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Time uncertainty, site formation processes, and human behaviours: New insights on old issues in High-Resolution Archaeology.

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1. Introduction

Time is a widely applied concept in archaeology. Going further, we can assert that it is a foundational concept of this discipline. The main aim of archaeology is to study the behaviours of past populations and changes over time. ‘Before’ and ‘after’ are terms continuously used to describe, infer, and interpret archaeological contexts, past human behaviours, and cultural processes. The growing emphasis on radiocarbon dating, thanks to new methods and better quality control on samples (Wood, 2015), and the improvements in archaeological computing are leading to crucial advances in studying changes between regions across large block of time. These include, but are not limited to, the origin and spread of agriculture (Fuller et al., 2014), the transformation of social networks affected by long-distance migrations (Mills et al., 2013), and the relation between demographic processes and cultural changes (Riede, 2009; French, 2016).

However, in archaeology, we do miss a critical consideration of how time is registered in the archaeological layers and in the culture material that is stored in them. Studies traditionally have assumed that the materials found in a single archaeological layer were the result of a single occupation at the site. This means that the archaeological record is viewed – and studied – as the result of contemporaneous activities carried out by the same human group, without considering depositional processes and post-depositional disturbances. The limitation of this approach is that different items that are related to different and not necessarily connected import, export, production, foraging, and discard events are mixed together (Vaquero, 2008; Rivals et al., 2015; Romagnoli and Vaquero, 2016). Furthermore, it is currently impossible to obtain absolute the dating of each episode due to the short temporal gap between them that is not measured by absolute dating.

Consequently, the analytical units that are traditionally used in archaeology ('layer', 'horizon', 'phase', and 'culture') underestimate the variability of human behaviour at short temporal scales and homogenise our vision of past lifestyles in an inaccurate way. Indeed, the most visible behaviour in an archaeological horizon was not necessarily the most common, and we can lose the real rate of change in the archaeological record on which is based our definition of a cultural time period (Perreault, 2018).

Part of the problem is the huge amount of new discoveries and the advances in computational modelling that have led to the creation and processing of 'big data'. The use of these giant datasets is often the purview of specialists that have little understanding of specific archaeological problems such as taphonomy and low-scale temporal resolution because they relate to very different disciplines (e.g., computer sciences or physics), or because they are more comfortable with the empirical approach as opposed to 'getting the hands dirty' which is necessary when dealing with archaeological material.

None of that means, however, that the classical analytical units are not useful or informative (Nishiaki et al., 2017). Their most relevant contributions are, in our opinion, the creation of comparable categories that are advantageous for solving specific research questions on a large scale (as in the cases cited above), for obtaining large samples to be processed statistically, and for assigning a specific archaeological context to a cultural period.

The study of past cultures starting with the appearance of hominins on the planet has always been the focus of Archaeology and has allowed researchers to approach studying the behavioural evolution of humanity. What we are proposing is the need to reduce the scale of analysis of the archaeological record in order to enlarge our understanding of adaptive, flexible, and variable behaviours in past human groups and thus contribute to richer and more all-inclusive interpretations of the past. Furthermore, this approach could contribute to overcoming some concepts and models according to a renewed view over the archaeological record. We can define this as a new field of research: High-Resolution Archaeology. In this paper, we listed some of the contributions of current high-resolution research that is shedding new light on the contents of archaeology, also presenting the implication of these works to the categorization and interpretation of past human behaviours. Before we enumerate them, we examine some of the critical concepts and methods that constitute the basis of high-resolution archaeology and we address some of the misunderstandings that are still present when referring to time in archaeology.

2. Time resolution of archaeological contexts: concepts, problems, and implications

Time is the *raison d'être* of archaeology, but also one of its main problems. Through archaeology, we can access our most remote past and work with temporal scales to which very few disciplines can hope to achieve. Time is the essence of archaeology, but also that of the material entities with which archaeologists work: archaeological remains and assemblages of remains. Each of the material items that we find in a site is the result of a sequence of events developed over a more or less prolonged period, including those related to its manufacture or modification by humans, but also those that took place from its abandonment until its recovery by archaeologists. Each of these events has left its imprint on the material remains, whose interpretation depends on the extent to which we are able to unravel this sequence. In the same way, the archaeological assemblages that have constituted our fundamental unit of analysis are the result of a sequence of formation and deformation events. The use of the term *palimpsest* to characterise both remains and assemblages, regardless of whether this

term is appropriate in a strict sense, expresses this temporal nature of archaeological realities (Bailey, 2007).

Currently, it is common to recognise that the vast majority of archaeological sites are palimpsests. However, research has lived for a long time with its back to that temporal nature. This is related to the geological criteria traditionally used to define archaeological assemblages. The stratigraphic unit has been the fundamental reference in the construction of these assemblages. Although stratigraphy incorporates a temporal component, as a sequence of strata, it contribute to the creation of an illusion of contemporaneity within each unit. Implicitly or explicitly, it has been assumed that remains found in the same stratum constitute a unit from the cultural or functional point of view. The characterisation of these stratigraphic units has been the basis for the construction of the archaeological discourse and the interpretation of the record in historical, evolutionary or behavioural terms. Often, this characterisation has been the ultimate goal of research and it is common to find in numerous works conclusions such as "level X of site Y is Middle Magdalenian" or "corresponds to long-term occupations" or "it is a place specialised for hunting".

However, that illusion of contemporaneity and consistency referred to stratigraphically-defined assemblages cannot be maintained at present. Once the temporal nature of the archaeological sites has been assumed, the possibility arises that events of very different characteristics, even apparently contradictory, may have taken part in its formation. From this point of view, the dissection of these palimpsests is a necessity in the archaeological interpretation. The identification of units of higher resolution than the stratigraphic level can reveal the variability of formation contexts, without which the assemblage-as-a-whole can express a temporal mean that simplifies and distorts the complexity of human culture and behaviour (Lyman, 2003; Monahan, 1998). It is important to emphasise that the problems derived from time averaging do not only affect the palaeoethnographic approaches to the archaeological record, but also the very definition of the chronocultural entities or techno-complexes that have been the traditional object of study from a cultural-historical perspective.

The temporal dimension of archaeological assemblages forces us to reflect on two aspects. The first is that of the different temporal scales that can be distinguished in the archaeological reality and their consequences from the point of view of the issues that can be addressed in each of them (Holdaway and Wandsnider, 2008). Using the Braudel terms, this allows us to combine, on the one hand, the great temporal trends and continuities of the *longue durée* and, on the other hand, the variability of the responses to the specific conditions that take place in the short term. The former can be recognised in the low temporal resolution of stratigraphic units or sequences, the latter in the individual events identified in contexts of high temporal resolution (Beck Jr et al., 2007; Brooks, 1982). Integrating these two temporal scales in the same discourse is one of the challenges that archaeology poses at this time (Harding, 2005). Another challenge is the identification of intermediate temporal scales, which approximate the ethnographic time to which a good part of the models used in archaeological interpretation correspond.

The second aspect that emerges from the temporal nature of archaeological reality is the need to contemplate a reading of assemblages in historical terms. When we speak about the historicity of assemblages, we refer to a very specific principle: the events that occur in a certain place depend on those that took place previously. The past is not irrelevant to understand the activities that were carried out in a site. The history of use of a space influences its subsequent use (Bailey and Galadinou, 2009), which reminds us on the other hand of the dynamic nature of the archaeological entities, which are subject to a continuous process of transformation. One of the best examples of this dynamism is the

reuse and recycling of abandoned archaeological remains, a behaviour that can substantially modify the characteristics of an assemblage (Julien et al., 1992).

The development of high-resolution archaeology is essential to address the challenges we face when temporalizing the archaeological reality. In this objective, all areas of research are involved, although some play a fundamental role, such as archaeostratigraphy, taphonomy, and spatial analysis or refitting. However, it is necessary to continue working on the extension of the temporal agenda to the whole of archaeological research. Some of the papers published in this volume are good examples of this line of research. Another pending task is to broaden the spectrum of archaeological contexts analysed from a temporal perspective. Up to now, high-resolution perspectives have been applied mainly in contexts in which the formation processes themselves had generated poorly-developed palimpsests. That is, the high temporal resolution was the result of the formation dynamics of the stratigraphic deposit. However, if we want the temporal dimension to be of general interest to the archaeologists as a whole, it is necessary to advance in terms of applying high-resolution perspectives in low-resolution stratigraphic contexts. The dissection of large palimpsests is still a pending task, for which it will be necessary to develop specific procedures.

3. Teeth as time capsules: high-resolution from stable isotopes and dental wear

Among a variety of archaeological records, faunal assemblages can provide a unique type of information about the temporal resolution in archaeological sites through approaches that were developed in the past decades. Among the fossil record, teeth have always been of interest as they are at the interface between the organisms and their environment. Teeth act as temporal capsules that record the diet of organisms. This record occurs during formation of the teeth (period of growth) as well at the time of death (Davis and Pineda Munoz, 2016). Various techniques allow access to paleodietary information at these different moments in the life of an individual. The technique most commonly employed include stable isotopes and tooth micro- and mesowear. Palaeodiet in fossil mammals is a powerful proxy for reconstructing habitats and potential shifts related to temporal or spatial changes (such as seasonal changes, migrations, and transhumance).

High-resolution analysis of tooth enamel through serial sampling along the tooth crown permits researchers to study intra-tooth variability in stable isotopes and to detect seasonal-scale dietary shifts. Serial sampling of isotopes allows tracking changes in diet and temperatures during the formation of the tooth. In Pleistocene archaeological sites, besides the reconstruction of palaeodiets, such techniques are employed to establish animal migrations and hominin hunting strategies, or to test the contemporaneity of death in animal assemblages (e.g., Britton et al., 2011; Julien et al., 2015). In the Holocene, stable isotopes are used to analyse diet, mobility and seasonal reproductive patterns in domestic animals (e.g., Makarewicz and Sealy, 2015; Tornero et al., 2016).

Dental wear analyses refer to two techniques used to reconstruct dietary traits in mammals: microwear that records the diet at the time of death, and mesowear that reflects the diet in the last weeks or months before death. Due to their temporal resolution, these two techniques used in tandem track seasonality in the formation of archaeological or natural assemblages (Sánchez-Hernández et al., 2016; Mithlacher et al., in press). Tooth microwear is also a proxy for estimating the duration of formation of these assemblages (Rivals et al., 2015).

The integration of these two dietary proxies, dental wear and stable isotopes, is particularly powerful for providing high-resolution data about dietary traits in fossil species. It provides access to significant information about the diet and its variability at different timeframes during the

lifetime of an individual. Such approaches which combine stable isotopes and tooth wear (meso- and microwear) are employed to disentangle issues related to the formation of the sites as well the existence of seasonal patterns. Examples of combined analyses include the Oldowan site of HWK EE at Olduvai Gorge (Rivals et al., in press) or the Middle Pleistocene horse assemblage from Schöningen (Julien et al., 2015). Archaeological studies based on faunal remains should consider integrating these two techniques to achieve higher-resolution in the identification of specific events in the archaeological record.

4. The measuring of time

Even so, the calendar age of the identified event can only be determined using radiometric dating techniques. Among the numerous dating techniques, the most prominent one applicable to the period dealt with in this volume, the late Middle Palaeolithic and later, has been radiocarbon dating.

Radiocarbon dating has served as one of the most established dating techniques for years. The invention of more refined pre-treatment techniques of the samples and more precise calibration techniques (Levy and Higham 2014; Wood, 2015 and bibliography therein) has increased the availability of this technique for archaeology, offering opportunities to investigate behavioural issues on a range of time scales from large-scale processes such as the replacement of Neanderthals by Modern Humans and Mesolithic hunter-gathers by Neolithic farmers to smaller ones of site formation dynamics on particular locales in any period. Radiocarbon dating cannot escape from a probability variation of at least a few decades due to contamination at any stage of chemical treatment, measurement, or even sample accumulation itself. However, employment of more advanced statistical techniques like Bayesian methods and wiggle-matching as well as tree-ring and laminate structure chronology of the varve sediment data has opened avenues to identify the occurrence of a behavioural event over a 1- or 2-year time segment in theory (Taylor and Bar-Yosef 2014: 161). The ever-continuing methodological developments would further contribute to measuring archaeological time in greater detail.

Currently, the most relevant limitations in applying radiocarbon dating for interpreting archaeological events at short temporal scales of analysis are that dates are controlled using stylistic chronology and are modelled within a 'phase', e.g. taking the archaeological layer as unit of measure (Wood, 2015). As previously explained, each archaeological layer is the result of several events not necessarily interconnected. It is the temporal dissection of these single events that allow for the understanding of behavioural changes and socio-economic dynamics across time. This is why the use of radiocarbon chronologies in big-data projects to investigate cultural traits is useful to answer general questions such as 'when did a phenomenon start' (e.g., Fuller et al., 2014) but the reason underlying this phenomenon and the visibility apparent before it becomes a common behaviour could be perceived and analysed only by looking at short temporal scales.

5. New challenges: multidisciplinary approach in the definition of high-resolution events to interpret past human behaviours

Most of the archaeological records of human history represent palimpsests of multiple stages of behaviour at a particular place that have undergone further stages of deformation through taphonomic processes before discovery. High-Resolution Archaeology aims at identifying stages of human behaviours in as much detail as possible at short temporal scales to improve the understanding of long-term cultural dynamics. The development of this new perspective in archaeological studies is possible thanks to progress in terms of recent theoretical and methodological strategies to decipher the entangled cultural and natural palimpsests. The papers in this volume are representative of new directions in current behavioural approaches. They explore new pathways in the ‘archaeology of time’ (see Bailey, 2007) also employing innovative analytical techniques.

The study of soot traces preserved on the walls of caves and rock shelters is opening new perspectives for the identification of the number of occupation events at the site. The analysis of carbonated crusts from the Middle and Upper Palaeolithic sites of Grotte Mandrin and Balma de la Margineda showed the potential in measuring time at short scale (Vandeveldt et al., 2018). Despite the limits of radiocarbon dating for investigating changes at the micro-chronological scale, this method could be useful for investigating residential patterns in long-term Neolithic settlements, as demonstrated by the application of Bayesian techniques of 45 radiocarbon dates at Göytepe in the Southern Caucasus (Nishiaki et al., 2018).

Palimpsests need to be disentangled not only for occupational floors and archaeological layers, but also for burials and cemeteries. Grave reopening was a common practice in Central Europe in different Holocene periods. The application of multidisciplinary microstratigraphic field protocols applied in a Gáta Culture burial (Early Bronze Age) in eastern Austria increased the understanding of burial formation processes improving taphonomic analysis (Aspöck, 2018).

The study of culture material is central in Archaeology and includes both inorganic and organic elements. Macromammal tooth microwear patterns at Divnogor’ye 9 in Central Russia were used as high-resolution proxies for estimating the seasonal hunting events of Late Glacial horse hunters (Rivals et al., 2018). Refitting analysis of stone artefacts is highly suitable to investigate taphonomy and site formation processes although it is not often applied in a systematic way in Palaeolithic studies. Refit patterns allowed investigating site function and duration of occupation at Kiusu 5, a Late Upper Palaeolithic in Hokkaido (Takakura, 2018), and provided the high-resolution approach for identifying socio-economic changes at short scales otherwise unperceived along the stratigraphic sequence of Middle Palaeolithic Abric Romaní site (Romagnoli et al., 2018). The study of social organisation in past communities is rarely investigated thoroughly. This is mostly due to difficulties in perceiving social dynamics when looking at a macro scale. The contextual analysis of pottery deposition offers a novel method to approach the study of prehistoric family systems, as showed by the analysis of Middle Jomon settlements in central Japan (Tomii, 2018).

This collection of papers shows how innovative analytical techniques and original scientific questions shed new light on archaeological traditional issues and significantly contribute to understand past human behaviours in a more all-inclusive way. The ever-continuing methodological developments and pioneering and inventive approaches will further contribute to opening new perspectives regarding the knowledge of past cultural changes. An effective exploitation of this outcome would also depend on the search for samples of new kinds by archaeologists to provide new dimensions for the measuring of time.

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