Journal of Archaeological Science 49 (2014) 472–487

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

The role of raw material differences in stone tool shape variation: an experimental assessment

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ARTICLE INFO

Article history:
Received 27 March 2014
Received in revised form
29 May 2014
Accepted 30 May 2014
Available online xxx

Keywords:
Raw material
Handaxes
Experimental archaeology
Acheulean
Experiment

ABSTRACT

Lithic raw material differences are widely assumed to be a major determining factor of differences in stone tool morphology seen across archaeological sites, but the security of this assumption remains largely untested. Two different sets of raw material properties are thought to influence artifact form. The first set is internal, and related to mechanical flaking properties. The second set is external, namely the form (size, shape, presence of cortex) of the initial nodule or blank from which flakes are struck. We conducted a replication experiment designed to determine whether handaxe morphology was influenced by raw materials of demonstrably different internal and external properties: flint, basalt, and obsidian. The knapper was instructed to copy a "target" model handaxe, produced by a different knapper, 35 times in each toolstone type ($n = 105$ handaxes). On each experimental handaxe, 29 size-adjusted (scale-free) morphometric variables were recorded to capture the overall shape of each handaxe in order to compare them statistically to the model. Both Principal Components Analysis (PCA) and a Multivariate Analysis of Variance (MANOVA) were used to determine if raw material properties were a primary determinate of patterns of overall shape differences across the toolstone groups. The PCA results demonstrated that variation in all three toolstones was distributed evenly around the model target form. The MANOVA of all 29 size-adjusted variables, using two different tests, showed no statistically significant differences in overall shape patterns between the three groups of raw material. In sum, our results show that assuming the primacy of raw material differences as the predominant explanatory factor in stone tool morphology, or variation between assemblages, is unwarranted.

1. Introduction

Understanding the role that stone raw materials played in lithic artifact form and assemblage variability is an issue fundamental to archaeological research in all times and places in which flaked stone technology was utilized. Indeed, raw material "quality" has long been cited as a potentially important factor influencing lithic artifact morphology (Abbott, 1911; Goodman, 1944). Despite the fact that "quality" is often a subjective, poorly defined characteristic of knappable stone, for which there is no consensus (Brantingham et al., 2000; Braun et al., 2009; Browne and Wilson, 2011), several lithic analysts have emphasized the role that stone raw material "quality" plays in artifact form. For instance, Andrefsky (1994:23) suggested that the "quality" of lithic raw materials is one of the two most important factors in the organization of stone technology (the other being lithic "abundance"), and that "the quality … of lithic raw materials played a direct role in prehistoric tool makers decisions to produce various types of stone tools." Twenty years on, Manninen and Knutsson (2014:95) underscore this notion, stating that "when lithic technological organization is viewed as an intersection of many varying dimensions, the properties and availability of raw materials can be considered the most important determinants in how these dimensions intersect within any organizational context."

The motivation for these inferences perhaps stems from the Manninen inevitable co-variation between particular stone raw

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http://dx.doi.org/10.1016/j.jas.2014.05.034
0305-4403/

materials and particular tool forms (or lithic reduction strategies) at archaeological localities. As Brantingham et al. (2000:257) explain:

> The assumption is that the ability to execute formal technological designs is severely limited by the quality of the raw material. Toolkits based on high quality raw materials are thought to be easier to design because fracture is easier to control (Goodyear, 1989:3; Luedtke, 1992). In contrast, toolkits based on poor quality raw material are more difficult to design because fracture is unpredictable and results in severe, irreparable errors during reduction. Even where low raw material abundance would encourage formal technological design, raw material quality is thought to be the overriding factor constraining lithic technological organization.

While the archaeological co-variation between particular stone types and artifact morphologies certainly suggests that––in certain times and places––raw material differences were an influence on artifact morphology, it still remains to be determined whether raw material *automatically* influences stone tool form regardless of other input variables. The manner in which raw material interacts with other input variables can potentially be conceived of in two different ways. One of these is explicitly identified by Costa (2010:36) as “artificial forces” and by de la Torre (2011:788) as “technical incompetence.” This suggests that raw material influenced stone artifact morphology because hominins did not possess the knowledge, manual dexterity, skills, or incentive to tackle “challenging” raw materials. This hypothesis does not suggest that raw material plays *no* role in artifact form, but instead that there is nothing *inherent* to specific “knappable” rock types that automatically or necessarily influences artifact morphology in specific ways, and thus the source of artifact form ultimately lies with hominins themselves.

The second hypothesis identified by Costa (2010:36) and de la Torre (2011:788), respectively, is “natural forces” or “raw material constraints” hypothesis (see also Sharon, 2008). This hypothesis posits that raw material “determines” artifact morphology because it is physically impossible to create similar tool forms via flintknapping on substantially different raw materials. This hypothesis is different from the first because it suggests that rather than the interaction of behavioral and cultural factors with physical/geological ones, the dominant source of artifact morphology lies exclusively within the raw material itself; i.e. there exist natural raw material constraints that “dictate” artifact morphology.

It is plausible that the stone raw materials utilized by hominins may have dictated which artifact forms they could ultimately produce. When distinct isotropic rocks––i.e. those generally free of major cleavage planes or other inclusions that inhibit the free passage of energy––are compared directly, they often exhibit differing “internal” and/or “external” properties. Stone raw material “internal properties” consist of attributes relevant to the mechanical process of crack initiation and propagation, i.e. elasticity, brittleness, hardness, homogeneity, granularity, and isotropy (Goodman, 1944; Callahan, 1979; Whittaker, 1994; Andrefsky, 1998). “External properties” refer to the form (size, shape, surface regularity, cortex presence, etc.) of the initial nodule, block, or blank from which flakes are struck (Ashton and McNabb, 1994; Eren et al., 2011a; Jennings et al., 2010; Smallwood, 2010). However, despite these factors, several recent archaeological studies have questioned the automatic primacy of such constraints in determining artifact form (e.g., Brantingham et al., 2000; Sharon, 2008; Archer and Braun, 2010; Costa, 2010; Clarkson, 2010; Smallwood, 2012; Buchanan et al., 2014; Lycett and von Cramon-Taubadel, 2014). As intimated above, there remains a distinct risk that raw material factors are considered a dominant, if not sole, determinant of stone artifact morphology purely as a result of the coincidence between different raw materials and different artifact morphologies at different archaeological sites.

We are skeptical of the extent to which further studies of the archaeological record alone can contribute to these debates. For stone “constraints” to be tested, knowledge of both knapper intention and skill must be controlled (i.e. held constant across materials), and in prehistoric contexts these attributes remain unknown to the archaeologist. For instance, if a lithic analyst discovers a pattern in which thinner bifaces (on average) are made on “high quality” stone type A and thicker bifaces are made on “low quality” stone type B, it would be impossible to resolve whether (i) raw material constrained artifact form, (ii) the knapper(s) did not have the skill to make type B handaxes as thin as the type A ones, or (iii) there was some other behavioral or cultural reason that caused the knapper(s) to manufacture type B handaxes thicker than type A ones. For this reason, several lithic analysts have called for experimental tests to “document the impact of the properties of raw materials on the way in which particular tool types were produced” (Holdoway and Stern, 2004:55; see also Bar-Yosef et al., 2012:12). Indeed, over 70 years ago, Goodman (1944:431) advocated that experiments be conducted that examine “the degree to which the nature of the [stone] material in a person's hand may have guided or limited the work done upon that material by the artisan.”

In response to these calls, Eren et al. (2011a) conducted a 20-month long lithic replication experiment to determine whether, with continuous practice, a knapper's advancing skill in preferential Levallois flake production would be statistically identifiable if the high quality toolstone used was switched to a less tractable chert. Specific quantitative knapping goals were measured and assessed statistically, and overall the results showed that factors associated with knapping skill, rather than raw material quality, were the main causes of success or failure in achieving the set knapping goals. Although these results were inconsistent with the raw material constraints hypothesis, Eren et al. (2011a:2738) recognized the necessity of further experimental assessments. The two toolstones used in the Eren et al. (2011a:2738) experiment contrasted in both their internal and external properties, but both materials could be classified as “chert” in its broadest definition (Luedtke, 1992) and thus differed less prominently in their internal flaking properties than in their external properties. Furthermore, the knapping goals in that experiment involved individual morphological or economic attributes rather than holisitic assessments of gross morphology, leaving open to question the relationship between stone raw material differences and overall stone tool form.

Here, directly expanding upon the experiments of Eren et al. (2011a), we report a replication experiment that tested directly whether different stone raw material categories necessarily constrain artifact shape. The experiment examined three distinct stone raw materials––flint, basalt, and obsidian—which possessed different external and internal properties, and tested whether any of these materials prevented a knapper from successfully copying the shape of a replica handaxe model similar to those produced during the Late Acheulean. We chose this model for the experiment––acknowledging that future work should examine other tool types and reduction strategies––for two reasons. First, this particular tool type would provide a challenge to the knapper within the context of Lower Paleolithic technology (see e.g., Callahan, 1979; Edwards, 2001; Schick, 1994; Winton, 2005). Second, the influence of raw material differences on handaxe form has been debated extensively (e.g., Isaac, 1977; Jones, 1979; Wynn and Tierson, 1990; Roe, 1994; Schick, 1994; Clark, 2001; McPherron, 2006; Sharon, 2008; Archer and Braun, 2010; Costa, 2010; Lycett and Bae, 2010; Gowlett, 2011; Bar-Yosef et al., 2012; Diez-Martin and Eren, 2012), and thus the present experiment will contribute