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Ivory debitage by fracture in the Aurignacian: experimental and archaeological examples

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ABSTRACT

The recent focus on methods of osseous material transformation in the study of Upper Paleolithic technologies has shown that approaches to these materials vary between phases of the Upper Paleolithic. In the absence of the groove-and-splinter technique of blank extraction first widely documented in the Gravettian, production of ivory, bone, and antler blanks in the Aurignacian relied on processes of splitting and percussive fracture. The technological treatment of bone and antler in Aurignacian contexts has benefitted from renewed attention, but ivory processing and blank-production remains poorly understood in spite of the unique place that ivory occupies in many Aurignacian assemblages. In order to clarify the diagnostic features of ivory debitage, a series of experiments was conducted to produce ivory flakes under varying knapping conditions. These diagnostic features are products of the application of force to the complex internal morphology of proboscidean tusks, as explained in this article. Improved criteria for the identification of ivory flakes and manufacturing byproducts in the archaeological record are presented, and are illustrated with examples from two Aurignacian sites well known for ivory processing: Abri Castanet (Dordogne, France) and Hohle Fels Cave (Swabian Jura, Germany). A better understanding of ivory structure and improved identification of the products of ivory debitage in the Aurignacian will aid in the recovery and analysis of ivory artifacts and further efforts to reconstruct technological approaches to this complex material.

1. Introduction

The systematic exploitation of osseous raw materials is a definitive characteristic of the Upper Paleolithic. Approaches to exploitation of these materials changed throughout prehistory in ways that coincide with the acknowledged technocomplexes of the Upper Paleolithic (Aurignacian, Gravettian, Magdalenian, etc). The diverse techniques used to process these raw materials have recently received increased attention. Many studies have explored context-specific processes of transforming osseous materials into artifacts based on comparative studies of experimental archaeology and the archaeological record (Averbouh, 2000; Christensen, 1999; David, 2007; Khlopachev and Girya, 2010; Knecht, 1991, 1993; Tartar and White, 2013; Tejero et al., 2012). Ideas of linear evolution in osseous technology, marked by the impression that techniques became increasingly sophisticated and efficient over time, have been challenged by this new body of research. Shifts in approaches to these materials over the course of the Upper Paleolithic have been proven to be more cyclical, and closely related to other aspects of Paleolithic technology such as available lithic technologies (Baumann and Maury, 2013; Pétillon and Ducasse, 2012).

Ivory artifacts constitute one of many developments in approaches to raw materials in the Aurignacian, appearing in archaeological assemblages from Cantabria to the Russian Plain (Álvarez-Fernández and Jöris, 2007; Vanhaeren and d'Errico, 2006). While ivory was used to produce utilitarian artifacts such as projectile points, awls, and beveled tools, the most numerous and well-known ivory artifacts of the Aurignacian are of a symbolic nature: figurines of people and animals, thousands of beads and pendants, and even musical instruments (Conard, 2003b, 2009; Floss, 2007; Hahn, 1986; Malina and Ehmann, 2009; White, 1997, 2007; Wolf, 2013). Experimental ivory work has a long history (Christensen, 1999; Hahn, 1986; Hahn et al., 1995; Khlopachev and Girya, 2010; Malina and Ehmann, 2009; Semenov, 1964) and some of this research has focused on techniques for reducing tusks or tusk

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segments into workable blanks. This preliminary phase of artifact production remains more poorly understood than subsequent stages of artifact fabrication. This article explores the evidence for ivory debitage by fracture in Aurignacian contexts and the relationship between ivory's complex structure and the fracture patterns indicative this activity.

Debitage has been defined as: "A term conventionally used to denote the intentional knapping of blocks of raw material, in order to obtain products that will either be subsequently shaped or retouched, or directly used without further modification" (Inizan et al., 1999: 140). For most lithic materials, knapping is the primary method of raw material reduction. For osseous materials, the term "debitage" has been adapted to include a number of additional techniques for the reduction of a block of material into products that can be subsequently reshaped or directly used (Averbouh, 2000; Tejero et al., 2012) These techniques have been grouped into three primary approaches for the reduction of osseous materials in the Upper Paleolithic (Averbouh, 2000; Averbouh and Pétillon, 2011).

- Debitage by segmentation: a transverse operation, the reduction of a block of material into segments, often by such techniques as transverse or circumferential grooving, sawing, or chopping (Averbouh and Pétillon, 2011:41).
- Debitage by extraction: the extraction of a longitudinal segment of predetermined size and shape from the exterior surface of the material (Averbouh and Pétillon, 2011:41). The technique of "groove-and- splinter" (*double rainurage* in the widely adopted French terminology) by which parallel longitudinal grooves are carved to extract a blank is a well-known example.
- Debitage by fracture: fracture of a block of material by knapping in order to produce flakes (Averbouh and Pétillon, 2011: 41). The process of splitting and wedging, also common in the Aurignacian (Knecht, 1991) is another type of debitage by fracture.

These approaches are not mutually exclusive, but it has been noted that for certain periods of the Upper Paleolithic, one is often predominant in osseous assemblages while others are largely or entirely absent. Debitage by extraction, for example, is widely known in Gravettian contexts (Goutas, 2009), while segmentation and fracture are more common methods in the Aurignacian (Liolios, 1999; Tartar, 2009; Tejero et al., 2012; White, 1997).

Distinctive tool traces are frequently evident in cases of debitage by segmentation and debitage by extraction, but the products and byproducts of debitage by fracture can be difficult to detect in osseous materials, especially when the features diagnostic of this technological process are not clearly defined. It has been demonstrated that the morphology of fracture planes on purposely fractured osseous materials can be used to identify osseous-material exploitation in the archaeological record, and even to identify specific techniques of fracture (Averbouh, 2000; Averbouh and Pétillon, 2011; Baumann and Maury, 2013; Tejero et al., 2012). When these diagnostic features are familiar to the analyst, flake morphology can indicate osseous material processing even in the absence of more commonly recognized tool traces.

Debitage by fracture has been most extensively discussed in reference to antler-working in the Aurignacian (Tejero et al., 2012) and Late Upper Paleolithic (Averbouh and Pétillon, 2011; Baumann and Maury, 2013; Pétillon and Ducasse, 2012). In these cases, experimental and archaeological research have improved the recognition of antler flakes produced by debitage by fracture in the archaeological record, and contributed substantially to current understandings of technological processes in the Upper Paleolithic. With this article, we hope to add to these growing discussions through experimental and archaeological examples of ivory debitage by fracture in the Aurignacian. An understanding of the structure and mechanical behavior of proboscidean ivory paired with experimental debitage by fracture aids in the identification and interpretation of ivory flakes in archaeological contexts. The aim of this article is therefore three-fold: 1) to demonstrate the diagnostic features produced by experimental debitage by fracture of ivory; 2) to contextualize these features in terms of the complex internal structure of ivory; and 3) to present archaeological evidence for ivory debitage by fracture in early Aurignacian levels from Hohle Fels Cave (Swabian Jura, Germany) and Abri Castanet (Dordogne, France).

2. Characteristics of ivory and ivory flakes

2.1. Structural features of ivory

In extant proboscideans and their extinct relatives, "the permanent tusks are composed of a highly modified dentine completely unique in structure and which alone is properly called ivory" (Saunders, 1979: 56). This "modified dentine" is unique both chemically and structurally. All osseous raw materials are rigid biological composites composed of a network of collagen fibers embedded in a mineral matrix of hydroxyapatite. The mineral matrix in proboscidean ivory is not true hydroxyapatite, but a material very similar to hydroxyapatite in which there is a ten percent substitution of magnesium for calcium within the apatite crystals. These crystals are smaller than those that make up the mineral matrix of antler and bone, a fact that contributes to the renowned fineness of ivory (Su and Cui, 1999). Compared to bone and antler, ivory is a highly homogenous material. Except for a thin layer of enamel at the tip of the tusk (which often wears off in the first several years of the animal's life) and a thin layer of cementum covering the surface of the tusk, the tusk presents a solid mass of modified dentin. The apparent homogeneity of ivory, however, masks a remarkable structural complexity (Locke, 2008) whose hierarchical arrangement makes ivory a truly unique material

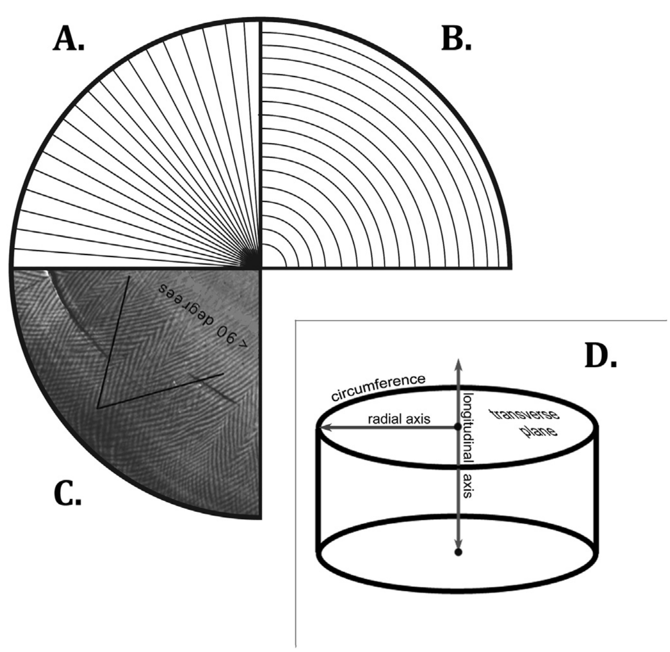

Fig. 1. A schematic diagram of the structural features in an ivory tusk as seen in transverse view: the radial microlaminae (A), the circumferential growth rings (B), and the Schreger Pattern (C). A diagram of the planes and axes within a tusk segment is provided to orient the reader (D). These features are (A–C) are pictured separately for clarity, but overlie and intersect with each other in the cross-section the tusk.