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Editorial

Diagenesis in Progress, Progress in Diagenesis – The Skeletal Archives

1. Introduction

Skeletal remains serve as first-hand witnesses of our past, providing crucial information for reconstructing important events in human and animal history. These valuable remains hold information about the dietary habits, mobility patterns, biological profile and, genetic history of the individual during its life. They also provide insights into the ecological niches and environment in which the individual lived. Diagenesis, however, may blur the comprehensive range of information that is archived in bones and teeth, potentially hindering successful retrieval of such data. To improve our understanding of fossilization pathways and exchange knowledge about techniques (isotopes, trace elements, DNA, proteomics, etc.) for extracting reliable data from skeletal material, researchers from diverse backgrounds have been convening every four years since 1988 at the International Bone Diagenesis Meeting. This collaborative effort has yielded the publication of special issues that showcase the latest findings and advancements in the field[1] (see Schwarcz et al., 1989; Fernández–Jalvo et al., 2002; Lee-Thorp and Sealy, 2008, Tütken and Vennemann, 2011; Balter and Zazzo, 2014; Snoeck and Lee-Thorp, 2020). In September 21–24, 2021, the 9th International Bone Diagenesis Meeting took place in Évora, Portugal, in a hybrid format due to the COVID-19 pandemic. Over three days, nearly 100 participants from 20 different countries attended the conference (Fig. 1). The scientific program was divided into five distinct sessions: 1) Taphonomy, preservation, environment; 2) Preservation of organic molecules in bones in deep times; 3) Advance in sample preparation, analytical technique, and experiments on skeletal tissues; 4) Non-traditional and new chemical proxies applied to ancient bones and teeth; 5) Diagenesis in forensics. Session 5 was a novel addition to the Bone Diagenesis Meeting, as it was sought as a possibility to promote interdisciplinary collaboration between forensic and archaeological research fields, recognizing the potential for mutual enrichment and synergy.

Highlighted in this Special Issue are nine contributions that discuss recent advances in the study of bones and teeth diagenesis, initially presented during the 9th International Bone Diagenesis Meeting. These contributions present progress made in population genetics, diet, mobility, and health investigations through the analysis of bone organic and inorganic preservation. Bone diagenetic changes are also evaluated regarding anthropogenic (funerary practices, application of consolidants and preservatives, post excavation process) and environmental (peat-rich gravel and marine settings) influence. Finally, short timescale diagenetic modifications are discussed, with implications for interpretating archaeological and forensic findings.

2. Contributions in this volume

The contributions are organized in a manner that offers a comprehensive overview of the diagenetic trajectories of skeletal tissues over time.

Tranchant et al. (2023, this volume) investigated concentration and distribution of various elements in mammoth ivory and bone from the Palaeolithic Hohle Fels Cave in the Swabian Jura (Germany) using a non-invasive approach involving micro-Particle-Induced X-ray Emission and Gamma-ray Emission (micro-PIXE-PIGE) and synchrotron-induced micro-X-ray fluorescence (synchrotron-XRF) analyses. The combination of these two cutting-edge techniques and the comparison with modern reference samples allowed the authors to improve the discussion of the biogenic versus diagenetic origin of Zn, Br, Sr, F, Cr, Rb, Ba, Pb, Ti, Mn, Fe, Zn, Se and Y in the mammoth ivory and bone. The results provide evidence for the endogenous nature of Zn and Br, and suggest that Cu may also exhibit similar characteristics. As such, Cu could potentially be utilized as a marker of origin in future studies. The diagenetic alterations between the archaeological ivory and bone samples were found to be similar.

Iliopoulos and Stathopoulou (2023, this volume) applied three different collagen extraction procedures to animal bones spanning from the Pleistocene to the Holocene and originating from three Greek (Charkadio/Tilos Cave and Dispilio) and Cypriot (Aghia Napa) sites. The authors used Fourier Transform (FT) spectroscopy in both mid-Infrared Attenuated Total Reflectance (FTIR-ATR) and near-infrared (FT-NIR) to characterize bones samples before collagen extraction and collagen extracts. The authors discussed how successful collagen extraction was only possible from samples obtained from the Neolithic site of Dispilio. They also examined the limitations of the collagen extraction methods used and the impact of Mn oxides on bone collagen preservation. Similar to previous studies, the authors suggested that NIR spectroscopy could be the most suitable approach for pre-screening purposes.

Loy et al. (2023, this volume) utilized advanced techniques – FTIR, XRF, Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM-EDS), and micro-Computed Tomography (micro-CT) - to investigate the diagenetic trajectories of Neolithic bones retrieved from the Etton Causewayed Enclosure, a site rich in peat-infused

[1] Conference Proceedings of 1993 and 1996 Meetings have been published respectively in Journal of Archaeological Sciences 22, Issue 2 (1995) and in several issues of Bulletin de la Société Géologique de France in 1997.

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Fig. 1. Group picture of the participants to the 9th International Bone Diagenesis Meeting, taken during the visit to the Castelo de Monsaraz, Alentejo, Portugal. Credits: Roshan Paladugu.

gravel in the UK. The findings of the study revealed that the mineralization patterns observed on the periosteal and endosteal surfaces of the bones were a result of complex processes involving microbial activity, fluctuating groundwater levels, and possible post-excavation treatments such as washing and drying cycles. These processes led to the accumulation of iron and Mn-rich layers, as well as the formation of Fe and Mn oxide and oxy-hydroxide.

Moreiras Reynaga et al. (2023, this volume) investigated the impact of two types of bone consolidants (polyvinyl acetate, PVAc, and acrylic resin, Paraloid B-72™) and their removal using solvents on the bone isotopic composition. The isotopic composition examined included $\delta^{13}C$ and $\delta^{15}N$ in bone collagen (col), $\delta^{13}C$ and $\delta^{18}O$ in bone structural carbonates (sc), and $\delta^{18}O$ in bone phosphate (p). In addition, the authors explored the effects of different protocols for organic matter and secondary carbonate removal on $\delta^{13}C$ and $\delta^{18}O$ values in bone carbonates. The study revealed that the two types of consolidants and removal protocols employed had no significant influence on $\delta^{13}C_{col}$, $\delta^{15}N_{col}$, $\delta^{18}O_{sc}$ or $\delta^{18}O_{p}$, but did affect $\delta^{13}C_{sc}$. Additionally, the authors suggested that using fewer treatments was preferable for maintaining the integrity of the biogenic isotope signal in bone collagen.

Maurer et al. (2023, this volume) investigated the potential influence of funerary practices on the early diagenetic processes affecting human skeletons from the Merovingian period at Saint-Linaire in France. Bone crystallinity, carbonate and fluoride content, porosity and organic amounts were examined in regard to grave filling, grave type and biological age of the individuals. The study findings suggested that while there was a tendency for a better preservation of the skeletons in humus, and of juvenile bones compare to the adult skeletons, the type of bone was the most critical factor determining the fate of the skeletons at Saint-Linaire, with in general a better preservation of the ribs.

Leskovar et al. (2023, this volume) conducted a comprehensive review of their recent works, which utilized FTIR-ATR spectroscopy in combination with statistical analyses, including machine learning algorithms, applied to human skeletal remains discovered in archaeological, modern and forensic contexts. The authors evidenced that this rapid, cost-effective, and minimally destructive method offers promising opportunities for assessing the post-mortem interval, the preservation state of skeletons, and the DNA degradation.

Mein and Williams (2023, this volume) put forward an experimental approach for evaluating bone bioerosion within brief timeframes by counting normal and diagenetic osteocyte lacunae in bones from thin sections. Their research design involved domestic rats (defleshed, excised and whole carcasses) that have been exposed to ambient weathering or placed in soil for four to 28 weeks. The researchers noted changes in the osteocyte lacunae within the bone structure as early as four weeks after deposition, with a sharp increase after 16 weeks, coinciding with complete skeletonization. The authors proposed that tracking osteocyte lacunae changes in short timeframes can capture subtle deterioration missed by the OHI. However, further research, including addressing observer errors, is necessary to refine the approach, as pointed out by the authors.

Turner-Walker et al. (2023, this volume) used SEM analysis to explore bacterial bioerosion on animal and human bones under known taphonomic conditions, ranging from field experiments to a forensic case. Their findings revealed that bacterial tunnelling was only evident in bones exposed to soil bacteria, while bones devoid of such exposure displayed no discernible traces of tunnelling. These results challenge the hypothesis that gut bacteria are always involved in bone bioerosion in burial contexts, and have significant implications for the (re-) interpretation of human behaviours such as mummification, animal sacrifice, and other related practices.

Guareschi et al. (2023, this volume) conducted a pioneering study on bioerosion in terrestrial mammalian bones found in marine environments, and specifically retrieved from shipwrecks spanning from 69 to 316 years old, shedding light on an under-explored research area. By integrating macroscopic and microscopic (micro-CT and SEM analysis) examination methods, the authors were able to observe the presence of sponge tissues and characterize the features left by bioeroding sponges. This approach enabled identification of sponge species responsible for bone bioerosion, providing insights into the marine taphonomic environment and sponge habitat preferences. The study's implications extend beyond underwater archaeology, as it has relevance for forensic investigations involving underwater recovery of skeletal remains.

3. Concluding remarks

We are thrilled to have curated this Special Issue in Quaternary International, featuring a collection of valuable contributions that enhance our understanding of skeletal diagenesis and its implications. We trust that readers will derive equal enjoyment and enrichment, akin to our own, from the perusal of the profound and enlightening content within.

The 10th International Bone Diagenesis Meeting will be held in Athens, Greece, in 2025, with organization led by Ioannis Kontopoulos, Elizabeth Stathopoulou, and Takis Karkanas. We extend our best wishes for the continued success and enduring impact of this conference.

Finally, in heartfelt tribute, we dedicate this volume to the memory of the late Alain Person, a true enthusiast of archaeological science (Amblard-Pison et al., 2019). Alain's unwavering dedication to the International Bone Diagenesis Meetings was remarkable, as he rarely missed any of these gatherings. Tragically, he passed away in November 2019 during a field trip in Djibouti, Africa - a place he cherished deeply for its people, culture, history and art. His absence is acutely felt. We would like to honour his enduring legacy as a true inspiration to all who share his passion for post-mortem processes, and more broadly archaeology.

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