as knives or scrapers (Andrefsky, 2005), most were clearly designed to tip weapons. Those artifacts arguably reached their maximum potential use if they found their mark. Alternatively, because stone points often break catastrophically upon impact (Cheshier and Kelly, 2006; Lafayette, 2006; Odell and Cowan, 1986; Titmus and Woods, 1986), actual use and maximum potential use may be viewed as the same. Other times, points can be rejuvenated after breakage and used again (Flenniken and Raymond, 1986); thus, resharpening points may allow more potential utility to be extracted[1]. Whether points were used as projectiles or for other purposes, resharpening typically makes them shorter (Ahler and Geib, 2000; Flenniken and Raymond, 1986; Hoffman, 1985). If that occurs, then the relationship between a point's actual use and maximum potential use (i.e., the degree to which it was curated) can theoretically be calculated. By calculating a resharpening ratio (original length:haft length), which could range from 0 on an unresharpened point to 1 on a point whose blade was resharpened completely down to the haft element, Shott (1986) argued that it is possible to measure point curation. In reality, however, we rarely know the original lengths of points prior to them being used and resharpened unless we rely on ethnographic data or on caches of presumably unused points (Shott and Ballenger, 2007). Thus, we should not use resharpening ratios to indicate to what degree points were used relative to their maximum potential utility because we usually do not know their maximum potential utility.

That being said, we can use resharpening ratios or other methods to determine if points within particular morphological types (e.g., one Elko dart point vs. another, but not a Clovis spear point vs. a Rosegate arrow point) were more curated relative to each another, assuming they started out with the same original lengths (Shott, 1986). While the assumption that points were manufactured to similar specifications is just that – an assumption – many researchers argue that stone tools were designed either to be optimal in terms of energy (e.g., Kuhn and Miller, 2015; Surovell, 2009; Torrence, 1989) or according to cultural norms (e.g., Bettinger and Eerkens, 1999; Nelson, 1997). Both arguments suggest that standardized forms were desirable, and the persistence of certain point types over many millennia in some regions, for whatever reason, suggests that this was the case.

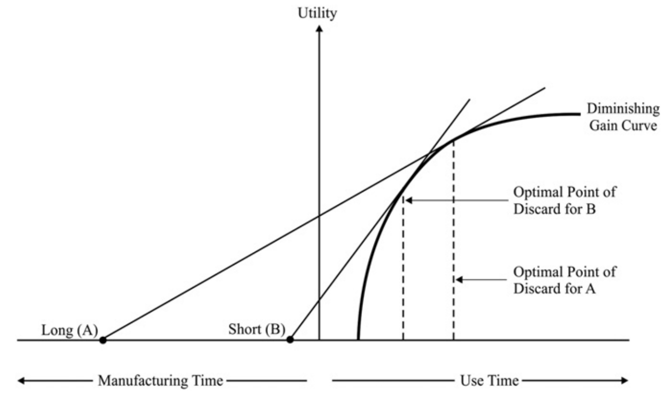

Fig. 1. Clarkson et al.'s (2015) model showing the effect of different manufacturing time on overall utility gain rate. When a tool reaches maximum utility, it should either be discarded and replaced with a new one, or rejuvenated to increase its utility.
Redrawn from Clarkson et al. (2015).

While Shott and Ballenger (2007) suggest that maximum length alone is not an appropriate measure of curation since resharpening points often only indirectly affects length, Flenniken and Raymond's (1986) study shows that dart points do become significantly shorter following rejuvenation[2]. Because flintknapping is a subtractive process, resharpening points following lower-impact activities (e.g., cutting, scraping) should also decrease their lengths. Thus, in the absence of haft element data required to calculate resharpening ratios, which are often not reported, the degree to which points have been curated relative to one another can still be assessed using maximum length alone. Flenniken and Raymond's (1986) experiment shows that width and weight are also useful measures of curation. Thickness, which is difficult for flintknappers to control (Cheshier and Kelly, 2006), has been shown to not decrease significantly between rejuvenation events (Flenniken and Raymond, 1986), and has not been definitively linked to original size (Shott and Ballenger, 2007), is less useful as a standalone measure of curation. Finally, although studies of retouch invasiveness (e.g., Andrefsky, 2006) also measure projectile point curation, given the large sample used in this study I did not employ those methods here.

3. Raw material quality and availability, functional efficiency, and modeling prehistoric decision-making

Flintknappers embrace obsidian because it requires less force to detach flakes than other material types and can be fashioned into exceptionally sharp implements (Andrefsky, 2005; Callahan, 1979; Whittaker, 1994). Based on experiments designed to compare the ease with which different raw materials in the Great Basin can be worked, Elston (1990) concluded that obsidian was best for flintknapping, followed by chert, basalt, and other materials. In terms of sharpness, and in turn, cutting

[1] Experimental studies consistently show that projectile points, especially those made on obsidian, break within a few strikes of a target; however, discussions with colleagues during the early stages of this paper generated questions about how many times a projectile point can be rejuvenated and still function effectively as a projectile (e.g., once, twice, more than twice), as well as what shape a diminishing utility curve for projectile points might take (see Fig. 10.2 in Kuhn and Miller, 2015 for some hypothetical trajectories). Flenniken and Raymond (1986) demonstrated that most broken dart points can be rejuvenated at least once, although sometimes this produces different morphological types. After one rejuvenation event, their replicated Elko dart points were on average ~81% of their original lengths (3.8 cm vs. 4.7 cm) but still long enough to function effectively as projectiles based on the effectiveness of Cheshier and Kelly (2006) sample of replicated "short, thin" and "short, thick" replicated projectile points, both of which averaged ~2.6 cm in length. Assuming a constant rate of length loss of ~19% after each rejuvenation event (an untested assumption that Shott and Ballenger (2007) correctly note is probably wrong), points that are rejuvenated twice should still average ~3.1 cm in length — long enough to still function effectively as projectiles based on Cheshire and Kelly's (2006) study. While this argument is based on a small sample of points used in Flenniken and Raymond's (1986) study and an untested assumption, it suggests that many projectile points can be rejuvenated more than once. It is important to note that the potential for individual points to be rejuvenated is likely influenced by many variables including original length, delivery system, the types of material they impact, how they break, and other perhaps random factors.

[2] Flenniken and Raymond (1986) threw 30 replicated obsidian Elko dart points at a target and rejuvenated 26 of them following impact and breakage. They recorded basic metric data (length, width, thickness, and weight) for each specimen before and after impact. While specimens in the before and after samples differed significantly in length ($t = 4.203$, $df = 52$, $p < .001$), width ($t = 2.076$, $df = 52$, $p = .043$), and weight ($t = 3.586$, $df = 52$, $p = .001$), they did not differ significantly in thickness ($U = 293.000$, $Z = -1.286$, $p = .198$).

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