Advanced digital approaches to functional analysis of Palaeolithic grinding tools

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Introduction

Macro-lithic tools, such as grinding tools, are among the most relevant tools for the reconstruction of the environmental context, the behaviour, and the social organisation of past human communities. The functional study of these artifacts allows to identify some productive activities which are difficult do detect otherwise in the archaeological record, such as, for example, the production of vegetal based food.

Traceology, residue analysis, and experimental archaeology have the potential to provide a reliable basis for functional analysis, in order to reconstruct the operational chain and the use of these artefacts and evaluate the past subsistence economy. Furthermore, the integration with digital heritage technologies may improve the reconstruction of the nature of prehistoric tasks and resource utilization. Numerous previous studies[1] have demonstrated the huge potential contribution of these approaches to better understand aspects of the human evolution still unknown.

The work presented here aims at better understanding the functions, the use(s), and the possible manufacturing processes of artefacts mainly – but not exclusively - involved in the processing of vegetal resources during the Upper Palaeolithic period. Using experimental archaeology, digital heritage techniques, scientific visualisation and archaeological sciences, it is possible to test and create a validated methodology to capture, annotate and describe traces and functional areas on Ground Stone Tools (GSTs) mainly used to process wild plant materials. The framework of this research is constituted by two main projects: “PALEO-DIET”, led by the Cyprus institute – Science and Technologies in Archaeology Research Center in collaboration with the Russian Academy of Science and “PLUS_P – Plant use in the Palaeolithic”, guided by the Italian Institute of Prehistory and Protohistory (IIPP).

It is intended to propose an integrated methodological approach, based on macro and micro investigation of the 3D geometry of Ground Stone Tools’ working surface, centred on the analysis of

[1] See for example Adams et al., 2009.

their surfaces' roughness and related use–wear traces. Functional areas will be first delineated by changes in surface roughness patterns and further investigated microscopically at various magnifications, in order to isolate and describe use-wear traces, coupled with analyses on the residues associated with wear-traces.

Materials and methods

Artefacts, mainly pebbles without traces of lithic reduction, were selected for the study. The artefacts show morphometric characteristics potentially referable to grinding / pounding activities, such as grinding stones, pestles, etc. The archaeological implements object of this work come from the Gravettian seasonal site of Bilancino (Italy), dated to 30,000 BP[2].

Furthermore, it was necessary to select experimental Ground Stone Tools to be used as a reference to be compared both at the macro and microscopic level to the original artefacts. Several experimentations were carried out, particularly to understand the processing of *Typha* sp. The implements used in these experimentations were used as comparative samples.

In order to develop a geometric surface analysis and a punctual annotation methodology of the use-wear present on the Ground Stone Tools, it is intended to perform on each implement (both experimental and archaeological):

- a 3D documentation based on geometry and rugosity analysis using a high-resolution structured-light scanner (Fig. 1). The 3D models created are measurable and allow the collection of quantitative data related to the morphometry of the single traces, the functional areas and the overall object and will constitute also the basis for the punctual annotation of the traces and the functional areas;
- the observation and analysis of the Ground Stone Tools at low and high magnifications using the digital microscope (Fig. 2), in order to analyse functional areas at both a macro and micro scale. By combining the analysis of macro and micro wear identified over a tool's surfaces, it will be possible to isolate features associated with the worked material, as well as to the specific gestures applied during its processing. The results of this study might be also useful to address future samplings methodologies for residue analysis;
- the sampling of identified functional areas on the Ground Stone Tools in order to collect, observe and determine residues, according to Revedin et al. (2017);
- the development of a scientific visualisation platform where results from the various techniques used (SEM, digital microscopy, etc.) are integrated and interrogated;

To manage and describe the heterogeneous type of data (both qualitative and quantitative) produced by the analysis of these artefacts, the CIDOC-CRM ontology has been applied (Fig. 3), integrating different extensions of CRM[3]. The objective is to clarify the process of data acquisition, trying to build the model by following pre-existing and often non-homogeneous bibliographic information related to grinding stones. Moreover, this is an attempt to create a framework suitable to become the core schema of the graph database of the work.

[2] Aranguren et al., 2008.

[3] The reference technical documentation for the construction of the model is the "*Definition of the CIDOC Conceptual Reference Model*", v. 7.0 June 2020, and its extensions CRMarchaeo v. 1.5.0 February 2020, CRMsci v. 1.2.8 February 2020, CRMdig v. 3.2.1 April 2016 and CRMinf v. 0.7 February 2015.

The final product will be a 3D GIS for each artefact, integrating morphometric data and the results of residue analysis, with the exact position of the traces and the functional areas on the artefact. The use of 3D technologies in the reconstruction of these tools has the potential to allow the geometric analysis and characterisation of single traces and functional areas of the stone. In this way, it will be possible to analyse and interpret the kinetics of the tools, to better understand behavioural aspects of prehistoric humans.

The results of this study might be also useful to address future samplings methodologies for residue analysis. The key innovation is the multidisciplinary approach merging experimental archaeology and digital heritage technologies applied to the archaeological samples. The project can be extremely beneficial to provide a model for future investigations on artefacts related to the exploitation of vegetal resources and other raw materials, maximising data acquisition while minimising the manipulation of archaeological tools.

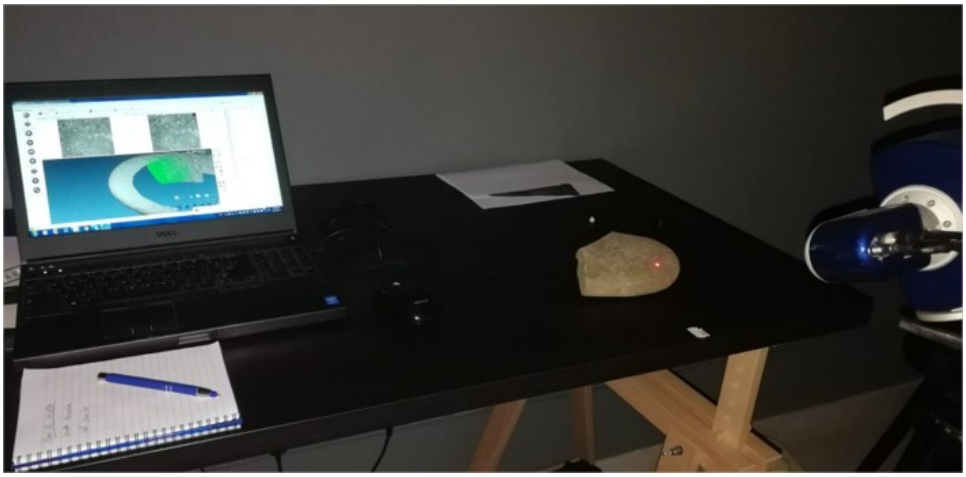

Fig. 1. The 3D scanning of an experimental grinding stone at the Cyprus Institute – Andreas Pittas Art Characterization (APAC) Laboratory (© S. Florindi).

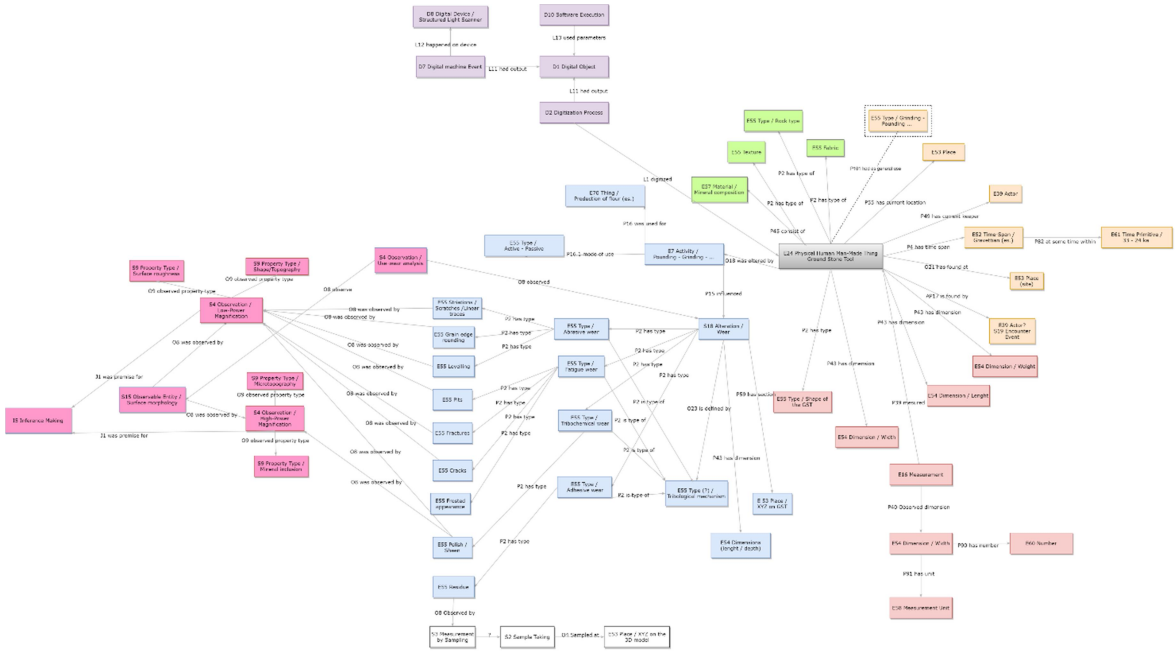

Fig. 2. The observation of an archaelogical ground stone found in the gravettian site of Bilancino (Italy) under the digital microscope. The use-wear analysis of the artifacts was performed at the Cyprus Institute - Andreas Pittas Art Characterization (APAC) Laboratory (© S. Florindi).

Fig. 3. The draft of the CIDOC- CRM ontology designed for the study of the Ground Stone Tools (© S. Florindi).

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