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Establishing statistical confidence in Cortex Ratios within and among lithic assemblages: a case study of the Middle Paleolithic of southwestern France

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ABSTRACT

Recent studies have demonstrated the usefulness of the Cortex Ratio for quantifying the cortex composition in lithic assemblages and as a viable index of prehistoric artifact transport. Yet, the lack of means for assigning statistical confidence to archaeologically observed Cortex Ratios inhibits the approach's utility for objective comparisons and interpretation. Here, we derive statistical confidence for archaeological Cortex Ratios through Monte Carlo and resampling techniques. Experimental data with known geometric properties and measured cortex values were employed as a reference for attaching a probability to an archaeological assemblage's Cortex Ratio. The method is demonstrated on assemblages from the Middle Paleolithic sites of Roc de Marsal, Pech de l'Azé IV, and Combe-Capelle Bas in southwestern France.

1. Introduction

In stone artifact archaeology, cortex is an attribute commonly used for assessing reduction intensity and sequence (Andrefsky, 2005; Clarkson, 2013; Dibble et al., 2005; Henry, 1989; Marwick, 2008), raw material exploitation and transportation (e.g., Reher, 1991), site use (e.g., Roth and Dibble, 1998) and mobility (e.g., Fernandes et al., 2008; Olszewski et al., 2010; Kuhn, 1991, 2004). Because lithic technology is reductive in nature, the amount of cortex retained on stone artifacts is correlated with the degree of nodule reduction (Dibble et al., 2005; Douglass et al., 2008; but see Clarkson, 2013). However, as Dibble et al. (2005:545) noted, it often remains unclear whether an assemblage has more or less cortex than expected given models of varying site use, curation, and technological organization. A large part of this uncertainty relates to the variability in the initial cortex abundance of lithic assemblages caused by differences in the size and shape of the cobbles from which artifacts were produced from.

Recognizing this issue, Dibble et al. (2005) established an objective measure for examining whether the cortex-to-volume relationship observed in lithic assemblages can be accounted for by the geometric properties of the originally worked materials. To do this, the approach computes the amount of cortex that should be present in a given assemblage, assuming that the artifacts represent products of on-site knapping. This is calculated based on estimates of the geometric shape of unworked stone cobbles, the volume of the assemblage measured, and the number of nodules worked. This “modeled” cortex amount is then compared to the total cortical surface present in the assemblage. The relationship between these two values, expressed by the Cortex Ratio, thus provides a point of comparison determining whether the archaeological data deviates from a baseline pattern where all products of nodule reduction are present at a location – i.e., Cortex Ratio is equal to 1. If the ratio is less than or greater than 1, then it suggests that less or more cortex, respectively, is present than would be expected under the assumption of fully cortical nodules knapped in place without subsequent transport.

While the concept is clear, further studies are needed to objectively interpret archaeological Cortex Ratios. Specifically, we would like to know how far the ratio has to deviate from a value of 1 to indicate with confidence the effects of artifact transport.

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Likewise, we currently lack a sound statistical basis with which to interpret variation in Cortex Ratio values for different archaeological samples. The purpose of this paper is to investigate the use of Monte Carlo sampling approaches to derive sampling distributions for the Cortex Ratio that, in turn, will allow us to assign a probability for rejecting or accepting the null hypothesis that differences between archaeological Cortex Ratios are due to sampling error alone. We will then apply this method to the Cortex Ratios from several French Middle Paleolithic assemblages.

2. Background

Aside from the original experiments by Dibble et al. (2005), the robustness of this methodology has also been repeatedly verified by other experimental testing (Douglass and Holdaway, 2011; Douglass, 2010; Douglass et al., 2008; Holdaway et al., 2008; Lin et al., 2010; Parker, 2011). Subsequent applications of this approach demonstrated its feasibility for assessing the relative extent of artifact transport and, hence, the degree of past mobility (Dibble et al., 2012; Douglass, 2010; Douglass et al., 2008; Holdaway et al., 2010, 2012, 2013; Phillipps, 2012). Differences in cortex composition among lithic assemblages therefore provide an objective and quantitative way of comparing variation in the patterns of past movement and technological behavior.

To date, the most thorough application of the cortex approach was by Douglass (2010; also see Douglass et al., 2008; Holdaway and Allen, 2013; Holdaway and Douglass, 2012; Parker, 2011) with the mid-to-late Holocene surface lithic assemblage in western New South Wales, Australia. Other applications of Cortex Ratio includes Phillipps' (2012; also see Holdaway et al., 2010) study of lithic assemblages at stratified Neolithic sites in the Fayum, Egypt, and Dibble et al.'s (2012) study of the Middle Stone Age site of Contrebandiers Cave, Morocco. Other research have also applied the cortex approach to contexts where the primary knapped materials existed in more varied forms, such as large blanks, as opposed to cortical nodules (e.g., Brown, 2011; Ditchfield et al., 2014).

These studies have all helped to demonstrate the effectiveness of the cortex methodology in capturing the relative amount of cortex to volume of a given archaeological sample. However, a calculated ratio value is simply a number at this point, and it is less clear how different Cortex Ratios can be compared objectively. This problem raises two key issues. First, how do we assess whether the cortex composition of a given assemblage is different from that of a complete assemblage not influenced by artifact transport? That is, how can we determine with confidence that a ratio value above or below 1 does, indeed, indicate that transport has affected assemblage composition? For example, do the ratios of .7–.9 observed by Phillipps (2012) at the Fayum reflect real cortex deficits, or could they instead be due to sampling error? The second issue relates to the method of determining if Cortex Ratios between two different assemblages are indeed different from one another at a given level of statistical significance and thus reflect different patterns of production, selection, transport and discard. In Dibble et al. (2012), while the Aterian assemblages at Contrebandiers with ratios in the .5 range have less cortex relative to artifact volume than the Mousterian assemblage that has a ratio of .7, it is impossible to say immediately whether this difference is significant or, again, whether it is simply due to sampling error.

3. Archaeological assemblages

The archaeological data used here are from three Middle Paleolithic sites located in southwestern France. The rationale for the use of these sites is that they contain a range of assemblage sizes among stratigraphic layers that allows the assessment of sampling error in Cortex Ratios. Their spatial proximity and diachronic lithic sequence spanning the late Pleistocene across different Mousterian industries also offers the potential for comparing different Cortex Ratio values with existing models of Neanderthal mobility in Western Europe (e.g., Delagnes and Rendu, 2011).

Roc de Marsal is a small cave site located in a small tributary valley of the Vézère River in the Dordogne region of southwestern France. Original excavation of the site was carried out by Lafille from 1953 to 1971. The study presented here is based on material from new excavations that took place from 2004 through 2009 (Sandgathe et al., 2011a, b; Turq et al., 2008). A roughly 2 m stratigraphic sequence containing 13 stratigraphic layers was recognized, of which Layers 13 through 10 at the base of the sequence represent sterile layers formed through in situ weathering of the limestone bedrock (Sandgathe et al., 2008, 2011b). Thermal luminescence (TL) and optically stimulated luminescence (OSL) dates obtained on sediment samples from these basal layers indicated that initial occupation of the site occurred in Marine Isotope Stage (MIS) 5a (Guérin et al., 2012; Guibert et al., 2009; Sandgathe et al., 2008).

Artifact densities in the Paleolithic layers 9 through 2 are very high, with over 23,000 lithic artifacts greater than 2.5 cm in maximum dimension. The lower layers (9–5) contain Mousterian artifact assemblages that are relatively high in Levallois components and include some so-called Asinipodian or small-flake production elements (Bordes, 1976; Dibble and McPherron, 2006, 2007) and relatively few scrapers. The abundance of fauna remains belonging to forest adapted species, including red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), horse (*Equus* sp.), and wild pig (*Sus scrofa*) (Castel et al. in Sandgathe et al., 2008) throughout these lower layers indicates a more temperate climate, although recent OSL and TL dating by Guérin et al. (2012) suggest the association of these layers with the colder MIS 4.

The upper layers (4–2) saw a change in the lithic assemblage with greater frequencies of scrapers, including numerous diagnostic Quina scrapers. A dominance of reindeer (*Rangifer tarandus*) and various vole species, including common vole (*Microtus arvalis*) and water vole (*Arvicola terrestris*), from these layers indicate a much colder, drier and more open environment (Marquet in Sandgathe et al., 2008). Electron spin resonance (ESR), TL, and OSL dates from these upper layers suggest correlation with MIS 4 and 3 (Guérin et al., 2012; Sandgathe et al., 2008).

Pech de l'Azé IV: is one of a complex of four Lower and Middle Paleolithic sites located in the Dordogne region, about 24 km east of Roc de Marsal. The site is a collapsed cave originally excavated by Bordes (1975) from 1970 to 1977 (McPherron and Dibble, 2000). The assemblages examined here come from renewed excavations at the site that took place from 2000 to 2003. Eight major Pleistocene layers were identified that in general matched the sequence identified by Bordes (Turq et al., 2011). The basal layer, Layer 8, rests directly on bedrock and contains rich Middle Paleolithic materials as well as numerous superimposed combustion features (Dibble et al., 2009; Goldberg et al., 2012). The lithic components are marked with high frequencies of scrapers and Levallois elements. Recent TL dates attributed this basal layer to MIS 5c (Richter et al., 2013). The overlying Layer 7 represents a solifluction lobe, which is indicated by a general lack of faunal material and a large component of heavily rolled, rounded, or edge-damaged lithics (Sandgathe et al., 2011b). This layer is capped by a layer of major roof fall, thus providing further evidence of severely cold conditions during its formation. Layer 6 (subdivided into 6A and 6B) contain lithic elements with high scraper proportions and noticeable Levallois and Asinipodian components. The faunal record in this