Quaternary International 424 (2016) 24–31

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

The effect of raw material properties on flake and flake-tool dimensions: A comparison between quartz and chert

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ARTICLE INFO

Article history:
Available online 26 March 2016

Keywords:
Quartz
Raw material properties
Flake-tools
Flake thickness
Lithic technology
Hunter–gatherers

ABSTRACT

Experimental studies suggest that the high fragmentation tendency of vein quartz can be controlled to some degree by favorable technological choices, i.e., by producing thicker artifacts and by using bipolar-on-anvil reduction. In this paper, I explore the question of whether strategies that reduce quartz fragmentation were used in prehistory and present data that suggest that this was often the case. It has been suggested that due to its fragmentation proneness vein quartz should have been avoided by highly mobile groups when raw materials of better flakeability and controllability were available because of higher transportation costs and greater risk of raw material failure when using quartz. The data presented here shows that quartz nevertheless was not always avoided by highly mobile groups but that the inclusion of quartz into the raw material base necessitated the acceptance of thicker tools when using relatively large flake blanks, or the use of technological strategies that compensated for the risk of failure when relatively thin quartz flakes were in use.

1. Introduction

Flake fragmentation during and after reduction is known to happen regardless of the lithic raw material in use. It is well known that core reduction always produces flakes that are broken in half longitudinally or transversely (e.g., Inizan et al., 1999, pp. 34–35; Hiscock, 2002; Jennings, 2011). The fragmentation proneness of flakes, however, is raw material dependent and raw materials such as macrocrystalline vein quartz, which has low tensile and compressive strengths and a generally large degree of internal flaws, mostly related to geological processes affecting the formation and state of vein quartz, are more likely to break both during and after reduction (e.g., Schick, 1986, pp. 20–42; Callahan et al., 1992; Domanski et al., 1994; Mourre, 1996; Knutsson, 1998; de Lombera Hermida, 2009; Tallavaara et al., 2010; Pargeter, 2011).

Although quartz flakes tend to break into pieces partly as a result of faults in the material, the heavy fragmentation caused by percussion mostly happens because of radial fractures that advance from the point of impact and simultaneous transverse fractures caused by the flake bending during detachment (e.g., Cotterell and Kamminga, 1990, p.129; Callahan et al., 1992; Driscoll, 2010; Tallavaara et al., 2010). Often these breaks happen simultaneously and the fragility of the material leads to large amounts of waste in the form of small fragments and shatter which are so common at quartz knapping floors (Fig. 1).

Despite the proneness of quartz to break during reduction and use, causing it to be in most cases unfavorable for technologies that require good control of the core and aim at standardized flake forms, such as prismatic core blade production, it was in some instances used for making relatively large tools, such as scrapers and arrowheads from flake blanks, even by groups with considerable residential mobility (e.g., Kuhn et al., 1996; Thacker, 2002; Manninen and Knutsson, 2014; de la Peña and Wadley, 2014).

The organization of lithic technology among residentially mobile groups is a recurrent topic in the study of prehistoric hunter–gatherers. There are a multitude of factors that affect lithic technological solutions of mobile peoples, but from an ecological (and organizational, see Manninen, 2014a; Kuhn and Miller, 2015) perspective three dimensions are often considered the most important, that is, transport cost, reliability when needed in encounter hunting, and the availability of raw material (see e.g., Surovell, 2009).

From studies of human behavior it is known that people that move a lot tend to keep the weight they carry around preferably low (e.g., Bird, 1997; Monahan, 1998; for ethnoarchaeological examples). Therefore it can be assumed that hunter–gatherers will generally avoid carrying around rocks with a large share of unusable material (e.g., Parry and Kelly, 1987; Kelly, 1988; Rasic and Andrefsky, 2001; Beck et al., 2002; Hertell and Tallavaara, 2011; see also; Shott, 1986).

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http://dx.doi.org/10.1016/j.quaint.2015.12.096
1040-6182/

Fig. 1. Typical shattered quartz flake with several angular fragments and a large proportion of small chips/dust. Freehand percussion with antler hammer. Photo: Mikael A. Manninen.

It is also clear that people that rely on encounter hunting to get food, do not want the arrow- or spearhead to break at the most critical moment. Also, the time and energy invested in raw material acquisition can be increased only up to a point. Therefore the availability of raw material that enables the successful production of the lithic parts of the tool-and-weapons system plays an important role in the overall organization of technology (e.g., Kuhn, 1991; Andrefsky, 1994a; Surovell, 2009, pp. 187–191).

Because of its wastefulness, unpredictability, and fragility, it seems evident that when carrying costs or reliability are of concern, quartz is a problematic raw material (Tallavaara et al., 2010). This is because of the potentially very large amount of waste in a core of macrocrystalline quartz and the high risk of unintentional breakage if carried around as flakes or tools with thin un-retouched edges. Instead of highly mobile groups, it would seem better suited for more sedentary hunter–gatherers that do not have the need to carry things around as much and are also likely to have decreased dependence on encounter hunting of large terrestrial animals.

However, there were situations in which chert or materials with chert-like workability were not all the time available for hunter–gatherers, or not available at all (e.g., Gould et al., 1977; Callahan, 1987; Rankama et al., 2006; Arias et al., 2009; see also; Mourre, 1994). This kind of situations occurred especially in areas where raw material packages of better workability or smaller waste content are scarce or unevenly distributed, and were sometimes the consequence of decreasing ranges or territorial shifts caused by changes in food availability (Kriiska et al., 2011; Manninen and Knutsson, 2014; Manninen et al., in press). In these situations the use of vein quartz was often not avoidable, and a trade-off between raw material availability and raw material quality led to the use of vein quartz even in highly mobile toolkits (see Ellis, 1989 for a discussion of the benefits of this kind of strategy). Since also groups with high residential mobility in some cases did use macrocrystalline quartz for making relatively large flake tools, we can expect that they would have looked for ways to increase the utility of the raw material by controlling and reducing fragmentation during production and use.

1.1. Ways of decreasing the fragmentation of vein quartz in lithic production

There probably are several ways of decreasing the fragmentation of quartz flakes in lithic production, such as optimal hammer hardness, the use of smooth “neo-cortical” surfaces as striking platforms (Tavoso, 1978, p. 34; Mourre, 1994, p.19; 1996, p. 209), and the regulation of fracture propagation and flake attributes (Tallavaara et al., 2010). In this study the focus is on possible controlling of flake length and thickness.

In quartz reduction experiments conducted at Uppsala University a larger proportion of intact flakes was achieved using bipolar-on-anvil knapping on vein quartz (the vertical axial method, see van der Drift 2001 in Diez-Martin et al., 2011: Fig. 1) than by reduction employing freehand platform cores. While only 16–23% of detachments produced using freehand platform reduction in four separate reduction sequences stayed intact, four sequences with bipolar-on-anvil reduction produced 31–57% intact flakes (Callahan et al., 1992; Knutsson and Lindgren, 2004).

Although quartz flakes produced by vertical axial bipolar reduction stayed intact more often than platform flakes in the Uppsala experiments and bipolar-on-anvil reduction has also other advantages when working with quartz, such as ease of flake removal (Gurtov and Eren, 2014) and the possibility to work with small raw material packages (e.g., Flenniken, 1980:, p. 30; de la Peña and Wadley, 2014; Hiscock, 2015), there is ample evidence that platform reduction was used to produce blanks for scrapers and arrowheads of vein quartz (e.g., Clarkson, 2007, pp. 99–100; Manninen and Tallavaara, 2011; de la Peña and Wadley, 2014).

A series of experiments conducted at the University of Helsinki (Tallavaara et al., 2010) were focused specifically on freehand platform reduction. The main purpose of these experiments was to study whether the frequency of the diverse fragment types in core reduction is related to hammer type or choices made by individual knappers, and therefore there was no attempt to intentionally reduce fragmentation. The experiments resulted in 413 quartz detachments of which the 298 broken flakes (72% of all detachments) were conjoined and their properties studied against the 115 flakes (28% of all detachments) that did not break. One of the results was that relatively thicker fakes had better odds of staying intact (Tallavaara, 2007b, pp. 61–62; Tallavaara et al., 2010). This indicates that to reduce the fragmentation of quartz flakes when using freehand platform flaking, relatively thicker flakes have to be produced.

From the poor elasticity due to low tensile strength and the frequently occurring relatively high degree of internal flaws, it can be hypothesized that also the production of relatively shorter flakes could be used to reduce quartz flake fragmentation. Although there have been attempts to develop methods to reconstruct the size of the tool blank from retouched tools (e.g., Dibble and Pelcin, 1995; Eren et al., 2005), due to factors related to retouch location and use-life of tools the length of the original blank usually cannot be reliably studied from discarded tools (e.g., Davis and Shea, 1998; Shott et al., 2000; Shott and Weedman, 2007). Nevertheless, the in average smaller size of quartz flakes and artifacts, in comparison to other raw materials, has been observed in some studies (e.g., Hiscock and Hall, 1988; Leng, 1998: 427; Bracco, 1993; Wadley and Mohapi, 2008; but see; Siiriäinen, 1977; Seong, 2004). To investigate to what degree the strategy of producing relatively thicker flakes and the possible strategy of producing relatively shorter flakes to reduce fragmentation when using quartz were employed by prehistoric knappers, three simple hypotheses can be formulated and tested with archaeological data:

Hypothesis #1. If the fragmentation of quartz flakes was intentionally reduced by making shorter flakes, quartz flakes should be shorter when compared with flakes produced from better workability raw materials in the same assemblage.

Hypothesis #2. If the fragmentation of quartz flakes was commonly reduced by making relatively thicker flakes, quartz flakes should often be on average relatively thicker than flakes