ARTICLE IN PRESS

Quaternary International xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Editorial

New technologies applied to archaeology. Contributions of photogrammetry and geometric morphometrics to the resolution of taphonomic issues

The application of Taphonomy to the study of archaeological sites has a long history, stretching back over a century if we consider the pioneering albeit preliminary works of the 19th century. The major contributions of Taphonomy to archaeological research, however, arguably date back to 1981, a year when several researchers published a series of ground-breaking books and articles (Binford, 1981; Brain, 1981; Bunn, 1981; Gifford, 1981; Gordon and Buikstra, 1981; Haynes, 1981; Jochim, 1981; Potts and Shipman, 1981; Scott and Klein, 1981; Shipman, 1981).

The 1980s witnessed the consolidation of taphonomic research, providing further avenues for the study of the past. These new techniques and approaches offered alternative perspectives, which significantly contributed to our understanding of Palaeolithic populations. Taphonomy often played a key role in the reformulation of fundamental paradigms in hominin behaviour, as evidenced by the hunting vs scavenging debate (Binford, 1981; Blumenschine, 1986; Bunn and Kroll, 1986; Bunn, 1991). Nowadays, taphonomic approaches are still paramount in archaeological praxis, with multiple specialised areas of research involving a growing number of researchers. One of the most cutting-edge research areas involves the application of new technologies, such as 3-dimensional microscopy, photogrammetry, geometric morphometrics, machine and deep learning to archaeological materials (Bello and Soligo, 2008; Bello et al., 2009, 2013; Bello, 2011; Maté-González et al., 2015, 2016; Courtenay et al., 2017, 2018; 2019a; Yravedra et al., 2017a, 2018; Byeon et al., 2019); . These novel techniques are showing huge analytical potential for taphonomic research, contributing in multiple ways to a better understanding and interpretation of archaeological sites (Yravedra et al., 2017b,c).

New methodological approaches are constantly growing, with most aiming towards the improvement of taphonomic trace identification in archaeological sites. The objectives of these studies intend to avoid subjectivity in the classification of taphonomic processes, thus offering alternative empirical interpretations that reduce equifinality in the identification of alterations to the fossil record.

A number of important advances in the taphonomic study of osteological materials are presented in this Special Issue. The publications presented here display a series of examples describing some of the most recent technological and methodological advances that employ new technologies in taphonomic studies.

The first paper by Maté-González et al. (2019a, this volume) describes the different methods available for tridimensional reconstructions of taphonomic traces. Here the authors describe how a combined use of photogrammetry, digital modelling and geometric morphometrics can provide highly useful data for the study of different taphonomic traces, including tooth marks by carnivores, rodents, percussion marks and cut marks.

Following this, Bello and Gallway-Witham (2019, this volume) highlight the advantages of combining multiple analytical and visualisation techniques for the internal and external features of modified bone, teeth and antler. Said study confronts this topic by presenting the use of Focus Variation Microscopy (FVM), the Alicona InfiniteFocus optical surface measurement system, Scanning Electron Microscopy (SEM) and other extensions of SEM using Energy Dispersive X-Ray (EDX) Spectroscopy or Micro-Computed Tomography (μCT). These different systems prove complementary in the extensive analysis of modifications that can affect and alter the internal structure of organic specimens, with μCT data also being able to help visualise gross surface morphology when obscured by other materials. Together, these approaches provide in-depth assessments and insights into bone taphonomy on the inside and the outside.

The 3rd paper sees Maté-González et al. (2019b, this volume) debate the effect that different sized animals and anatomical elements may have on cut mark morphology. Through this study, the authors describe how 2D and 3D landmark models were unable to find substantial differences in cut mark morphologies caused by these different variables, providing a solid framework that may help plan future experimental studies.

The studies that follow present different practical examples of case studies for the analysis of different bone surface modifications, whether they be cut, trampling or tooth marks both experimentally and archaeologically.

With this, the 4th paper presented within this issue by Linares-Matás et al. (2019, this volume) describes the morphological variations produced by experimental cut marks made by bifacial handaxes in flint and quartzite. Applying recently developed tridimensional geometric morphometric analyses, these authors' conclusions reveal cut marks produced by different handaxes of different raw materials to be non-differentiable, indicating the tool type to be more of a conditioning factor than the raw material in larger cutting tools. Here these authors highlight other factors to be considerable in cut mark analyses, including the angle, thickness and type of retouch present on the cutting edge. Nevertheless, discriminant functions are able to classify up to 74% of these experimental samples, indicating that the use of Machine Learning algorithms might have the potential to produce greater results.

In continuation, Courtenay et al. (2019, this volume) discuss the development of new methodological approaches using high resolution digital microscopy. Here the authors present the HIROX KH-8700 3D Digital Microscope as a potential analytical tool for the study of superficial taphonomic traces. Results were able to detect morphological

https://doi.org/10.1016/j.quaint.2019.06.030

patterns amongst this preliminary trampling mark sample, indicating that the trampling phenomena may be more complex than once assumed. With these newfound marks named *scratches* and *grazes* the authors offer a possible hypothesis behind their interpretation, indicating sedimentological factors to be a possible cause for this variation. Product of this, these authors offer a possible new analytical approach to confronting problems in equifinality present in arqueopalaeontological sites with possibilities for the future of superficial linear mark analysis.

Equifinality is a frequent phenomenon proving to be problematic in many studies, as discussed in the following article by Rosell et al. (2019, this volume), who reflect upon the different taphonomic traces produced by bears that can easily be mistaken with anthropic alterations. Likewise, Arriaza et al. (2019, this volume) present a similar case study, showing how geometric morphometrics can be used to provide in depth studies of carnivore tooth pits produced by hyenas and felids. The application of new methods for the study of carnivores is concluded with the Rodríguez-Alba et al.'s study about the taphonomic analysis of the Jaguar (Rodríguez-Alba et al., 2019, this volume).

The final series of articles present a number of practical cases applying these studies to the analysis of archaeological sites. The first of these confronting the taphonomic register in the Magdalenian Cave of Coímbre (Asturias, Spain) followed by the study of the Upper Palaeolithic site of la Lluera (Asturias, Spain) (López-Cisneros et al., 2019 this volume, Yravedra et al., 2019 this volume).

The final application consists in the morphological analysis of the tooth marks found on *Paranthropus boisei* remains in the Lower Pleistocene site of Bell's Korongo (BK, Olduvai Gorge, Tanzania). Aramendi et al. (2019, this volume) shows the potential of recently developed methodological approaches combining photogrammetry, geometric morphometrics and machine learning algorithmic classifiers for the identification of which carnivore agent was responsible for the cut marks observed on the OH80 *Paranthropus boisei* fossil. Conclusions withdrawn identified felids to be the most likely candidate for the tooth pits observed on this fossil.

Data presented within this Special Issue present a series of interesting insights and advances in the field of taphonomy. Together, the combination of different analytical techniques and inclusion of different statistical approaches can be seen to overcome a wide range of different issues presented by equifinality. Nevertheless, despite the exceptionality of some of these results, different archaeological and paleontological research teams should still continue with this line of investigation, searching for new methods and techniques that could be used to refine and improve these results. These techniques have been able to provide a wealth of new information that could inspire multiple future research projects, hopefully reaching a point of significant improvement for the interpretation of palaeo-archaeological sites.

Acknowledgements

We would like to thank all the editors and reviewers who have worked hard to evaluate and improve the papers presented within this issue. We would also like to thank the Editor-in-Chief Thijs van Kolfschoten for his support and help producing this issue. Additionally we would like to thank Elsevier who have made this volume of work possible. Finally we would like to express our gratitude to all the authors who have taken their time to produce this Special Issue; we greatly appreciate their trust and confidence in this body of work.

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