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Distribution patterns of stone-tool reduction: Establishing frames of reference to approximate occupational features and formation processes in Paleolithic societies

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ABSTRACT

The main goal of this work is to illustrate the interpretative potential of regionally oriented tool-use-life approaches to infer patterns of mobility, occupational intensity, and assemblage formation processes. We apply a wide reduction analysis to 15 Late Upper Paleolithic lithic assemblages. We perform an exploratory data analysis to observe reduction intensity tendencies among the different assemblages, and we characterize reduction distribution patterns using Weibull probability distribution functions. To avoid sampling effects, resampling and bootstrapping were performed. The Weibull profiles of the analyzed data show different degrees of occupational intensity and/or length that are not observable through the classical techno-typological approaches. A referential reduction space is also simulated to create a frame to interpret our results in a more absolute scale.

1. Introduction

Stone tools were used by prehistoric societies for a large variety of daily activities. Inherently, some of the features characterizing the archaeological stone tool associations recovered by archaeologists should allow us to infer patterns of economic (Binford, 1977, 1979, 1980) and cultural organization of the prehistoric groups. The levels of inference performed through the study of lithic remains are closely related with the depth of the analysis and the outlined questions about the prehistoric dynamics. In some cases, the single appearance of a particular tool type or technology is enough to answer some of it, but this only covers classification, the lowest level of analysis that archaeologists can conduct. Notwithstanding, a classificatory approach is not enough to define structural social patterns or ranges of behavioral variability, especially between highly analogous assemblages of stone tools. The identification of regional settlement and mobility dynamics, the definition of site functions, or the establishment of land-use patterns represents the inferred results from approaches such as raw material procurement, knapping strategies or tool maintenance and discard (*e.g.*, Bamforth, 1990; Andrefsky, 1994; Bicho, 2002; Aubry et al., 2012).

Ever since the empirical application of the "reduction thesis" precepts (Fig. 1) (Dibble, 1984, 1987a,b, 1995), reduction patterns, understood as the life history of every single tool (from the time that it is shaped or detached from a core until it is refused), have been largely explored and have been found to have a great potential in the identification of past dynamics (see Andrefsky, 2009 and Andrefsky and Goodale, 2015 for detailed reviews).

To illustrate this potential, the reader can picture two assemblages with exactly the same composition, and assume the degree of reduction of each one must be correlated only with the amount and duration of the activities performed during the occupation of the sites. In a basic scenario, if one site is occupied continuously for several weeks, the observed reduction and discard patterns at the end of the occupation must be different to those displayed by a three-day bivouac campsite or even a site occupied during the same several weeks but only for the performance of particular activities in a daily mobility schedule. In every case, the resulting assemblage should be generally determined by the economic value of raw material in every systemic context.

According to this, the characterization of the assemblage reduction structure has evident implications in terms of occupation patterns, site function, mobility dynamics, regional networks, or in site formation processes (Schiffer, 1987). Thus, a standardized tool to analyze and compare reduction structures implies an important

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Fig. 1. Reduction process on an experimental endscraper.

step forward in the analysis of lithic assemblages, and this is what survival analysis applied to stone tools provides.

Reduction intensity approaches necessarily imply the study of the mathematical distribution of the reduction values. According to this idea, Shott and Sillitoe (2004) recovered the Schiffer (1975) note remarking "that unless all specimens in a category had identical histories, however, the distribution of use-life values is as important as its central tendency". Reduction intensity applied to every single tool is important *per se*, and the singular distribution of individual reduction intensities in a continuous space can be more informative about the occupation patterns than the average value of all of the artifacts.

One theoretical reduction distribution may be observed in an assemblage characterized by similar proportions of poorly reduced and highly reduced tools. This situation could be ideally interpreted to be singular of an organizational scheme where tools are initially shaped and used at one site, then transported and progressively used at some other independent sites; finally, a few of them are carried back to the first location and abandoned there when they are exhausted. In this case, an averaged value of the reduction intensity would probably lead to interpreting the site as a middle-intensity occupation where tools were reduced until half of their maximum potential.

To enhance this coarse-grained view of using averaged reduction values, it is necessary to work with the individual reduction value for each tool, taking it as a single and measurable prehistoric event. This value represents the amount of extracted utility of a single tool at the discarding time (Shott, 1996). Therefore, tools can be analyzed individually in terms of how many time they have been "surviving" in its prehistoric economic context. The integration, at the assemblage scale, of these tool "surviving times" build-up the survival distribution of the archaeological tool assemblages. The application and utility of survival distribution dealing with lithic assemblages has been repeatedly demonstrated by Shott studies on different types of tool classes (Shott, 2002; Shott and Sillitoe, 2004, 2005; Shott and Seeman, 2015). The reduction pattern of each assemblage can be understood in terms of tool discarding or survival dynamics and expressed as a probability distribution. This work follows recent methodological proposals (Shott and Seeman, 2015) to analyze tool reduction as Weibull distributions and to calculate Weibull parameters, Weibull probability distribution functions (pdf) and cumulative failure plots.

Distribution patterns of reduction, as a part of tools' use-life, has been explored for singular scenarios and concrete situations (see (Shott and Seeman, 2015) and references for a review), but no attempt to unravel regional prehistoric dynamics through the empirical comparison of sets of reduction patterns has yet been made. In this work, we address the information provided by survival analysis of a whole regional context to characterize prehistoric site occupational patterns and to identify prehistorical dynamic processes.

An exploratory and scaled analytical procedure has been established to look for the inferential power of each methodological step, and the full set of raw data is provided as Supplementary Data S1 to give the possibility of testing and exploring the presented method. A final objective of establishing robust frames of reference for the interpretation of stone tool analysis results is desired, and we consider that this proposal can result in a useful tool to progressively achieve this goal.

2. Materials

To illustrate the different steps of the methodological approach using real data, assemblages from a well-studied prehistoric context formed by 15 archaeological Late Upper Paleolithic layers from five different sites with the same geographical and environmental constraints have been selected for the study. Fixing the geographical variable as a common trend in all of the sites, we can partially dismiss the role of divergent local adaptive behaviors to climate, unequal resource distribution, raw material constraints or established mobility routes *inter alia* during the interpretation of the results. Assuming that this uniform chronological and geographical site distribution entails a similar or at least comparable behavioral, and economic frame, it is possible then to focus on the variability explained by the reduction patterns as a non-dependent and standardized variable.

The selected sites are located in the north-eastern region of the Iberian Peninsula (Fig. 2), a Mediterranean-influenced territory that is characterized by the coexistence of sea-level littoral and pre-littoral plains flanked by mid-altitude mountain ranges that barely surpass 1000 m.a.s.l. This enclosed distribution configures an independent biotope at the end of the Ebro basin, which encompasses the northern area of the Iberian Peninsula. The high abundance of knappable raw materials is one of the most important features generating territorial uniformity, especially from a Paleolithic forager perspective. Many chert-rich Muschelkalk, Lutetian/Bartonian and Sannonian formations have been identified along the mountain ranges (Soto et al., 2014). These formations are drained by small independent fluvial basins rising in the ranges