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Mechanical characterization of raw material quality and its implication for Early Upper Palaeolithic Moravia

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ABSTRACT

Raw material mechanical tests were conducted to answer the question whether differences in raw material procurement among Early Upper Palaeolithic populations in Moravia (Czech Republic) may have been driven by different mechanical properties of those materials. Characterization of mechanical properties of erratic flints and Krumlovský les I type chert show that the relatively finer-grained erratic flints, preferred by local Aurignacian populations, are more easily and probably also predictably knapped at higher speeds, such as reached with soft (antler, wood) percussors, whereas cherts of Krumlovský les I type, exploited by both Szeletian and Aurignacian populations, are more resistant to fracture propagation. This implies the suitability of the former material for fine blade and bladelet production, and of the latter to projectile (e.g. Szeletian leaf points) manufacture, and possibly explains the export of leaf points from Szeletian areas (the Krumlov Forest) to Bohunician and Aurignacian sites within Moravia. Exploitation of erratic flints was easier as regards Aurignacian, and probably entire Upper Palaeolithic knapping technology. Certain tasks, however, were better met with other raw materials, thus reflecting the relativity of chipped stone raw material quality perception in the Palaeolithic.

1. Introduction

1.1. Raw material quality

Raw material *quality*, as a degree of excellence and presence/absence of deficiencies, represents one of the variables which caused disproportionate use of different raw materials in prehistory and the reason why certain materials, though often difficult to acquire, were intensively exploited at the expense of others (e.g. Stout et al., 2005; MacDonald, 2008; Harmand, 2009). Also, in chipped stone manufacture (or "(flint) knapping"), different materials are usable but the resulting products are not equally applicable for the desired tasks. This is of importance e.g. when creating behavioral models of prehistoric societies or explaining diversity in chipped stone assemblages (e.g. Geneste, 1991; Ludwig and Harris, 1998; Goodale et al., 2008). For this and other reasons, chipped stone material *quality* has been dealt with in a number of analytical studies. It soon became clear that the most natural method to distinguish between "good" and "bad", i.e. experimental knapping, is hard to quantify and reproduce by independent researchers (Woods, 2011) so that other specialized methods have been proposed which, however, often test different types of *quality*. Theoretically speaking, good knapping material should be brittle, elastic and isotropic (Cotterell and Kamminga, 1987; Cotterell and Kamminga, 1990) and these characteristics can be tested through mechanical tests like fracture toughness (Domański et al., 1994, 2009; Woods, 2011), Young's elastic modulus (Yonekura and Suzuki, 2009), compressive strength (Webb and Domański, 2008), or through optical microscopy (Brantingham and Olsen, 2000; Webb and Domański, 2008). On the other hand, if tool durability (Braun et al., 2009), durability of edges (Lerner et al., 2007; Yonekura and Suzuki, 2009), sharpness of edges (Harmand, 2009; Yonekura and Suzuki, 2009) or their hardness (Harmand, 2009; Yonekura and Suzuki, 2009) or fracture predictability (Braun et al., 2009; Harmand, 2009) are major priorities, different test types should also be used. Different mechanical qualities are often in positive or negative correlation with one another and with other physical, non-mechanical properties like grain size (Ludwig and

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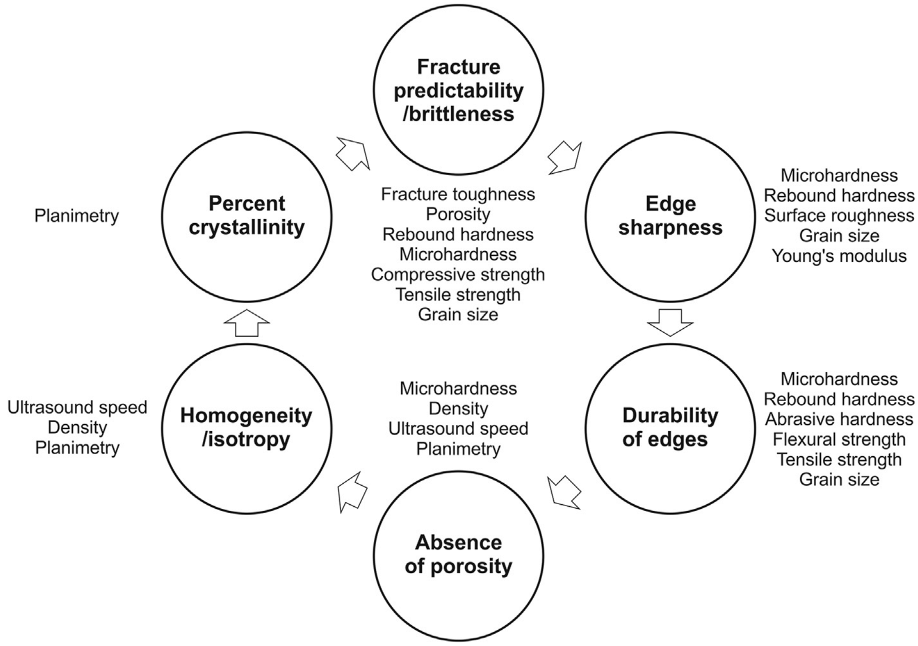

Fig. 1. Positive and negative chipped stone *quality* measures (in circles) and methods of their analysis (Cotterell and Kamminga, 1990; Domański et al., 1994, 2009; Brantingham and Olsen, 2000; Yonekura et al., 2006; Domański and Webb, 2007; Lerner et al., 2007; Webb and Domański, 2008; Braun et al., 2009; Schöpfer et al., 2009; Yonekura and Suzuki, 2009; Hamdi and Lafhaj, 2013; Baud et al., 2014).

Harris, 1998; Andrefsky, 2005; Stout et al., 2005; Webb and Domański, 2008; Braun et al., 2009; Domański et al., 2009; Harmand, 2009; Yonekura and Suzuki, 2009; Gross and Seelig, 2011) and crystallinity (Stout et al., 2005), the amount of α-quartz in the matrix (Yonekura et al., 2006), surface roughness (Yonekura and Suzuki, 2009), the amount of cement in the matrix (Webb and Domański, 2008) or homogeneity and isotropy (Inizan et al., 1999; Brantingham and Olsen, 2000; Andrefsky, 2005; Stout et al., 2005; Lerner et al., 2007). Although such correlations have also been tested on chipped stone materials, a larger number of tests have been conducted on man-made materials, e.g. construction materials such as concrete and steel so that qualities like density (Brown and Reddish, 1997), compressive strength (Baud et al., 2014) or ultrasound propagation speed (Hamdi and Lafhaj, 2013), which are in good correlation with one of the qualities mentioned above, remain yet to be tested on chipped stone material.

In all, about six principle chipped stone qualities can be distinguished, each identified as important to prehistoric knappers or in good correlation with one of the qualities mentioned above (Fig. 1). This correlation, among other things, means that certain methods can be substituted with others, though only after estimating the degree of such correlation for the specific material. It would be erroneous to generalize positive correlation between e.g. microhardness and flexural strength, which has been observed in slates (Yonekura and Suzuki, 2009), as there would be probably low flexural strength in flints despite their increased hardness, the reason being that no mica layers (responsible for high flexural strength; Cárdenes et al., 2010) are present in flint.

As for fracture predictability and brittleness of knapping material, these can be best tested through fracture toughness (FT) measurements (e.g. Domański et al., 2009; Domański et al., 1994; Domański and Webb, 2007), though the absence of voids and fractures (Brantingham and Olsen, 2000), possibly related to greater rebound hardness and Young's modulus (Braun et al., 2009), is equally important. FT, however, has the disadvantage of being a static test and does not simulate the behavior of the material in dynamic deformation, such as experienced during knapping. For this reason, dynamic mechanical tests should also be applied for raw material *quality* testing, at least so as to get to know their knapping qualities.

1.2. Regional setting

When significant change in raw material supply or knapping technology occurs in time or space, questions may be raised as to the role of raw material *quality* in this process. In the present study, we observe the role of raw material quality, knappability in this case, in Moravia (Czech Republic) during Early Upper Palaeolithic (EUP) when changes in raw material procurement took place. In EUP Europe, progressively blade-oriented Aurignacian industries probably first coexisted with and then substituted older EUP assemblages (e.g. Gamble, 1999), represented by the Bohunician and the Szeletian in Moravia (Oliva, 2009; Neruda and Nerudová, 2013). Radiocarbon dates confirm this as the Aurignacian, dated here at 39.4–27.5 ka cal BC (Neruda and Nerudová, 2013), partially overlaps with both the Bohunician (46–37 ka cal BC) and the Szeletian (43–39 ka cal BC). Whereas the origin and manufacturers of both Bohunician and Szeletian assemblages are unclear or unknown (Richter et al., 2009; Hublin, 2015), the Szeletian is often stated to have been manufactured by the local Neanderthal population (e.g. Álvarez Fernández and Jöris, 2008; Bolus and Conard, 2001; Škrdla, in press; the arguments are summarized in; Hublin, 2015).

Moravian Aurignacian assemblages, produced by anatomically modern humans (Bolus and Conard, 2001), represent a change in the raw material economy in the form of increased exploitation of erratic flints (EFs; predominant at 47% of local Aurignacian sites (Fig. 2) when also sites of unknown preferred raw materials are counted; equivalent numbers for Bohunician and the Szeletian sites are 6 and 10% respectively), especially within the natural corridor of the Morava River valley (cf. Oliva, 1984). This is not given just by the