Journal of Archaeological Science 46 (2014) 37–49

Contents lists available at ScienceDirect

Journal of Archaeological Science

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

Flake variation in relation to the application of force

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ARTICLE INFO

Article history:
Received 22 February 2014
Accepted 24 February 2014
Available online 12 March 2014

Keywords:
Lithic technology
Flintknapping
Force application
Controlled experiment
Experimental archaeology

ABSTRACT

The appearance of new force application techniques in the production of stone artifacts over the course of human evolution has been associated with the increasing technological capacity of hominin groups. Yet, the causal relationship between the knapping practice and the flake characteristics upon which these behavioral inferences rest remains largely untested under controlled settings. Here we present a recent controlled experiment examining the effect of various force application variables (hammer shape; location of force application; angle of blow; hammer displacement speed) on flake morphology. Results indicate that the independent variables interact with flake attributes in a complex way that makes simple analogies between particular attributes and specific force application techniques extremely difficult. However, trade-offs among the variables cast new light on the possible mechanisms underlying variation in force application techniques used in flintknapping.

1. Introduction

An important step toward the explanation of lithic assemblage variability is to understand the flaking techniques used by prehistoric knappers. One of the major concerns is to distinguish the various kinds of force or load that were applied for flake production. Since the initial appearance of stone artifact production over two million years ago, the adoption of innovative knapping force applications (hammer type and percussion technique) have been associated with the increased cognitive complexity and technological capacity of past hominins as well as evidence for cumulative cultural evolution (Ambrose, 2001; Mellars, 2006; Stout, 2011; Schick and Toth, 1993; Weaver, 2005).

Novel percussion techniques also relate to innovations in subsistence, technological, and economic practices which likely incurred both new costs and benefits that were evolutionary significant to hominin evolution (e.g., Brown et al., 2009; Mourre et al., 2010; Hayden, 1987). For instance, the use of soft hammer percussion technology and the ability to exert fine control over artifact morphology and reduction trajectory has implications for artifact design and use-life, and by extension was likely inter-related with technological innovations as well as mobility and subsistence strategies (Bleed, 1986; Kelly, 1988; Kelly and Todd, 1988; Nelson, 1991). Indeed, such arguments have been made concerning North American biface technology (Morrow, 1995), blades and microblades of the Upper Paleolithic and later periods (Newcomer, 1975; Desrosiers, 2012), the Mousterian of Acheulian tradition in Middle Paleolithic Europe (Newcomer, 1971), the Acheulian industry of the Lower Paleolithic (Hayden, 1987; Bergman and Roberts, 1988), and, more recently, the Still Bay and Howiesons Poort industries of Southern African Middle Stone Age (Mourre et al., 2010; Villa et al., 2010; Soriano et al., 2007). In this context, it is essential to develop a better understanding of exactly how different variables related to the application of force affect particular aspects of flake morphology. This paper presents the results of a highly controlled experiment designed to address these issues.

Previous research based on the current experimental design has focused on a number of independent variables that are under the control of a knapper, including the role of platform depth, exterior platform angle, angle of blow, hammer velocity, and exterior core morphology (Dibble and Rezek, 2009; Rezek et al., 2011; Lin et al., 2013). The set of experiments described in this paper focus on the application of force, including the material and shape of the hammer and the location of the strike. However, because some flake attributes are affected by the interaction of

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http://dx.doi.org/10.1016/j.jas.2014.02.029
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two or more variables, and because some of the earlier relationships were not tested using conditions as defined here, variables such as angle of blow and hammer speed are again included in these analyses.

There is little doubt that direct percussion lithic technology is a complex process given the number of independent variables involved as well as the number of flake attributes that can be affected by them. This requires that a series of experiments be performed, and each of these experiments requires a different set of parameters. Additionally, since our goal here is to test under highly controlled conditions relationships that have, for the most part, already been proposed on the basis of replicative experiments, each experiment will be presented here in the context of those discussions. For this reason, the format and organization of this paper has been slightly modified both to simplify and clarify the presentation of results: while some basic parameters are common to all of the experiments, others are specific to each experiment, and each experiment will be presented in terms of its background in the archaeological literature.

2. Basic materials and methods

The experimental design employed here builds on the one recently used to investigate the role of several other variables related to flake production, including exterior platform angle, platform depth, angle of blow, and exterior core morphology (Dibble and Rezek, 2009; Rezek et al., 2011; Lin et al., 2013). The flaking apparatus, as described in Dibble and Rezek (2009), consists of a pneumatic cylinder to which hammers made of different materials can be attached. A core mount is situated directly below the hammer, and cores are securely clamped in it on the sides and the back. When the cylinder extends the hammer makes contact with the cores and a flake is detached. In most of the experiments presented here, the strikes are dynamic, though one experiment (see below) includes static loads as well. The shape of the end of the hammer varies, however, given the goals of each experiment. The mount is adjustable for changes in the angle of the core platform surface relative to the angle at which the hammer strikes the platform (angle of blow) and also the distance from the point of percussion to the platform edge (platform depth, as defined by Dibble and Whittaker, 1981; Dibble and Pelcin, 1995). The exterior surface of the core is exposed to prevent potential interference from the mount during flake formation. The cores used in this study are manufactured from molded soda/lime glass with a semi-spherical surface (Fig. 1) (see Dibble and Rezek, 2009), and are consistent in size and shape, although core weights varied between 472 g and 695 g, depending on how much material was removed to produce a desired exterior platform angle.

Major independent variables involved in this study that are relevant to most of the relationships explored here (see also Dibble and Rezek, 2009; Rezek et al., 2011; Lin et al., 2013) include:

- *Exterior platform angle (EPA)*: measured where the platform and exterior core surface intersect. Each core was cut transversely at the platform end to the appropriate EPA using a wet diamond saw and measured by a goniometer. Cores were designed in a way that there was no longitudinal curve along the exterior surface immediately behind the platform, thus allowing unambiguous measurements. EPAs of 55, 65 and 75° were used.
- *Platform depth (PD)*: measured from the point of percussion to the exterior edge of the platform. For each flake, platform depth was measured independently by more than one observer and the average of their recorded values was used for analysis to minimize inter-observer error. Platform depth varies continuously.

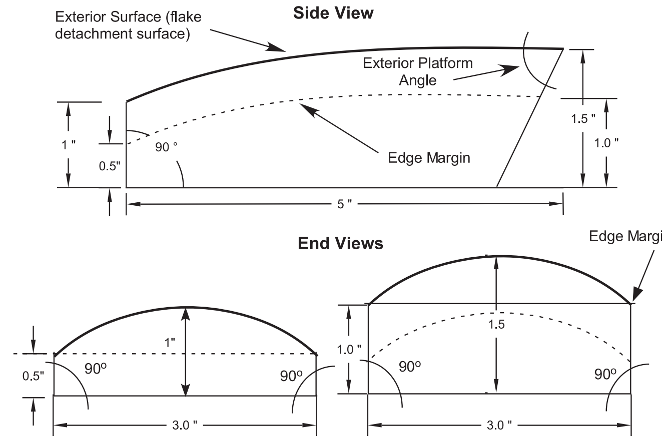

Fig. 1. Side and end views of the glass cores used in the experiment. Different exterior platform angles are produced by changing the angle at which the proximal end of the core is cut.

- *Angle of blow (AOB)*: as in previous experiments (Dibble and Rezek, 2009), an AOB of zero represents the hammer aligning perpendicularly to the core platform (Fig. 2B). A positive AOB would indicate oblique blows striking "outward" to the core (Fig. 2A). Likewise, negative values indicate strikes hitting "inward" to the core (Fig. 2C).
- *Location of force application*: Two locations of hammer percussion were employed in this study: either the hammer strikes directly on the platform surface some distance away from the core exterior (Fig. 2A and B), which are here called platform surface strikes, or the hammer strikes the exterior platform edge (on-edge strikes; Fig. 2C), similar to techniques associated with biface thinning. In our experiment, on-edge strikes on untreated edges led to many crushed edges and failed flake production. To reduce this problem (although it could not be completely eliminated, as discussed below), the exterior platform edges were lightly abraded with a diamond sander to produce a slight rounding. This is in keeping with the common flintknapping practice to make the edge "…well prepared to receive a percussion blow without shattering, and transmit the force as a fracture resulting in the removal of the intended flake" (Sheets, 1973). Other independent variables will be discussed below in the context of each specific study.

For every flake produced, a series of dependent variables were recorded. Flake weight was measured with an electronic scale to

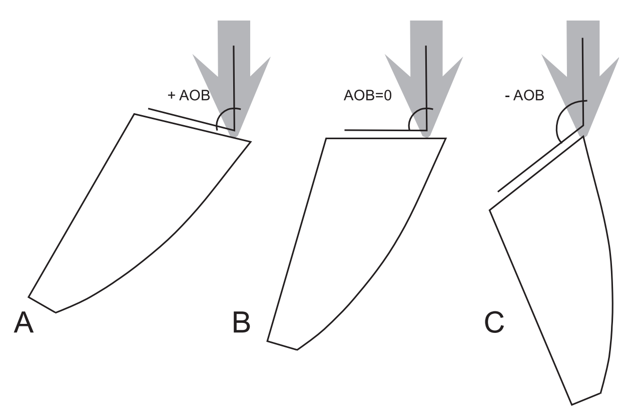

Fig. 2. Illustration of different AOBs and location of force.