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Analytical potential of 2D shape analysis to study Epigravettian lithic assemblages

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***Abstract* – In this paper we apply for the first time a 2D shape analysis to a sample of Epigravettian lithic artefacts with the aim of evaluating the potential of such approach. The lithic sample comes from layer 9c2 (Evolved Epigravettian, Upper Palaeolithic) of Grotta Paglicci (Apulia, southern Italy).**

After extracting the outline coordinates from high-resolution images using the software DiaOutline, we conduct Elliptic Fourier Analysis, Principal Component Analysis, and Linear Discriminant Analysis in the R package *Momocs* to investigate the internal variability of the sample. The results of the analysis are extremely promising and highlight significant separation between common tools, laminar blanks, and backed tools. Furthermore, this analysis can be useful to evaluate the technical investment in the retouching of the blanks to manufacture backed points.

I. INTRODUCTION

This work is part of a PhD project aimed at investigating the Epigravettian hunting strategies and behavioural dynamics in Southern Italy.

The Epigravettian is an Upper Palaeolithic technocomplex attested in Italy, Southeastern France and east-west of Balkan Peninsula, and dated between c. 26-25ka and 11.9-11.6 ka cal BP [1][2] and references therein].

In Italy, the Epigravettian, based on a typological study of lithic industries, was originally defined and divided into three phases (ancient, evolved and final) by G. Laplace [3]. Later on this subdivision has often been reconsidered [e.g., 4][5][6][7]. Based on lithic technological studies, a subdivision of the Epigravettian in two phases (i.e., early and late) has recently been proposed with a chronological limit between the two around 16,000 cal BP [8]. Despite that, researchers are still discussing about the adoption of a shared model for the chrono-cultural development of this technocomplex. In Italy, the Epigravettian lithic assemblages have been analysed following a technological approach, mostly in the central-northern area of the country [5][7][8][9][10][11][12], while in the southern part this kind of approach has been applied only exceptionally [13][14]. In the light of this, it is important to conduct new studies that integrate the typological, technological, and geometric morphometrics approaches. Shape outline has often been considered an important variable in the analysis of prehistoric lithic implements. However, quantification of shape outlines is not commonly applied in the analysis of unretouched laminar products and has never been used for the study of Epigravettian retouched and unretouched artefacts. In this paper, we will thus explore the use of shape outlines in relation to the production and modification of laminar artefacts. Recent studies carried out on an Upper Palaeolithic laminar assemblage have highlighted the potential of combining the quantification of shape with techno-typological assessments [15][16]. Outline analysis offers a time-effective and reliable alternative to a landmark-based analysis [17].

Namely, for what concerns the use of this approach in the study of backed tools, its potential has been demonstrated by several studies that have pursued the aim of understanding the diffusion of a specific element through time and space and to understand interrelation between morphology and techniques applied during production processes [17][18][19].

Our contribution is to be considered a preliminary step in framing the issues surrounding the Epigravettian technocomplex, not only on a typological basis but also with an integrate modern approach, in order to understand, in particular, if the Evolved Epigravettian effectively exists in southern Italy on the basis of the evidence of technical behaviour distinguishable from the other phases.

The material analysed in this study comes from the cave of Grotta Paglicci, a key site for the Palaeolithic of Mediterranean Europe. Grotta Paglicci (Rignano Garganico – Foggia) opens on the southern slopes of the Gargano Promontory at 143 m a.s. l. [20]. The cave yielded an important Upper Palaeolithic stratigraphic sequence spanning from the Protoaurignacian to the Final Epigravettian. New multidisciplinary investigations with both traditional and innovative techniques are currently being carried out by the University of Siena [21][22].

II. MATERIALS AND METHODS

The analysed material is a sample composed of entire laminar blanks and retouched artefacts retrieved from the layer 9c2 of Grotta Paglicci attributed to the Evolved Epigravettian (18,002-18,956 cal yr BP [20]).

The dataset sums to 49 items belonging to different classes and technological categories. The lithic sample were analysed using a technological-typological approach [23], [24] and each artefact was attributed to a specific reduction sequence and phase (i.e., initialization, management, and production).

In order to conduct a shape outline study, we took pictures of each implement in dorsal view and oriented according to the flaking axis. To facilitate the later processing of figures, photos were processed in Adobe Photoshop.

Subsequently, we imported the photos in the open-source software DiaOutline [25] and we automatically extracted the coordinates of each item. Coordinates were saved in .txt format and were imported in R [26] to conduct shape analysis in the package *Momocs* [27]. We followed the required steps to center, scale, and rotate all outlines, prior to performing Elliptic Fourier Analysis (EFA). We used 24 harmonics after estimating the harmonic power in *Momocs*. Principal Component Analysis (PCA) was then performed on the Fourier coefficients to explore shape changes across the sample. We selected the first three principal components (PCs) to further explore differences based on the screen-plot technique [28] (Fig.1). Finally, we used Linear Discriminant Analysis (LDA) implemented in *Momocs* [27] to further explore variability.

III. RESULT

All analysed artefacts are made on chert and can be assigned to three different type of blanks; blades, bladelets, and microbladelets (Rossini et al. in preparation).

The main results of the technological analysis are shown in Table 1. The sample consists of 49 items divided into 41 unretouched blanks (23 blades, 10 bladelets, and 8 microbladelets) and 8 retouched artefacts. These are composed of 4 backed points (PD4) and 4 common tools (two end-scrapers, one bec, and one side scraper). The metric attributes of artefacts (length, width, thickness) are shown in Figure 1.

Figure 2 presents the shape variation explained by the first three PCs. PC1 refers mostly to elongation and slenderness, while both PC2 and PC3 define the degree of distal asymmetry and broadness of the apex We assessed differences in the studied sample using a PERMANOVA test on the first three PCs, finding a significant variation ($F = 8.208$, $p < 0.01$).

Table 1. Technological classes and categories divided according to reduction sequences. Init: initialization; Man: management; Prod: production; Tot: total; Microbl: microbladelets

	Init	Man	Prod	Tot
Backed tool	**1**	**-**	**3**	**4**
Bladelet	1	-	3	4
Tool	**1**	**2**	**1**	**4**
Blade	1	2	1	4
Blank	**3**	**24**	**14**	**41**
Blade	1	19	3	23
Bladelet	-	4	6	10
Microbl	2	1	5	8
Tot	**5**	**26**	**18**	**49**

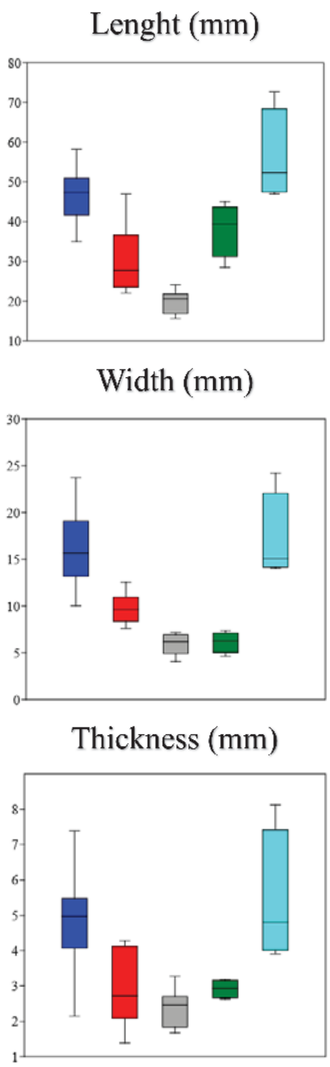

Fig. 1. Boxplot showing the distribution (in mm) of length, width, and thickness in blades (blue), bladelets (red), microbladelets (grey), backed tools (green) and tools (cyan).

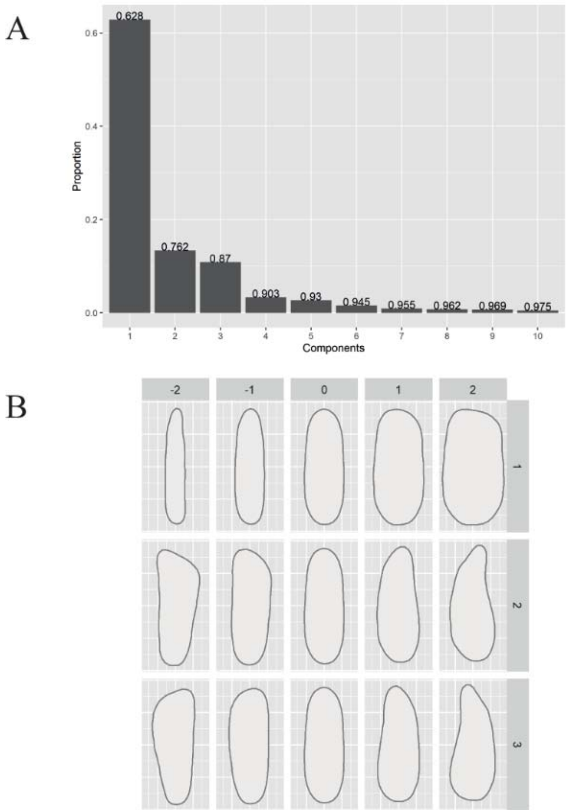

Fig. 2. Results of the 2D shape analysis: ***A*** *displays the proportion of variance explained by the first ten principal components.* ***B*** *presents the shape variation of the first three principal components.*

The most interesting outcome of the PCA is represented by the clear cluster formed by the backed points in the negative extreme of PC1 (Fig. 3).
Furthermore, the blank class occupies a larger portion of the PCA space, highlighting a significant variance within this group, which is indeed formed of blanks belonging to different stages of the core reduction.
In the light of these results, we observe a low variability of shapes for backed point which form a highly homogeneous cluster compared to the variability of blanks and tools.
On the other hand, backed points appear to be highly standardized tools that were selected and further modified according to a specific tool design.
The LDA further supports these results. Figure 4 displays the results of the LDA after a leave-one-out cross-validation. Overall, almost 80% of the analysed sample has been correctly classified. Remarkably, all backed points were correctly classified. Interestingly one narrow bladelet blank (ID 408) has been classified as a backed point. Its shape, size, and technological attributes (such as the trapezoidal cross-section, and the flat bulb) suggest that this artefact could have been selected to manufacture a backed point with little investment in the retouching of the back (Fig. 5).

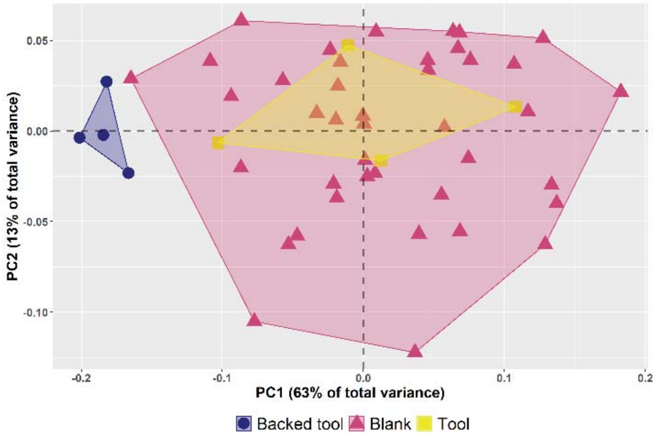

Fig. 3. Bivariate plots of the first two principal components (PC1 versus PC2). See legend for colors.

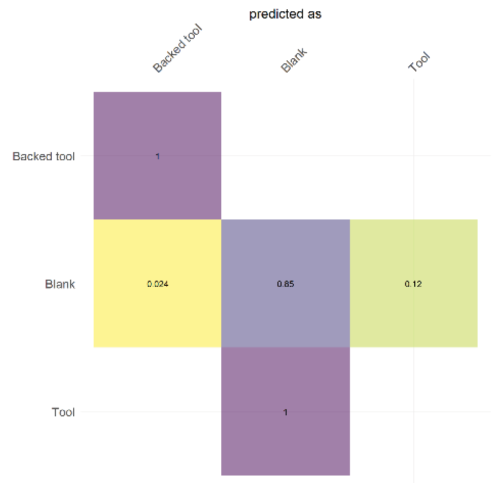

Fig. 4. Results of cross validation tests over LDA inputs. The rows show the class of artefacts and the columns show the prediction.

Fig. 5. On the left side backed point (PD4, ID 32) and on the right side the bladelet (ID 408).

Despite this interesting case, our results suggest that the shape of Epigravettian backed tools was drastically modified during the retouching phase. However, we underline that it will be necessary to implement this data with the ongoing study of the entire lithic assemblage to better understand Epigravettian behaviour in relation to the manufacture and use of backed points.

IV. CONCLUSION

In this work, we discussed the potential of applying 2D shape outline analysis to an Epigravettian assemblage. This analysis allowed us to quantify the difference between shape outlines of common tools, laminar blanks, and backed tools and to discuss the technological implications of such variability.

The future aim will be to increase our dataset with new data to conduct a comprehensive study on the different morphologies of the blanks linked to different reduction sequences and to compare it with other Epigravettian lithic assemblages. Another objective will be to compare the backed points with those of other Epigravettian contexts chronologically and geographically differentiated.

The methodology used in this work opens important perspectives for the routine implementation of morphological analyses complementary to the classical technological analysis. These analyses will support, complete and clarify the qualitative observations that form the basis for the definition of the different techno-economic groups within the lithic assemblages.

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