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NEW INSIGHTS IN CERAMIC & METALLURGICAL TECHNOLOGIES

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Introduction
New Insights in Ceramic & Metallurgical Technologies

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From 5 to 9 October 2020 took place the first International Doctoral Summer School organised by the Department of Prehistory and Archaeology of the University of Granada, the Archaeometry Laboratory 'Antonio Arribas Palau', the Unit of Scientific Excellence Archaeometrical Studies. Inside the artefacts & ecofacts and the International Graduate School.

The school was launched under the title 'New insights in ceramic & metallurgical technology' and its main objective was to create a learning and discussion forum for PhD students and early career doctors from all over the world. The participation of researchers of the highest calibre also provided them with the opportunity to obtain excellent feedback on their ongoing research. To this end, the sessions were organised with a first formative part with master classes by the invited experts and a second part of sessions in which the participants presented their own work and had the opportunity to comment and discuss it with them. As a result of this enriching and stimulating forum, this volume crystallises in which we have examples of the most recent research work on ceramics and metallurgy in Archaeological Sciences.

The metallurgical sessions took place during the first three days of the school. The first session was given by Prof. Marcos Martinón-Torres, Pitt-Rivers Professor in Archaeological Sciences at the University of Cambridge, who gave a brilliant introduction on the Archaeometallurgy of gold, addressing methodological and archaeometric issues as well as presenting some of the latest work carried out in different parts of the world such as North Africa, the Iberian Peninsula or Colombia, providing not only a global vision of gold metallurgy but also a diachronic and transcultural one.

The second session, on the emergence and evolution of copper metallurgy, was given by Prof. Thilo Rehren, A.G. Leventis Professor for Archaeological Sciences and Director of the Science and Technology in Archaeology and Culture Research Center at the Cyprus Institute. With admirable pedagogy, Prof. Thilo Rehren gave an overview of the first metallurgical stages in Eurasia,

their dispersion throughout the continent and their subsequent technological development, excellently combining the most purely technological and archaeometric questions with the more social questions of this new technology, all exemplified in recent studies from the Near East and Central Europe.

Finally, the last metallurgical session, on 'the archaeology of iron' was given by Michael Charlton, Lecturer in Archaeomaterials at UCL Institute of Archaeology (UK), who addressed the extractive principles of this complex technology, the possibilities and potential of its study, the latest advances in iron provenance studies, as well as its social implications, offering very interesting case studies in Wales or Sudan.

In the afternoon sessions, we have the presentations and discussion of results from the PhD students and early career researchers collected in this volume. Thanks to them we have a diachronic view of case studies from all over the world. Thus, we can make a journey from the first copper and arsenical copper-based metallurgy in the Iberian Peninsula, the production of crucible steel in South-Central India, through Roman metallurgical productions in late antiquity, medieval metallurgy in frontier contexts, studies on silver coins in the seventeenth century or iron metallurgy in the nineteenth century.

On the last two days, the sessions focused on ceramic studies. Professor Héctor V. Cabadas, a specialist in the genesis and classification of soils in central Mexico and the Yucatán peninsula, from the University of the State of Mexico, gave an exceptional introduction to ceramic studies from the perspective of micromorphology, using specific case studies from his research, mainly carried out in Mesoamerica.

The closing session was led by researcher Valentine Roux, from the Centre national de la recherche scientifique (CNRS), who combined ethnoarchaeology in India and archaeology in the Near East with the aim of highlighting the anthropological regularities underlying the evolutionary trajectories of ancient technological traditions. This was the focus of his masterly, eminently practical seminar, in which it was possible to follow individual and group learning processes through the network analysis approach.

The closing session was led by researcher Valentine Roux, from the Centre national de la recherche scientifique (CNRS), who combined ethno-archaeology in India and archaeology in the Near East with the aim of highlighting the anthropological regularities underlying the evolutionary trajectories of ancient technological traditions. In this sense, he oriented his masterly seminar, eminently practical and in which it was possible to follow the individual and group learning processes through the network analysis approach.

Undoubtedly, this exceptional panel of researchers was an unbeatable way of approaching the complexity of archaeometallurgical and ceramic studies, from which the present book emanates, in which we bring together a series of works that aim to tackle from different perspectives and methodologies

case studies of various materials that will undoubtedly serve as a model for future work on the subject.

For this reason, the work incorporates two brief methodological proposals - Chapters 2 and 5 - with the aim of giving an initial perspective to the work that can be carried out on these themes in order to scrutinise information that will allow us to approach the operational chains developed in the manufacturing processes of ceramics and metallurgy.

Two case studies are presented by the researchers who attended the summer school, covering different geographical areas and chronologies, from the Copper Age in Jaén's Guadiana Menor river –Chapter 3– to the rich pastures of Mesopotamia –Ch. 4–. On the other hand, the archaeometallurgy works undoubtedly provide a rich and vast knowledge about these complex artefacts born at the dawn of the Copper Age and their extensive development during the Bronze Age –Chapter 6–. These productions will become more complex in later times and will be enriched with new metals such as iron, forming part of true votive deposits –Chapter 7– and with increasingly complex chains -Chapter 8-, until they reach true standardised processes in medieval times -Chapter 9- and pre-industrial times -Chapter 10-. The work ends with a study of one of the most commonly used metallic forms, the coin -Chapter 11-, as a reflection of the variability of forms that metal can acquire but, above all, the way in which it is implemented in the relations between East and West through the colonies.

The monograph is intended as a contribution to the work being done in these lines of research in order to generate new discussions in a discipline that is increasingly dynamic, open to other branches of knowledge and multidisciplinary, with a growing geographical spectrum that will allow the development of new discourses and, perhaps, the generation of new questions.

Introducción
Nuevos enfoques en tecnologías cerámicas y metalúrgicas

Alberto Dorado Alejos
Mercedes Murillo Barroso
Francisco Contreras Cortés

Del 5 al 9 de octubre de 2020 tuvo lugar la primera International Doctoral Summer School organizada por el Departamento de Prehistoria y Arqueología de la Universidad de Granada, el laboratorio de Arqueometría 'Antonio Arribas Palau', la Unidad de Excelencia Científica *Archaeometrical Studies. Inside the artefacts & ecofacts* y la Escuela Internacional de Postgrado.

La escuela se lanzó bajo el título 'New insights in ceramic & metallurgical technology' y tenía como objetivo principal crear un foro de aprendizaje y discusión para estudiantes de doctorados y recién doctorados de cualquier parte del mundo. La participación en el mismo de investigadores del más altísimo nivel, también les brindó la oportunidad de obtener un *feedback* de excelencia sobre sus investigaciones en curso. A tal fin, las sesiones se organizaron con una primera parte formativa con clases magistrales de los expertos invitados y una segunda parte de sesiones en las que los participantes exponían sus propios trabajos y tenían la oportunidad de comentarlos y discutirlos con ellos. Como resultado de aquel enriquecedor y estimulante foro cristaliza este volumen en el que contamos con ejemplos de los más recientes trabajos de investigación en *Archaeological Sciences* de cerámica y metalurgia.

Las sesiones metalúrgicas se desarrollaron durante los tres primeros días de la escuela. La primera sesión corrió a cargo del Prof. Marcos Martinón-Torres, Pitt-Rivers Professor en Archaeological Sciences de la University of Cambridge, quien realizó una brillante introducción llamada Archaeometallurgy of gold abordando tanto cuestiones metodológicas y arqueométricas como presentando algunos de los últimos trabajos realizados en distintas partes del mundo como el Norte de África, la Península Ibérica o Colombia, proporcionando no solo una vision global de la metalurgia del oro si no también diacrónica y transcultural.

La segunda sesión, on the emergence and evolution of copper metallurgy, corrió a cargo del Prof. Thilo Rehren, A.G. Leventis Professor for

Archaeological Sciences and Director of the Science and Technology in Archaeology and Culture Research Center at the Cyprus Institute. Con una admirable pedagogía, el Prof. Thilo Rehren realizó un recorrido sobre las primeras etapas metalurgias en Eurasia, su dispersion por el continente y su posterior desarrollo tecnológico, conjugando de forma excelente las cuestiones más puramentes tecnológicas y arqueométricas, con las cuestiones más sociales de esta nueva tecnología, todo ello ejemplificado en estudios recientes de Próximo Oriente o centro Europa.

Finalmente, la última sesión metalúrgica, sobre 'the archaeology of iron' corrió a cargo de Michael Charlton, Lecturer in Archaeomaterials at UCL Institute of Archaeology (UK) quien abordó los principios extractivos de esta compleja tecnología, las posibilidades y potencialidades de su estudio, los últimos avances en estudios de procedencia de hierro, así como sus implicaciones sociales, ofreciendo interesantísimos casos de estudio en Wales or Sudan.

En las sesiones de la tarde, contamos con las presentaciones y discusión de resultados de los estudiantes de doctorado y early career researchers recogidos en este volumen. Gracias a ellos tenemos una visión diacrónica de casos de estudio en todo el mundo. Así, podemos hacer un recorrido desde la primera metalurgia de base cobre y cobre arsenical en la península ibérica, la production of crucible steel in South-Central India, pasando por las producciones metalúrgicas romanas en la antigüedad tardía, la metalurgia medieval en contextos de frontera, estudios sobre monedas de plata del siglo XVII o la metalurgia de hierro en el siglo XIX.

Los últimos dos días, las sesiones se centraron en los estudios cerámicos. En este sentido, el profesor Héctor V. Cabadas, especialista en génesis y clasificación de suelos del centro de México y la península de Yucatán, procedente de la Universidad del Estado de México, realizó una excepcional introducción a los estudios cerámicos desde la perspectiva de la micromorfología a partir de casos de estudio específicos de sus investigaciones, desarrolladas fundamentalmente en mesoamérica.

El cierre lo protagonizó la investigadora Valentine Roux, del Centre national de la recherche scientifique (CNRS), quien combina la Etnoarqueología en la India y la Arqueología en el Cercano Oriente con el objetivo de poner de manifiesto las regularidades antropológicas que subyacen a las trayectorias evolutivas de las antiguas tradiciones tecnológicas. En este sentido orientó su magistral seminario, eminentemente práctico y en el que se pudieron seguir lo procesos de aprendizaje individuales y de grupo a través de la aproximación del análisis de redes.

Sin duda, este excepcional panel de investigadores supuso una inmejorable forma de acercarnos a la complejidad de los estudios arqueometalúrgicos y cerámicos, de lo que emana el presente libro en el que

recogemos en una serie de trabajos que pretenden aboradar desde diferentes persctivas y metodologías casos de estudio de diversos materiales que, sin duda, servirá como modelo a futuros trabajos en la materia. Por ello, la obra incorpora dos breves propuestas metodológicas –Caps. 2 y 5– con objeto de dar una inicial perspectiva a los trabajos que puedan desarrollarse sobre estas temáticas con objeto de escudriñar información que permita aproximarnos a las cadenas opertativas desarrolladas en los procesos de manufactura de la cerámica y la metalúrgica.

Se presentan dos casos de estudio presentados por las investigadores e invertigadores que asistieron a la escuela de verano, atendiendo así a diversas áreas geográficas y a distintas cronologías, desde la Edad del Cobre en jiennense Guadiana Menor –el Cap. 3– a los ricos pastos de Mesopotamia –Cap. 4–. Por su lado, los trabajos de arqueometalurgia, sin duda, suponen una rico y vasto conocimiento sobre estos complejos artefactos nacidos en los albores de la Edad del Cobre y su amplio desarrollo en momentos de la Edad del Bronce –Cap. 6–. Estas producciones se irán complejizando en momentos ulteriores y se irán enriqueciendo con nuevos metales como el hierro, formando parte de verdaderos depóstidos votivos –Cap. 7– y con cadenas cada vez más complejas –Cap. 8–, hasta alcanzar verdaderos procesos estandarizados ya momentos medievales –Cap. 9– y preindustriales –Cap. 10–. Como colofón a la obra, se aporta un estudio de uno de una de las formas metálicas más comunmente utilizadas, como es la moneda –Cap. 11–, como reflejo de la variabilidad de formas que el metal puede adquirir pero, sobre todo, el modo en que este se implementa en las relaciones entre Oriente y Occidente a través de las colonias.

Con todo, la obra pretende ser una aportación a los trabajos que vienen dándose en estas líneas de investigación con el objetivo de generar nuevas discusiones en una disciplica cada vez más dinánica, abierta a otras ramas de conocimiento y multidisciplinar, de espectro geográfico cada vez mayor que, con todo, va a permitir el desarrollo de nuevos discursos y, quizás, la creación de nuevos interrogantes.

Obtaining information from ceramics: a polyhedral perspective

Alberto Dorado Alejos*

INTRODUCTION

The fact that Archaeometry has become a discipline that works hand-in-hand with Archaeology is not something new. Its contribution to the study of artifacts and ecofacts form a multidisciplinary point of view, and reinforced by analytical techniques from other scientific fields, has created and important documental bases that substantially enlarges the empiric base upon which novel historical and archaeological knowledge is generated. Furthermore, in the last few years, and as a result of the increasing important of the application of these analytical techniques, archaeometry has grown in its representation within academic publications with different ends. In this sense, regarding the study of ceramic material, it has led to important information regarding the production process of different cultures, obtaining relevant data regarding the mobility of populations, what were their relationships were, the use of abiotic resources within a territory or the identification of new production processes.

Nevertheless, and despite the methodological advancements, it seems evident that we are at an impasse with regards to the analytical strategies, where "archaeometric innovation" is now a days almost irrelevant. Therefore, we find ourselves before publications that systematically reproduce the same techniques on different materials form different areas and cultures, but there is no interest in innovating techniques and their application to this field of study. In fact, an important part of our discipline is oriented precisely towards generating new questions regarding the archaeological materiality in hopes of possibly reaching

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new answers and formulating new questions. Without a doubt, it will be the capability of different institutions and researchers to develop new formulas of understanding cultural material where the future success of archaeometry lies. And on the contrary, if the field becomes stagnant, it will lead to parasitic conducts and consequently become subservient to other disciplines. Therefore, innovation must be an objective in and of itself. The formulation and reformulation of new questions and new recipes with which one can approach the archaeological record must be present at every stage of archaeological research.

In relation to ceramic studies, its history does not invite us to think any differently, with expectation of the theoretical point of view. This has gone through different stages until now a day reaching a certain degree of complexity which, in occasions, can lead to the mythification of the studies objects understanding them as a functional and symbolical element with great complexity. But if we accept this point of view, how can its production have extended throughout almost all prehistoric and historic societies throughout the entire planet? Maybe, in this sense, it has been the researchers specialized in ceramic studies those who have fallen into the mythification of the object, leading us to consider its production to be more complex, when in reality, productive practices involved in ceramic production are not that complex (Rye 1981), taking into account that ceramic is fundamentally clay and water exposed to fire. Therefore, the question we must ask ourselves is not what the complexity of the elaboration process of ceramic vessels is (which does exist), but to understand the complexity for people of the XXI century to determine the technical gestures and the *savoire faire* that are alien to us, and finally we must try to characterizes their attributes and functional properties.

Nevertheless, many changes have taken place throughout history in relation to the study of ceramics, which has tried to organize its production depending on different characteristics. These ceramic studies can be divided into three large phases according to Orton *et al.* (1997), who may have been influenced by the works of A. Comte and his work *A general view of positivism* (1844, 1980). The first phase is defined as the historical-artistic phase, based on the description of the object. During the 15th century, T. Ebendorfer (Orton *et al.* 1997: 17-18) describes prehistoric cooking pots discovered at Stockerau as objects *born from the soil and created by gnomes*, which would correspond to the initial phase of science itself as defined by A. Comte called the *Fictitious or theological state*. After Ebendorfer´s magical phase, P. Albinus, in 1587, would excavate prehistoric urns from Meissen with the intention of ascertaining their real origin, to prove that they had been made by humans (Orton *et al.* 1997: 20). Throughout this period there would be a growing interest in ceramics, as is the case of Weber

(1719), in such a manner that during the 18th and 19th centuries we find a completely different landscape, where studies now center on different periods and raw materials. The accumulation of different types of ceramics would lead to the development of historicization with the intention of classifying information, seen in the works of Birch (1858).

This phase would soon be surpassed by the need to classify large amounts to ceramic vessels recovered during excavations. This would lead to the works of Cochet (1860) who tried to date burials based on ceramics. Nevertheless, it would not be until the decade of the 1880´s when the first typological studies would appear (Pitt-Rivers 1906), which are continued to be made even today, though now applying statistics and is regarded as morphometry. It is important to highlight that during this period spatial and regional distribution was also taken into account, ceramic being the main directing fossils, uniting local sequences of the same region, thus defining cultural areas (Childe 1929). Derived from this, seriation would become a tool to recreate cultural chronologies based on percentual data, culminating in research such as that done by J. A. Ford (1962). But, if anything characterizes this period it is typology, which, once created, could be organized according to the idea of development and evolution. In Europe this concept would be defined based on the typical shape, to which a number would be added, and usually corresponded to the drawing of the excavation reports (Orton *et al*. 1997: 21 ss.).

Though since the end of the 18th century there have been sporadic archaeometric studies applied to archaeological ceramics (Caley 1967; Quinn 2013), it would not be until the middle 20th century when A. O. Shepard (1976) would develop an analytic methodology that, including different tendencies, was oriented to revealing the chronology based on types, the identification of materials, it provenance as well as the study of the physical characteristics of ceramics, reaching the positivist or real stage (Comte 1980), that is currently maintained in part through the description of materials. It is at this point when a new line of research begins to appear that abandons the previous methods of research and focuses its attention on the technology, the raw materials, or in how to understand the distribution of materials, based on typology and the stratigraphic sequence, establishing moments in which changes were made effect. Without a doubt, A. O. Shepard set the base for new ceramic studies that would try to debunk ceramic studies that treated ceramics only as directing fossils, centering on smaller analytical units, and opening up to a large spectrum of scientific techniques that would lead us to the point where we are today. The application of these new techniques would give Shepard the information needed to determine the large distances covered by common ceramics created by Pueblo Bonito (New Mexico). This motive

popularized certain techniques such as thin section petrography that was quickly widespread throughout the USA, Great Britain and Europe, and would be later complemented by the identification of crystalline structures through the use of X-Ray Diffraction.

The expansion of Archaeometry applied to ceramic studies also had an important influence in Spain, where a large number of significant studies began to appear. The first works date from the 1970´s (Antón Bertet 1973) center on Iberian ceramics from the sites of La Serreta, Las Bastida and Valencia, or Cerro de la Encina and Cuesta del Negro (Capel and Delgado 1978). Nevertheless, analytical studies of ceramic materials have multiplied in both number and techniques, and are currently more oriented towards the total characterization of elements that constitute a ceramic element with the intention of obtaining more precise information regarding the intrinsic characteristics of the object.

This is the point at which we find ourselves today. In the following lines we will present the classic analytical techniques applied to archaeological ceramics, as well as include some new ones that are currently being developed. Therefore, we will present the most commonly applied techniques, some of which have a long tradition within archaeometric studies such as X-Ray diffraction, X-Ray Fluorescence, or thin section petrography, and the most common uses they have. On the other hand, and taking into account the need for innovation, we will present some techniques that are currently being developed or new applications of already developed techniques, which provide novel information regarding the technical gestures carried out when creating ceramics that are found in archaeological sites. In any case, our intention is to present analytical strategies to reaching a holistic perspective that allows us to obtain answers regarding the different attributes that constitute an archaeological ceramic -or at least intend to-, though the chronological difference between the people who created them, and we who study them, may hinder our complete understanding.

APPROXIMATIONS TO CERAMIC TECHNOLOGY

Before looking at the different types of analytical techniques it is important, to first the basis upon which archaeology is based: graphic documentation. This is a fundamental part of our discipline upon which we create analogies and with them the comparison which allows the construction of stratigraphic sequences and chrono-cultural series. Therefore, the need to obtain good planimetric documentation (which include new technologies of photogrammetric modeling) must be incorporated

to ceramic studies. Thus, we must question the continuity of handmade drawings, or those that simply represent shapes or decorations, instead of applying new graphical techniques that end up generating more information and allow to envision certain aspects related to technological processes (changes in coloration, decoration, superficial voids or surface treatments) (e.g. Dorado 2012; Alba *et al.* 2017; Padilla and Dorado 2017). This is not a trivial aspect, since some of the techniques that we will see throughout the paper will recover those representation with the objective of carrying out image analysis with the intention of obtaining novel information regarding decorations lost during the post-depositional phase (Dorado 2018). Therefore, we can consider a photo of a ceramic shard -together with its profile- as a much richer representation that the tradition methods of presenting a ceramic repertoire.

Decorative Sequence

Decoration is one of the most relevant elements in some ceramic productions throughout different chrono-cultural moments, in occasions acting as a directing fossil, allowing the identification of areas of influences of sum cultures, as are the cases of Bell-Beaker productions (Harrison 1987) or Cogotas I in the Iberian Peninsula as examples (Abarquero 2005). Its importance resides, together with other traits of the ceramics and its necessary correlation to stratigraphic sequences, in its capacity to *express* some of the procedures done by potters during the elaboration of ceramics, while including a symbolic and technical language that allows us to define certain characteristics of a unique final product. To this end we propose a new model to comprehend decorations which we have defined as *decorative sequence* (Dorado *et al.* 2017; Dorado 2022). But, what is the objective of this proposal? In fact, it actually must be considered as a supporting element within the identification of different aspects that configure the *Chain Operatoire*, and therefore, determine the technical gestures done by the potter to be able to understand certain patterns in the decorative production that allows us to define the productions of one or more potters, or in more general terms, different traditions. This system allows us to identify geographic areas that belong to different ceramic tradition and a more detailed identification of production areas, as seems to have been the case of Bell-Beaker inlayed white paste ceramics (Martín Valls and Delibes de Castro 1989; Odriozola and Hurtado 2007; Odriozola *et al.* 2012; Molina *et al.* 2017).

The decoding must be carried out following basic procedures of our discipline: stratigraphy. The theoretical framework of this proposal was

previously established within architectural archaeology (Mannoni 1976; Brogiolo 1988; Parenti 1990, 2000), understanding ceramic walls the same as constructed walls, though, despite not being able to be transformed or modified over time, decoration has been constructed following a certain process that ends up creating the final composition. In the example we present we can perfectly observe the different steps that were followed when creating Bell-Beaker decoration on an ovoid vessel from Cerro de la Encina (Monachil, Granada, Spain) (fig. 1). We can see how the first step consisted in the creation of the zig-zag decoration by use of a spatula at the top of the fragment, to secondly generate a series of vertical lines created by incision that affect approximately three fourths of the preserved fragment and can be seen in the creation of the subsequent fields. After eliminating some of these lines by means of surface polishing a third decorative phase is carried out, consisting of incised horizontal lines that will conform the decorative fields- Subsequently, more zig-zag impressions are made through the use of a spatula. Finally, the last stage consists in the generation of incised oblique lines that close the bottom of each decorative field. Therefore, we can observe the fact that decoration was carried out by using both incision and impression, and that it was necessary to correct some of the patterns to allow for the elaboration of different motifs. The displacement of clay due to decoration, generated between different gestures, also invites us to believe that these gestures were carried out in a short period of time.

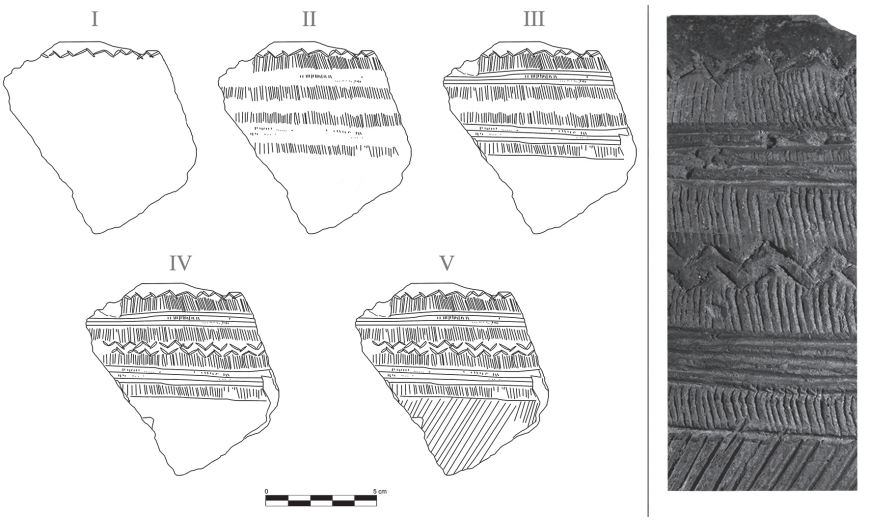

Fig. 1. Decorative sequence identified in an ovoid cup from Cerro de la Encina (Monachil, Granada, Spain) in which the different decorative gestures done by the potter can be seen (Dorado *et al.* 2017: 282, fig. 4).

Nonetheless, this method presents certain limitations that are determined by the stratigraphic relations between decorative gestures. In other words, to correctly assess the decorative sequence it is necessary that each gesture presents a certain relation to one another to be able to adequately sequence how each of them were applied by the potter. This fact substantially limits the ceramic set that can be analyzed in this fashion. Nevertheless, we consider that, in the cases were it can be applied, novel information can be obtained regarding ceramic production throughout different contexts and chronologies, as well as reveling information regarding ceramic production and the transfer of knowledge or knowhow, as are for example the relation master>apprentice.

Image analysis: recovering lost colors

Continuing with ceramic decorations, we now center on other techniques that allow for the identification of paint or slips. These types of decorations can be completely or partially lost over time due to post depositional processes which, we must not forget, which are most of the *lifespan* of ceramic elements that are then recovered during archaeological excavations. To be able to identify the use of pigments we have applied the DStretch® plug-in for ImageJ software (developed by Jon Harman) (Dorado 2018, 2019). Nevertheless, before our research, this method had already been applied to rock art (e.g. Fernández Ruiz 2009; Herrera 2009) and mural paintings (Evans and Mourad 2018), and its application to ceramic studies is marginal and has been applied to different ends to what we propose in this paper (Lahlil *et al.* 2013; Honeycutt 2015).

The protocol that must be applied for the correct interpretation of the results consists in taking high quality images with natural light upon a glass base with the objective of eliminating shading and allowing for easier processing through programs such as *Photoshop*, GNU-*Image Manipulation Program* (GIMP) or *Photoscape*. When taking photos, we avoided using artificial lighting and optic filters that could provoke interferences derived from the exposition of light or could alter the final result. Once the photographs are obtained, and thanks to the user-friendly interface of the plug-in, the processing of images and the changes in saturation, color, and contrast can be carried out quickly, being able to instantly see the results, adjusting the image according to the characteristics of the ceramic matrix (oxidizing, reduction or mixed firing).

The case study we present is a reduction fired vessel with a soft central careen form the Final Bronze Age of the Southeast form the site of Cerro del Real (Galera, Granada, Spain) (fig. 2) that had partially lost part of its decoration after having been fired, which can commonly happen in

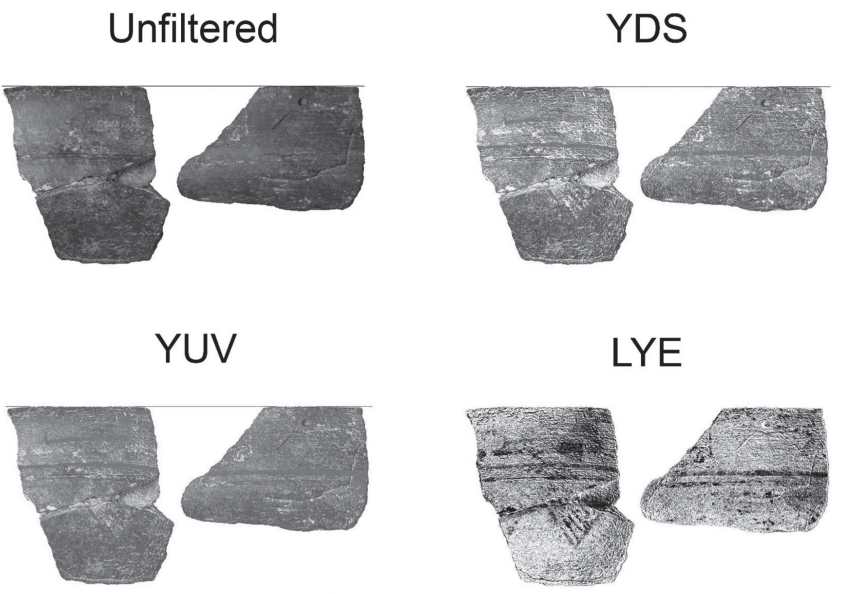

Fig. 2. Late Bronze Age cup with a central careen form the Southeast of the peninsular belonging to the site of Cerro del Real (Galera, Granada, España) having applied different filters through the DStrecht plug-in (Dorado 2018: 12, fig. 3).

other productions (Rodríguez y Celestino 2019). Thanks to the application of this new technique a more complete analysis of the decoration could be carried out, consisting of a metope at the lip, under which three horizontal lines with different width were traced, followed by triangles filled with oblique lines. As can be seen in the image, we can establish the use of at least two different minerals: red and yellow- Other studies have demonstrated the use of iron oxides (Fe_2O_3), for red tones, and goethite (α-Fe^3+O (OH)), for yellow tones (Celestino *et al.* 2018).

This is a none destructive tourniquet that can provide important information regarding the manufacturing techniques of ceramics without the need of taking samples or altering the ceramic fragment. This seems to be demonstrated by recent studies that have applied this technique after our first paper (García González *et al.* 2018; Rodríguez *et al.* 2019). Nonetheless, it has only been systematically used in one case study, regarding a large set form the Bronze Age (Late and Final Bronze Age of the Southeast) (fig. 3) and Early Iron Age (Dorado, 2019), which has allowed for the identification of decoration that was los after being buried, but the use of different tools that were unknown to have been used during this period, such as brushes.

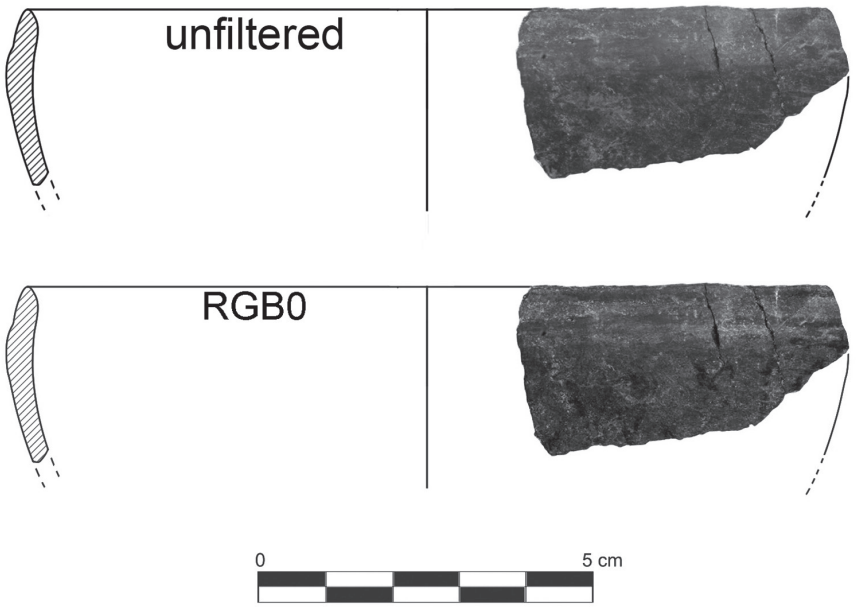

Fig. 3. Final Bronze Age Cup from Cerro de los Infantes (Pinos Puente, Granada, Spain) after having applied the RGB0 filter through the DStrecht plug-in (Dorado, 2019).

From the surface to the matrix: macro-trace and textural analysis

One of the first approximations that we must apply to the study of ceramic sets is the identification of macro-traces through the direct observation of ceramic surfaces and matrixes. This leads to more attention being given to the characterization of techniques such as modeling, surface treatments, decorative techniques and optimal approximation to firing techniques during different chrono-cultural periods. Nevertheless, its application presents certain limitations regarding the identification of minerals and rocks, and has been previously stated by different authors (De la Fuente and Vera 2015: 265, note 3): *it is important to not the submicroscopic identification of mineral inclusion through binocular microscopes (20X-40X) presents certain limitations. In my experience, after having examined mor than 10.000 fragments of recently cut ceramics, the use of a binocular microscope is restricted to the identification of the following minerals: crystalline quartz, muscovite, biotite, calcium carbonate inclusions (prior to tests with chlorohydric acid), clay inclusions, orgic inclusions, mollusks, and rock fragments at a generic level (when the presence of more than one mineral can be identified within the inclusions). In some cases, potassic feldspars can be identified if large that 1 mm and precent a certain cleavage that allows them to be seen with incidental light.*

The problem presented by G. A. de la Fuente and S. D. Vera indicates the limitations of a technique that is restricted to interpretations regarding the origin of raw materials. In fact, the observations through stereoscopy is not but the beginning of the search for more widespread answers than the mere identification of inclusions and tempers, for which more precise techniques exist. Despite this fact, there are many works that center on this type of analysis (e.g. Albero 2007; Echallier 1984; Gibson y Woods 1990: 255; Livingstone-Smith 2007; Rice 1987: 410; Spataro 2002: 37; Velde and Druc 1999: 140-176; Gámiz *et al.* 2013), though they are general supported by other studies that present a higher resolution for the identification of inclusions, such as mineralogical, chemical or petrographic analyses (e.g. Capel *et al.* 1982; Dorado 2015, 2019; Gámiz Caro 2011, 2018).

Therefore, before reaching the submicroscopic plane, we would like to highlight the importance that these studies have had regarding the identification of macro-traces, being the main objective the identification of the origin of certain traces generated during the productive process of ceramics, and can be linked to different procedures followed in a certain order. Its application began to be used in ceramic studies thanks to the results they gave regarding the definition of the *Chain Operatorie* (Roux and Miroschedji 2009; Forte 2013-14; Roux and Jeffra 2015), though its systematic application in the Iberian Peninsula is still scarce (Padilla and Dorado 2017; Padilla Fernández 2018; Dorado 2019). These studies applied concepts derived from the use-wear analyses (traceology) of lithic elements (Semenov 1964) that were quickly applied to ceramic material from both an ethnoarchaeological (Skibo 1992; Gelbert 2001, 2003; Roux 1994; Lugli and Vidale 1996) and archaeological point of view (Levi and Recchia 1995; Livingstone-Smith 2000; Livingstone-Smith and Viseyrias 2010). Though more novel is its application to metallic artifacts (Gutiérrez Sáez *et. al.* 2010; Bashore 2013).

Following the works carried out by previous authors (Skibo 1992; Gelbert 2001; Roux 1994; Livingstone-Smith and Viseyrias 2010; García Roselló and Calvo Trías 2013; Forte 2013-14), it is important to highlight certain aspects. Firstly, the identification of voids or empty spaces that can appear during the configuration of the ceramic body on the surface of vessel, both within its clay matrix and surface topography. Secondly, the identification of the orientation of fractures. And finally, the identification of other attributes such as shine, color, granulometry, and microtopography for the identification of modeling patterns (pitching, molding, roles, coiling, wheeled ceramics or mixed techniques) (fig. 4), as well as the identification of striations and their size which can allow us to identify the tools used for surface treatments. In this sense, we can combine experimental studies with the observation of archaeological

artifacts that allow for a better understanding of the production process to technical gestures in combination with the data obtained from macroscopic observation.

Fig. 4. Examples of macro-traces identified in ceramic production from samples from Los Millares (Sante Fe de Mondujar, Almería, Spain): a) basket traces used for molding (inv. nº LM-106031-12) and b) macro-traces linked to the modeling using the coiling technique (inv. nº LM-37082).

Has we have previously seen, the information that can be obtained from decoration can go beyond the basic description or definition the execution sequence. Now, we center on the identification of the techniques used for their development and, when possible, its iconographic interpretation. In other cases, as a consequence of the necessary *cultural jump*, we can at least present a simple description of the traces. By carrying out a study of the surface and matrix, we always look for elements that allow us to define the modeling techniques, surface treatments, and firing conditions, regarding the nature, order, morphology, etc. of the ceramics (Albero 2011a; Buxeda y Tsantini 2009; Capel 1978; Capel *et al.* 1982; Cuomo Di Caprio 1984: 187; Echallier 1984; Gámiz Caro *et al.* 2013; Orton *et al.* 1993; Velde y Druc 1999). Therefore, firstly, we will define the tonalities of the fine fraction differentiating the different elements that compose it, such as the nucleus of the matrix (N.), the area between the nucleus and the outer wall (Out. W) and the area between the nucleus and the inner wall (Inn. W.). In any case, the description of these sectors will give us an approximation to the raw materials used (Esbert *et al.* 1997), as well as the

variations suffered during firing depending on the level and regularity of being exposed to oxygen. In this sense, we recommend J. Capel *et. al.* study (1989-90) for the description of the areas that are present within the matrix as well as their order and relation between one another.

When determining the size of the tempers we must there are many methods and proposals to do so. But, without a doubt, the case study of each researcher will determine the parameters that are chosen for the study, given that they are the best to resolve the particular problem at hand. Coherence leads us to think that we cannot compare Neolithic productions to Bronze Age or Roman ones, each presenting different production models. In other words, any study must take into account which parameters are comparable to other production sequences or places, and their tables must be explicitly presented so they can be comparable for other researchers. There are many proposals regarding the granulometry of tempers and their morphology (e.g. . Gámiz *et al*. 2013) or their presence (e.g. Bullock *et al.* 1985; Stoops 2004) which can be followed to determine different aspects. Among these, the data obtained can be oriented to determine the degree of treatment of the raw materials (adding, grinding, shifting or levigation) or the possible aspects regarding the final quality of the production (exposition to fire, storage, etc.) as well as the obtention of raw materials in relation to angle and sphericity (Orton *et al.* 1997: 268, fig. A.5; Gámiz *et al.* 2013: 374, fig. 7). Nevertheless, currently, this model, more useful for semiquantitative approaches, is being surpassed by image analysis, which allows for a more precise quantification of inclusions and tempers within the ceramic matrix (Velde and Druc 1999: 198; Pijoan *et al.* 1999, 2002; Middleton *et al.* 1985; Fieller 1991; García del Amo 2000; Barceló *et al.* 2001; Polvorinos del Río 2001; Polvorinos del Río *et al.* 2003; Livingstone-Smith 2007; Livingood and Cordell 2009; Albero 2011a).

Colorimetric analysis

We have recently started using different techniques that can allow for a better identification of certain aspects that, generally, can vary according the observer: as is the case of color (Dorado, 2019). In this sense, the colorimetric study applied to the identification of changes in the color tones of ceramic surfaces and/or matrixes we be very useful when trying to establish the firing techniques. Furthermore, when we speak about color, we refer to the visual perception generated by our brain based on information gathered form our visual organs, which capture part of the visible spectrum that distinguish different wave lengths. Therefore, any illuminated body projects certain wave lengths that are captured by