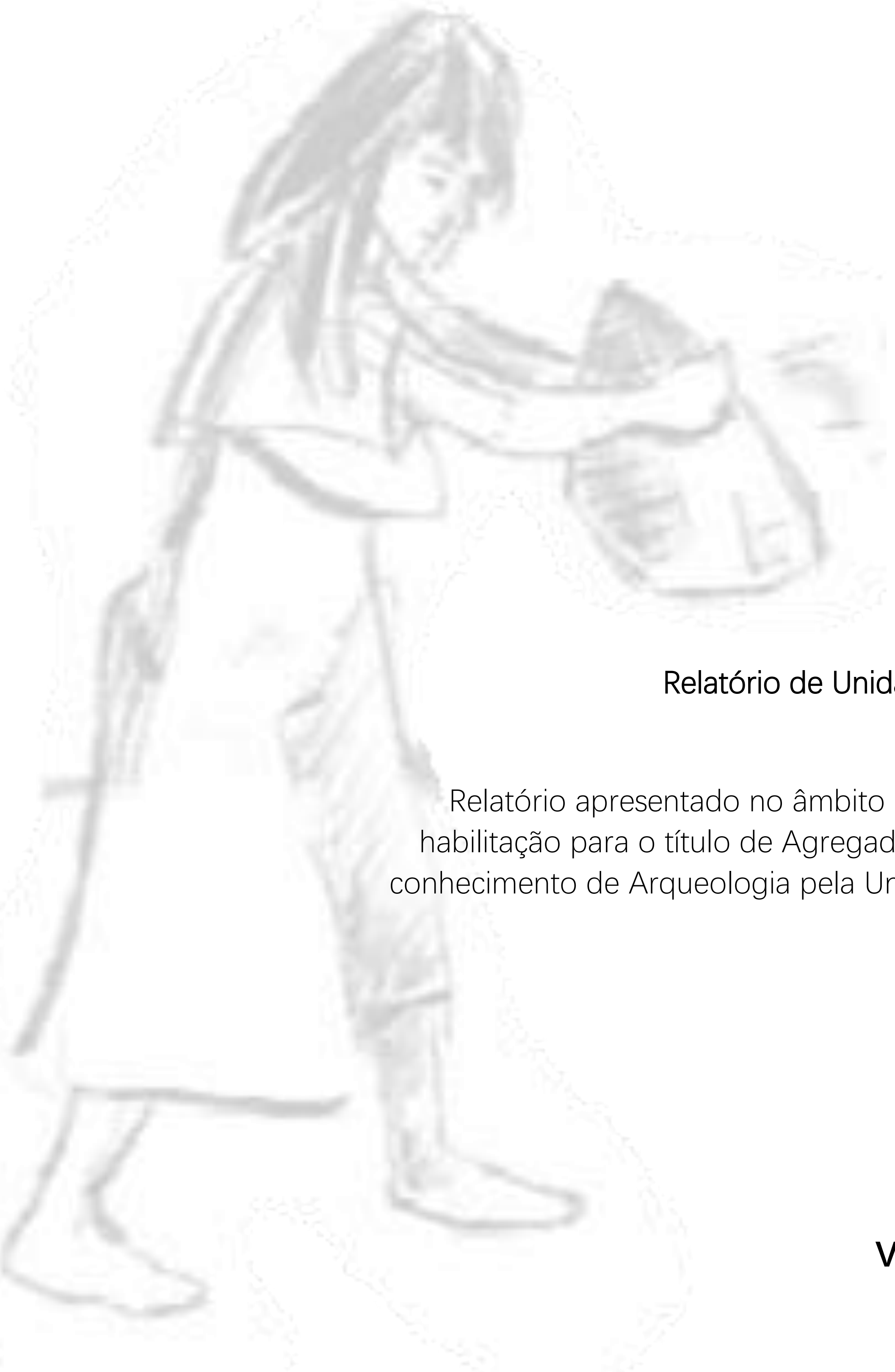
GEOARCHAEOLOGY OF HUMAN-MADE DEPOSITS



Relatório de Unidade Curricular

Relatório apresentado no âmbito das provas de habilitação para o título de Agregado no ramo de conhecimento de Arqueologia pela Universidade do Algarve.

Vera Aldeias

Faro, 2023

Contents

TABLE OF FIGURES

'Since archaeology (...) recovers almost all its basic data by excavation, every archaeological problem starts as a problem in geoarchaeology.'

Renfrew, 1976

1. Overview

The proposed course entitled "*Geoarchaeology of Human-made Deposits"* aims to integrate the academic formation of Universidade do Algarve (UAlg) in the Faculdade de Ciências Humanas e Sociais (FCHS). It is specifically tailored to the master's program in Archaeology, that is, for students enrolled in the 2º cycle.

The course is designed to offer a comprehensive examination of theoretical foundations, explore anticipations based on experimental and ethnographic research, examine instances of archaeological findings, and equip students with the skills required for investigating human-made deposits using a Geoarchaeological perspective. Anthropogenic deposits are defined as sediments whose formation processes (accumulation mechanisms and manufacture) directly derives from human agency. In this sense, anthropogenic deposits do not include sediments enriched by human actions through the simple incorporation of human inputs, or those depleted due to human actions. It does englobe, however, natural sediments used as raw materials (e.g., adobe, daub) as well as sediments or soils purposedly relocated by humans to, for instance, create mounds, turf structures, agriculture terraces, or other earth-based constructions. Notwithstanding, the alteration of soils due to human agency, as is the case of dark earths and anthrasols, will also be incorporate into this course since the formation and characteristics of these soils have been irrevocably shaped and altered by human action.

Each of the course's class focuses on illustrating distinct types of deposits through case-studies coupled with an integration of the archaeological debates and contexts for each of the study topics. An array of archaeological science tools is nowadays used to tease out information on human activities and behaviors from archaeological sediments and soils. Therefore, the course incorporates and aims to capacitate students to assimilate and critically assess the use of interdisciplinary methodologies, namely those associated with microarchaeological studies – specifically, soil micromorphology, infrared spectroscopy, and micro- X-ray fluorescence analysis.

A complementary explanation of basic geological and chemical concepts is essential in the study or archaeological sediments and soils. Given that the proposed course is incorporated in the faculty of social sciences (FCHS), brief introductory aspects of archaeological sciences will be provided to students. The practical components of the course will further deepen student's technical skills and methodological tools by having hands on sessions where the students will directly analyze archaeological thin sections under the microscope, produce elemental maps of archaeological thin sections, and obtain infrared spectra data from loose sediment samples.

The topics addressed in the course are not linked to a particular time period, nor do they pertain to a geographically defined area. Instead, lectures are designed to provide a breath of chronological and geographic frameworks, delivering an array of case-studies that span from hunter-gather Pleistocene contexts to the construction of infrastructures in later urban settings. The goal is for this course to appeal and engage students that are starting their own research, independently if their research interest lies in pre-history, protohistory, medieval or modern time periods. It will equally encompass a variety of geographical and environmental settings, with examples that will be relevant for students interested in cave settings, open air sites, but also constructed households or buildings in urban settings.

1.1 Syllabus Organization

Concerning the elaboration of the present report, in Section 2, I will first provide an overview of the relevance of the curricular unit, alongside more operational aspects on the course objectives, teaching philosophy, evaluation methodologies and organization characteristics. Section 2 aims to answer the questions of "why this course", "why I am capacitated to give this course" and "how is the course structured".

In Section 3, I will provide a specific synopsis of the individual lectures programmed. While the goal of these synopsis is not to give a complete script, word-by-word, of each lecture – a task that would be cumbersome and unrealistic without visual aids – what I intend with this section is to provide a clear understanding of the content of each of the designed lectures. Therefore, I will first supply a *rationale* that contains an abridgment of the background and scope of the lecture's chosen topic(s). This is followed by a second part – *summary of contents* – where I provide an outline of the specific programmatic content that will be given to students during each class, touching upon both the oral presentations and the materials that will be used for the practical sessions.

Finally, in Section 4, I will briefly outline an analysis of what I see as the strong points of the academic curricular unit proposed here, as well as the challenges that such a topic can face in the academic landscape of UAlg and FCHS.

2. Structure of the Curricular Unit

2.1 Relevance and Context of the Curricular Unit

A course focusing on archaeological anthropogenic deposits is unique in the scope of the Portuguese academic formation. It is equally unusual in the archaeological courses offered throughout other European and worldwide academic institutions. One could then ask, what is the relevance of studying anthropogenic deposits and how such a study relates to broader archaeological and anthropological questions? In other words: why this course. To answer these questions, I need to first address current trends in geoarchaeology and provide clear examples of how this curricular unit not only fills in an academic teaching gab, but also that reconstructing human behavior beyond the study of the material culture (the artifacts) is a timely research focus. I will try to achieve these goals in the paragraphs below.

Archaeological stratigraphies are the ultimate context for any archaeological endeavor (McAnany and Hodder, 2009). Stratigraphy, simply defined as the spatial and temporal arrangement of depositional units (Karkanas and Goldberg, 2018), needs to be well characterized and understood to correctly interpret the archaeological record and infer past behavior and human activities. To do so, site formation studies focus on reconstructing the sedimentary origins and the processes that lead to the development of a stratigraphic sequence. Formation studies provide crucial insights to relative time – with deposits at the bottom being older than those that overlay them. It also speaks to the degree of integrity of the archaeological assemblages, that is, reconstructing syn- and post-depositional processes that have affected the archaeological record during occupations and after burial. In this context, Geoarchaeology deals with understanding the context of archaeological materials embedded in sediments or soils and accessing if artifacts are in their primary (preserved) or secondary (reworked) positions. Preservation issues linked to weathering and decay of materials are key to reconstruct archaeological components that have been altered through time. Geoarchaeological studies also provide key insights into the paleoenvironments and paleoclimate at play when a give stratum was formed. Geoarchaeology can deal – and often needs to integrate – different scales of observation: from the microstratigraphy (> mm scale) to the stratigraphic sequence of a site (cm to several m scale), to the site's environments (m to km scale), and up to geomorphological landscape scales (several km wide).

The integration of site formation studies is a standard practice in prehistoric archaeological contexts, primarily since prehistory largely evolved in parallel with geology. In later periods, however, geoarchaeological studies are not as well established and often not integrated into the standard archaeological excavation methodologies. This derives from two major misinterpretations, namely that (1) more recent, historical contexts are not affected by natural agents both in the deposition and in the post-depositional history of a site, and (2) that geoarchaeological studies deal solely with natural formation processes. An increasing number of studies have started to demystify both aspects. An example is the identification of tsunami deposits that affected the roman city of Hispalis (Sevilla, Spain) in the third century AD (Gutiérrez-Rodríguez et al., 2022), with repercussions to understanding the abandonment and structural damage of buildings in these areas of the Roman Betica province. In the same vein, geoarchaeology is increasingly emerging as a key tool to study not only naturally formed deposits, but also accumulations made by humans. For instance, geoarchaeological studies of Mycenaean chamber tombs have shown the complexity of funerary rites, with (macroscopically invisible) constructed floor sequences inside the chambers and purposedly infillings of the access corridors with several moments of re-openings for new burials (Karkanas et al., 2012).

Indeed, in the last couple decades, it has become clear that a vast array of information is stored in the archaeological deposits themselves (Miller, 2011, Weiner, 2010). This awareness that archaeological deposits are not only relevant because they embed human artifacts, but that they themselves can be artifacts has become a revolutionary concept in archaeological and, particularly, in geoarchaeological studies. The study of these 'sedimentary artifacts' allows us to tap directly into past human activities – such as clearing, dumping, digging, sweeping, discarding, or placing – as well as past human behaviors related, for instance, to pyrotechnology, ritual practices, cooking, or pastoralism. Hence, through geoarchaeological investigations we can make behavioral inferences about major steps in human evolution, for instance, when did humans start to purposedly inter their dead, or when did humans start to use fire. Furthermore, the study and understanding of the information preserved in sedimentary artifacts provide new, and often unexploited, aspects on past human activities beyond the manufacture of artefacts.

As argued by Goldberg and MacPhail, the study of "anthropogenic deposits *cannot* be studied by the standard method and mind-frame use in traditional soil science and geology" (Goldberg and Macphail, 2006 p. 211). Instead, reconstructing the complex formation histories of stratified archaeological sequences is better achieved through the analyses of undisturbed sediments using the technique of soil micromorphology (henceforth, micromorphology). Micromorphology allows for studying intact (i.e., undisturbed) sediment samples. Studying intact, contextualized samples is key because archaeological excavations are inherently a destructive activity that breaks apart the original relationship between the sediments and the artefacts they embed, erasing depositional geometries and structures that provide knowledge on the formation histories of a deposit. As mentioned above, there is a growing awareness that sediments are not only the "dirt" that needs to be dug out of a site, but that they are fundamental parts of the archaeological record, on par with other types of more traditional archaeological artefacts (Miller, 2011). Micromorphology is at the forefront of this research and this technique has been used to evaluate the dynamics of deposition and post-depositional (i.e., after burial) processes forming the archaeological record (Karkanas and Goldberg, 2018, Goldberg and Aldeias, 2018). Furthermore, thin depositional events might be invisible during excavation, though they are readily identified under a microscope. To achieve this, micromorphological samples are carefully carved out of archaeological deposits as blocks and consolidated (using a resin-based impregnation) to maintain their original context.

From the consolidated sediment blocks, micromorphological thin sections (a 30 μm-thin veneer of the original deposits) are produced, which can be examined under the microscope at several magnifications (Courty et al., 1989). The remaining consolidated sediment blocks are, in effect, left over mirror images, of the thin sections manufactured for observations under a microscope.

Recent studies have shown that micromorphology can be coupled with biomolecule analyses, namely by drilling the consolidated sediment blocks that are a leftover of the production of thin sections. Rodríguez de Vera and colleagues (Rodríguez de Vera et al., 2020) targeted archaeological lipid biomarkers to characterize organic matter preserved at micro-contexts with known spatial and temporal resolution. Relevantly, ancient DNA was also shown to preserve in Pleistocene consolidated blocks from several archaeological contexts and that these molecular records can be targeted and isolated with a high degree of microstratigraphic resolution to identify stratified mammal remains, including human species (Massilani et al., 2022). Other techniques based on bulk methods (e.g., phosphate concentration, magnetic susceptibility, infrared analysis) can directly complement a micromorphological approach studying anthropogenic deposits. Furthermore, a series of spectroscopy techniques can be performed direct measures on thin sections, such as micro x-ray fluorescence (microXRF) to create elemental maps (Mentzer, 2017) and micro Fourier transform infrared analysis (microFTIR) to identify the functional groups present in organic and inorganic compounds (Berna, 2017). Therefore, current studies of anthropic deposits heavily rely on microarchaeological analysis, and the coupling between studying undisturbed thin sections and spectroscopy have proven to be a powerful tool to tease out depositional processes and human agency from archaeological stratigraphies.

Returning to the task of deciphering human-made deposits, these sediments will be more abundant in historical sites when human agency is the main driver of formation and accumulation of the archaeological record. However, even in prehistoric contexts where natural processes predominate, there are also lenses or features directly resulting from human agency (Goldberg et al., 2009b, Sherwood and Kidder, 2011, Leierer et al., 2020, Karkanas et al., 2012). Examples of these can be in the form of discrete accumulations of ashes due to hearths, or lamination of phytoliths associated with decayed bedding that would go unnoticed during excavations or in analysis using only loose bulk samples. On a landscape level, humans can alter sediments and soils outside habitational areas forming anthrasols and anthropogenic dark earths (Asare, 2022). Forest and woodland clearance activities leave identifiable traces in the soils (Goldberg and Macphail, 2006). Similarly, the practices of ancient cultivation and manuring produce sedimentary identifiable structures (e.g., ard marks, plough marks and space marks), whereas cultivation fields may encompass the construction of earthen structures such as terraces to mitigate soil loss, cultivation ridges and watering channel systems (Carter and Davidson, 1998, Macphail et al., 1990a). In Roman and post-Roman urban settings, enhanced organic deposits known as “dark earths” result from an interplay between human actions (manuring, composting, pasturing, farming) and bioturbation (e.g., earthworm activity) (Devos et al 2013).

It can be argued that the degree into which human activities have increasingly affected our planet is emphasized by the concept of the Anthropocene (Crutzen and Stoermer, 2000). Currently, it is still deeply discussed if the Anthropocene should be formalized as a defined geological epoch or a geological event (Randall, 2023), and if the onset of the Anthropocene should start in the mid-20th century, as recently proposed by the Anthropocene Working Group, or if this onset can be traced further back in time (Zalasiewicz, 2015, Butler, 2020). Independently, however, there is a consensus that human activities have reached a degree that their signatures are now part of the planet’s geological history. Tracing back the origins and evolution of such human activities relies on geoarchaeological studies of past human deposits.

These observations set the scene to why a course on the *Geoarchaeology of Human Activities and Anthropogenic Deposits* is being proposed and why this course will heavily rely on micromorphological studies. Overall, it is foreseeable that, in modern archaeological excavations, sediments will not just continue to be sieved away, but that analyzing sediments at a microscale will become an integral part of the archaeological workflow. This course aims to clear the misconceptions that geoarchaeological analysis relate solely to geogenic phenomena and that geoarchaeology is merely applied to prehistoric periods. With the proposed academic unit, I hope to contribute to the teaching diversification offered at UAlg and, more generally, contribute to the current worldwide need to have more specialists in geoarchaeology and, particularly, in micromorphology.

The number of academic institutions that provide a curricular unit on these topics can be counted by the fingers of one hand. The lack of academic formation may help explain why geoarchaeological analysis still lags in archaeological work in historic contexts. I do not expect that all students enrolled in this curricular unit will become micromorphologist practitioners in their academic research or commercial archaeology work. But what I do intend is for this course to provide both an awareness to the data that can be gleaned from studying archaeological sediments and, at the same time, contribute to form scholars that are capacitated to critically assess the data that can be retrieved from the sedimentary invisible record.

2.2 Course Objectives

The course is designed for students that already have had introductory level courses on Geoarchaeology and Site Formation processes. In fact, these two topics have been available for students enrolled in the master's program of University of Algarve since 2016, though not every academic year. The present course does not aim to replace introductory courses, but it is instead designed as an intermediate/advanced level course that provides students with a more in-depth and hands on approach on using geoarchaeological tools and methods to reconstruct past human behavior from the sedimentary matrix. Independently, however, throughout all the classes, basic competences on site formation processes and geoarchaeological techniques will be reviewed and provided so all students can be equipped to absorb the discussed subjects and case studies.

The general objectives of the course are (1) to deliver a body of basic and fundamental knowledge about anthropogenic deposits in archaeological sites; (2) to capacitate students to be able to identify and analyze these types of deposits and apply them in their future career in a variety of archaeological settings, and (3) to stimulate and reinforce the professional and scientific student capacity in archaeological sciences at UAlg.

Students' academic proficiency goals from this course are the following:

- Learn about the historical and theoretical framework of site formation studies and in particular recent developments in studying anthropogenic components.

- Understand the main principles guiding the formation and alteration of anthropogenic sediments and their links to specific human activities.
- Be proficient in understanding and discussing geoarchaeological tools to investigate varied archaeological deposits.
- Instigate critical analysis of different sources of information, interpreting and discussing different methodologies and their limitations on the study of anthropogenic sediments.
- Being able to communicate scientific results and evaluate published data.

2.2 Teaching Philosophy

My primary teaching goals are to build archaeological knowledge while providing students with the know-how on critical thinking skills. I also believe that teaching is an essential component of my career as a scientist, as it strengthens my understanding of a discipline, and provides perspective to relate to students the significance of my research to archaeological and anthropological questions.

During my formative years as a researcher and as a scientist, I have had the opportunity to be exposed to a diverse set of teaching both in the European and in the North American academic systems. Moreover, my training and class enrollment has always straddled the subdivisions between traditional academic disciplines, namely those of Humanities and the so-called "hard" Sciences. During my undergraduate years, I was enrolled in the Portuguese academic system where I took several classes of History and Archaeology, and, later, Geology classes in the Faculty of Science. I pursued this multidisciplinary formation during my time as a doctoral in the USA academic system. Here, I was enrolled in the Department of Earth and Environmental Sciences, though my main advisor was based in Anthropology, where I was also a teaching assistant. Since 2017, I have been a researcher at the University of Algarve where I have taught and co-taught several disciplines – *Geoarchaeology and Site Formation Processes, Georqueologia*, and *Scientific Writing* – in the PhD programs of University of Algarve.

This background has given me the firm believe that to understand the intricacies and many unknowns of our heavily biased data set (the archaeological record), teaching

Archaeology needs to provide students with both a theoretical framework on historical patterns and on techniques and methodologies from disciplines such as Biology, Ecology, Material sciences, and Earth and Environmental Sciences. My experience as a teacher has heavily relied on such multidisciplinary approaches.

At the graduate level courses, I have taught, students are not being asked to simply memorize or digest some finished product: they are being invited to join in on the quest for answers to some open questions. I think one of the attractions of learning about (and doing) science is that our understanding of the natural world is constantly changing: either being refined or completely reinvented. I emphasize how we gather data about archaeological topics, and how to critically analyze such ideas, so students see science as an ongoing process of discovery rather than a static set of facts. For instance, in my Geoarchaeology courses, I often rely on providing students real case-studies of this process by using well-known contexts to exemplify how a site was first interpreted by archaeologists and how such interpretations changed once geoarchaeological methodologies were used to analyze where the sediments at a site came from, how they were transported, and what happen after their burial. These latter aspects are typically the domain of geologists and were traditionally seen as giving a general climatic background that was, to a large extent, independent of human behaviors. However, in my classes I highlight to students how such geologically driven data are currently used to infer aspects such as assemblage integrity (e.g., are the artefacts in primary or secondary position?), critically analyzing dating results (e.g., are the dating materials reworked?), and direct data on human activities (e.g., are the organics at the site related to *in situ* activities?).

I believe students are better drawn into lectures when the material is brought closer to home for them, and I also recognize that "a picture is worth a thousand words". To implement these two aspects, the primary means of how I teach are graphic displays and analysis of specific examples from my own research. These examples vary from (1) natural-driven sedimentation (e.g., fluvial environments in the Negev desert in Israel, volcanic landscapes in Ethiopia, or karstic systems in Europe), (2) biogenic inputs in relation to human occupations (carnivore hyena den layers from Bacho Kiro in Bulgaria or bat guano accumulations in Montagu Cave in South Africa, for instance), and (3) human-made deposits (with examples from several prehistoric fire features and artificial mound construction of Mesolithic sites in Portugal). I also give particular examples – often showing my own microscopic photographs – of relevant post-depositional processes that have implications on how archaeological data is interpreted (for instance, bone dissolution or decalcification of ashes). I strive to put this data in context with broader anthropological questions related to topics such as the emergence of obligate fire use, or critical assessments on human internment of their dead. I think students respond positively to this: they are not being presented with some finished product created by someone else, they can see that there are always unanswered questions and important contributions to be made.

Part of my teaching strategy is to actively engage students to participate in the classroom debates. For this end, I typically provide specific readings before the class, and organize lectures where the students oversee leading the discussion about a selected subject. I have found that such approaches help students to feel at ease to talk during the class and to think critically about the readings they made. By not providing the complete answer on a topic, but letting students direct the lecture, I have found that they begin to feel the intellectual satisfaction that comes with trying to solve complex puzzles and combining analyses on the intricacy of the archaeological record.

During my career, I have found that I truly enjoy teaching students beginning their training and trying to understand where their specific interest lies within the field of Archaeology. Furthermore, my work as a site supervisor and director in several archaeological excavations involves teaching a variety of students from different backgrounds during fieldwork. I believe that teaching is more efficient when it provides hands on experience, and archaeological fieldwork and laboratory work provide this more than any other classroom activity could. Understanding our past involves solving complex puzzles and I see this as clear asset when it comes to teach students about the scientific method and how to critical think and evaluate our understanding of our shared past.

2.3 Evaluation Methodology

Individual Evaluation – written essay with 40% weight of the final grade

Oral individual presentation – presentation assessment on a case study topic, 40% weight for final grade. These individual presentations can be reorganized into group presentations of 2 to 4 depending on the number of students enrolled in the class.

Continuous evaluation of students in class participation – 20 %

2.4 Course Organization

ECTS: 10

Total work time: 280 h (= 10 ECTS)

Contact hours: 39S + 5OT

Evaluation time: 6 h

2.5 Course's Main Bibliography

Below is an overview of the main body of work available for the topics that will be discussed in this course. References in bold below are those that I consider as unavoidable and that should be used by students throughout the academic program. Topic specific bibliography is additionally provided for each lecture in section 3 of this document.

Boggs, S. 2001. *Principles of Sedimentology and Stratigraphy*, New Jersey, Prentice Hall.

Butzer, E. K. 1982. *Archaeology as Human Ecology*, Cambridge, Cambridge University Press.

Courty, M. A., Goldberg, P., & Macphail, R. (1989). *Soils and micromorphology in archaeology*. Cambridge University Press.

Gilbert, A. S., Goldberg, P., Holliday, V. T., Mandel, R. D. & Sternberg, R. S. 2017. *Encyclopedia of geoarchaeology*, Springer Netherlands.

Goldberg, P. & Macphail, R. 2006. *Practical and Theorectical Geoarchaeology*, Blackwell publishing.

Goldberg, P. & Aldeias, V. 2018. Why does (archaeological) micromorphology have such little traction in (geo)archaeology? *Archaeological and Anthropological Sciences,* 10**,** 269-278.

Karkanas, P., & Goldberg, P. (2018). Reconstructing Archaeological Sites: understanding the geoarchaeological matrix. John Wiley & Sons.

Macphail, R. I., & Goldberg, P. (2017). *Applied soils and micromorphology in archaeology*. Cambridge University Press.

Nicosia, C. & Stoops, G. 2017. *Archaeological soil and sediment micromorphology*, John Wiley & Sons.

Rapp Jr, G. & Hill, C. L. 1998. *Geoarchaeology. The Earth-Science Approach to Archaeological Interpretation,* New Haven and London, Yale University Press.

Rapp Jr, G. & Hill, C. L. 1998. *Geoarchaeology. The Earth-Science Approach to Archaeological Interpretation,* New Haven and London, Yale University Press.

Schiffer, M. B. 1983. Toward the Identification of Formation Processes. *American Antiquity,* Vol. 48, **,** 675-706.

Schiffer, M. B. 1985. Is there a ‘‘Pompeii premise’’ in archaeology? *Journal of Anthropological Archaeology,* 41**,** 18–41.

Schiffer, M. B. 1987. *Formation Processes of the Archaeological Record,* Albuquerque, University of New Mexico Press.

Stein, J. K. & Farrand, W. R. 1985. *Archaeological sediments in context*, Center for the Study of Early Man, University of Maine at Orono; Peopling of the Americas, Edited Volume Series 1.

Stein, J. K. 2001. A Review of site formation process and their relevance to geoarchaeology *In:* GOLDBERG, P., HOLLIDAY, V. T. & FERRING, C. R. (eds.) *Earth Sciences and Archaeology.* New York, Boston, Dordrecht, London, Moscow: Kluwer Academic / Plenum Publishers.

Stoops, G. 2003. *Guidelines for analysis and description of soil and regolith thin sections*, Madison, WI, Soil Science Society of America.

Stoops, G., Marcelino, V. & Mees, F. 2018. *Interpretation of micromorphological features of soils and regoliths*, Elsevier.

Waters, M. R. 1992. *Principles of Geoarchaeology: a North American Perspective*, Tuckson, University of Arizona Press.

Weiner, S. 2010. *Microarchaeology Beyond the Visible Archaeological Record*, Cambridge, Cambridge.

3. Schedule and Program

There is a wide variety of anthropogenic deposits and human-made structures that can be studied with geoarchaeological techniques. For this course, an array of examples was selected. While having to choose topics necessarily leave some types of structures and deposits out, this selection was made to provide students with a diversified and wide range of archaeological examples. At the same time, the choices made are also a reflection of the current state of research into types of deposits and structures that have more commonly been the target of geoarchaeological investigations. There is little doubt that such case-studies will grow with increased geoarchaeological research in the future.

Table 1 shows the organization of topics of the proposed program. As mentioned above, classes will always have a theoretical fist part where basic background, definitions and application examples are provided to the students in an oral presentation using visual supports. A practical session will complement the oral exposition for some of the lectures. The goals and techniques involved for each of the lectures are described in detail below.

Table 1: Summary of programmatic content and lecture typology as theoretical (T) and/or practical (P).

Lecture #	**Programmatic content**	**Lecture typology**	
		T	P
1	Introduction to Site Formation and Anthropogenic Sediments	x	
2	Preservation of Archaeological Deposits	x	x
3	Fire use and Pyrotechnology	x	x
4	Burials and Inhumations	x	x
5	Stabling and Fumiers	x	
6	Middens, Trash Pits and Latrines	x	
7	In-class student presentations		x
8	Earth Mounds and Shell Mounds	x	x
9	Construction Materials	x	
10	Occupation Surfaces and Use of Space	x	x
11	Anthrosols, Dark Earths and Agriculture	x	
12	Abandonment, Site Destruction and Decay	x	
13	Final Exam		

Lecture 1: Introduction to Site Formation and Anthropogenic Sediments

This first introductory lecture will provide the overall organization and evaluation methodologies for the course. Students will be asked to introduce themselves and share with the class what are their archaeological research interests. These brief student presentations will be used not only for all those enrolled to know each other, but also to gage possible topics for student's in-class presentation that is scheduled for lecture #7. The remaining of the lecture will focus on an oral presentation that aims to revise and refresh basic knowledge on geoarchaeology, archaeological stratigraphy and soils, and introduce the definition of anthropogenic deposits and guidelines for soil micromorphology analyses.

Rationale

Geoarchaeology is understood as the application of earth sciences principles and techniques to the understanding of the archaeological record. Geoarchaeology is then a scientific discipline that straddles the scientific domains of Archaeology, Geology, Sedimentology, and Pedology. The questions that geoarchaeology aims to answer, however, are always related to archaeological enquiries. Geoarchaeological approaches operate at several scales: microstratigraphy (> mm scale), stratigraphic profiles (cm to several m scale), the site's environs (m to km scale), and geomorphological landscape scales (several km scale).

Since Geoarchaeology bases its source of data on the study of sediments and soils, we first need to define and refresh the following concepts:

- Stratigraphy – while Stratigraphy has many definitions, a broad definition is that stratigraphy is the "spatial and temporal arrangement of depositional units" (Karkanas and Goldberg, 2018). The main laws of stratigraphy are those of the law of superposition, the law of original horizontality, the law of cross-cutting relationships, and the law of lateral continuity. Principles of stratigraphic succession of strata and types of boundaries and disconformities are key to reconstruct depositional sequences.

- Sedimentology – deals with the study of sediments, that is, natural particles that have been weathered, transported from their original parent rock, and redeposited elsewhere. Sediments can be characterized in terms of their size (granulometry: clays, silt, sand, gravel, etc.), minerology (e.g., clastic, carbonates, evaporites), and structures. Different depositional environments will produce distinctive signatures (e.g., coastal settings, aeolian settings, colluvial settings, etc.). The basic principles of stratigraphy defined above applies to sediments. To reconstruct the depositional histories of a given archaeological sequence, we then need to understand (1) what the sedimentary sources are, (2) what transport agents, (3) and what post-depositional processes were at play. These factors are part of studies on formation histories of a site.

- Pedology – is a scientific discipline that studies soils. Soils refers to components in the upper layer of Earth's crust that have been transformed by weathering, physical/chemical processes, and biological processes. Soils encompass mineral particles, organic matter, water, air and living soil organisms. Soil forming factors are parent material (host rock), climate, time, relief (landforms and topography) and organisms (vegetation and soil biota). Soils are organized in pedogenic horizons, with gradual boundaries between the horizons, whose characteristics will result in a soil classification system. Pedogenesis, that is, the processes of soil formation, can also act upon previously deposited sediments during a period of depositional stasis.

  The distinction between sediments vs. soils is an important one, and it is often conflated or ignored by archaeologists. It therefore crucial to recognize the distinctive ways different disciplines would describe a stratigraphic profile – as illustrate in fig. 1 below. For most of the lectures in this course, we will be talking about "archaeological sediments" and not "archaeological soil". The exception will be on lecture # 11 when the effects of humans in the formation of soils horizons will be directly discussed.

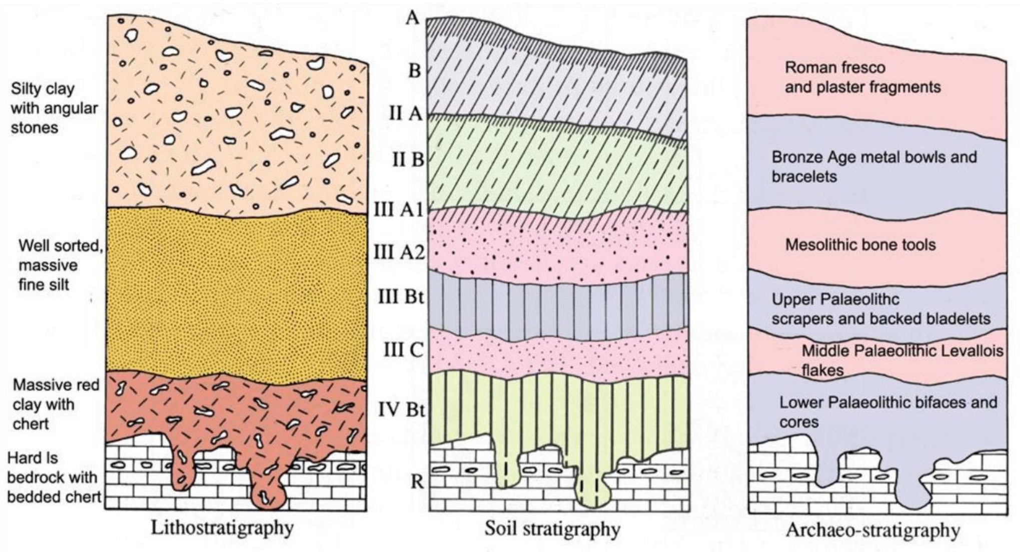


Figure 1: The same sequence described according to different stratigraphic perspectives (from Goldberg & MacPhail 2006)

- Anthropogenic deposits – are deposits whose formation and distinctive characteristic are a result of the strong and enduring influence of past human activities (Arroyo-Kalin, 2014). As such, studies of these deposits will investigate the nature of the sediments (lithology, fabric, composition, mineralogy, etc.), but also the deposition history, and post-depositional changes that these sediments have been subject too. Anthropogenic deposits do not include those enriched by human inputs or depleted by associated chemical alteration. They do include sediments relocated and transported by humans – e.g., mined from quarries, or unaltered sediments that were moved to produce platforms, earthen buildings, and structures. Deposits produced by human activities can be in the order of a few cm or thinner, and therefore can be difficult to identify and isolate during excavations (Miller, 2011).

There are an array of methodologies and techniques used in geoarchaeological studies. For this class that deals with anthropogenic deposits, a key technique is the use of micromorphology. Originally burrowed from soil studies – and, hence, traditionally names as 'soil micromorphology', this methodology has been increasingly applied to the study of archaeological sequences since the 1970s (Courty et al., 1989). It consists in carefully carving out archaeological deposits as blocks and consolidate them (using a resin-based impregnation) to maintain their original context. From the consolidated sediment blocks, micromorphological thin sections (a 30 µm-thin veneer of the original deposits) are produced, which can be examined under a petrographic microscope at several magnifications (Courty et al., 1989). A brief introduction to how micromorphology blocks are taken in the field and basic principles of petrography (plan polarized light, cross-polarized light, birefringence and interference colors of minerals) will be provided (Stoops et al., 2018).

<u>Summary of contents</u>

Introduction to this class – questions to students on what are their research and academic interests? What do they expect from this course?

Review with students the evaluation methodology for the course

Definition(s) of Geoarchaeology, Stratigraphy, Sedimentology and Pedology.

Archaeological sediments versus natural sediments – including a revision of what are sedimentary layers and what are soil horizons. Concepts of lithostratigraphy, soil stratigraphy and archaeo-stratigraphy.

Archaeological example on the importance of accurately recognizing stratigraphic sequences from the case-study of Liang Bua (Flores, Indonesia).

Introduction to the basic principles of soil micromorphology and petrographic analyses.

Specific and Further Readings

Arroyo-Kalin, M. (2014). Anthropogenic sediments and soils: geoarchaeology. In. Springer New York.

Courty, M. A., Goldberg, P., & Macphail, R. (1989). *Soils and micromorphology in archaeology*. Cambridge University Press.

Goldberg, P., & Macphail, R. (2006). *Practical and Theorectical Geoarchaeology*. Blackwell publishing.

Karkanas, P., & Goldberg, P. (2018). *Reconstructing Archaeological Sites: understanding the geoarchaeological matrix*. John Wiley & Sons.

Miller, C. E. (2011). Deposits as artifacts. *TÜVA Mitteilung*, *12*, 91-107.

Schiffer, M. B. (1987). *Formation Processes of the Archaeological Record*. University of New Mexico Press.

Stoops, G. (2003). *Guidelines for analysis and description of soil and regolith thin sections*. Soil Science Society of America.

Stoops, G., Marcelino, V., & Mees, F. (2018). *Interpretation of micromorphological features of soils and regoliths*. Elsevier.

Sutikna, T., Tocheri, M. W., Morwood, M. J., Saptomo, E. W., Awe, R. D., Wasisto, S., . . . Zhao, J.-x. (2016). Revised stratigraphy and chronology for Homo floresiensis at Liang Bua in Indonesia. *Nature*, *532*(7599), 366.

Waters, M. R. (1992). Principles of Geoarchaeology: a North American Perspective. University of Arizona Press.

Lecture 2: Preservation of Archaeological Deposits

Rationale

It is a general statement that the quantity and quality of archaeological evidence is time dependent, that is, that time will progressively reduce the evidence available in the archaeological record. The common expectation is that older sites will have fewer and less well-preserved evidence of human occupations than more recently occupied sites. This statement, however, is not a rule. Or maybe we should say that there are important and relevant exceptions to this general statement. To illustrate this, we can think of the spectacular example of the roman city of Pompeii. Because this settlement was quickly buried in 79 CE under a substantial thickness of volcanic debris, and subsequently abandoned, the degree of preservation of the archaeological buildings and deposits is far better than other, chronologically more recent, sites. As pointed by Schiffer (1987, p. 8), to understand the preservation of archaeological deposits, we need to focus on degradation processes "because degradation is caused by specific processes not the passage of time *per se*, deposits laid down at the same time, but subject to different formation processes, vary in their degree of preservation".

Conditions	Parent material	Soil type	Humus form	Soil fauna	Preservation potential	Comments/other
Acid pH <3.5–6.5	Quartz sand; schist	Ranker; Podzol (e.g. Entisols and Spodosols)	Mor and Moder	Mites, Enchytraeids, and non-burrowing earthworms	Pollen; macrobotanical material; phytoliths, soil diatoms	Loss of bone; possible damage to pottery; corrosion of iron (loss of magnetic susceptibility signal)
Neutral pH 6.5–7.5	Loams	Brown earth, Luvisols (e.g. Mollisols and Alfisols)	Mull	Collembola, Arionids (slugs) and burrowing earthworms (Lumbricids)	Bone, molluscs, phytoliths, soil diatoms; some macrobotanical material	Pollen is oxidized; large-scale mixing by meso and macrofauna; charcoal can become fragmented
Alkaline pH >7.5	Shell sand, chalk, salt lake sediments	Rendzina; Solonetz (e.g. Xerolls and Xeralfs)	Mull	As above but becoming restricted	Molluscs; bone; phytoliths (except for extreme pH > 8)	Pollen is oxidized; salt, carbonate, and gypsum crusts on pottery and other artifacts; large-scale mixing by meso and macrofauna, and fracture by secondary crystal growth
Waterlogged	Peat, estuarine sediments	Peat (Histosols)	Peat	None	Pollen, molluscs, diatoms, most organic materials, including fragile insects, skin, leather	Corrosion (loss of magnetic susceptibility signal from iron slags when fluctuating oxidizing/reducing conditions); soft-tissue "pickling" (bog man); secondary mineral formation when water tables fluctuate (gypsum, jarosite, pyrite, siderite, vivianite)

Note: Caveats
1. Fluctuating water tables (i.e. oxidation/reduction cycles) destroy pollen and "rust" iron slags
2. High biological activity mixes stratigraphy and displaces artifacts
3. Possible serendipitous preservation of strongly residual iron slag, burnt soil, fused fly-ash, phosphatized materials
(Note: gypsum ($CaSO_4 \cdot H_2O$), jarosite ($KFe_3(OH_6)_6(SO_4)_2$), pyrite (FeS_2), siderite ($FeCO_3$), vivianite [$Fe_3(PO_4)_2 \cdot 8H_2O$], see Bullock *et al.*, 1985, Table 6.2)

Figure 2: Preservation potential of archaeological components and materials (from Goldberg and MacPhail, 2006)

Degradation is dependent on the environmental and burial conditions to which the artifacts were subject to, namely sedimentation rates, chemical diagenesis, or mechanical alterations. On one hand, chemical reactions occurring within archaeological deposits can lead to modifications that have the potential to disrupt the initial stratigraphic arrangement. These reactions result in alterations such as shifts in volume, the blending of layers, the formation of additional layers, the obliteration of boundaries, and modifications to the original positions of artifacts and their interrelationships (Karkanas et al., 2000, Karkanas, 2010). The composition of the archaeological materials is equally relevant, with different formation processes acting selectively depending on the nature and structure of the artifacts (Weiner, 2010). For instance, while bones dissolve in sediments with pH below 8.2 (Karkanas et al., 2002, Berna et al., 2004), the same acidic conditions favor the preservation of other materials such as the opal-rich phytoliths (Cabanes et al., 2011) or charcoals (Boaretto et al., 2008). On the other hand, an array of mechanical disturbances can alter the way artifacts are spatially arranged in an archaeological horizon (Masson, 2010). Processes such as fragmentation, slumping, or freeze-thaw, for instance, result in a transformation of the spatial distributions, degree of clustering and temporal associations or archaeological materials.

Therefore, the assessment of the degree of preservation or alteration of archaeological deposits and materials must be a case-by-case endeavor. It needs to consider the geochemical environments, a basic understanding of degradation processes (acidification, hydrolyzes, dissolution, recrystallization, oxidation-reduction, etc.), as well as stability diagrams of primary anthropogenic components (e.g., bones, organic matter, ashes, phytoliths, charcoals).

The continuation of the introduction to petrographic microscopy analysis will be presented in the practical part of the lecture, providing students with an overview of optical mineralogy, namely optics of isotropic and anisotropic minerals.

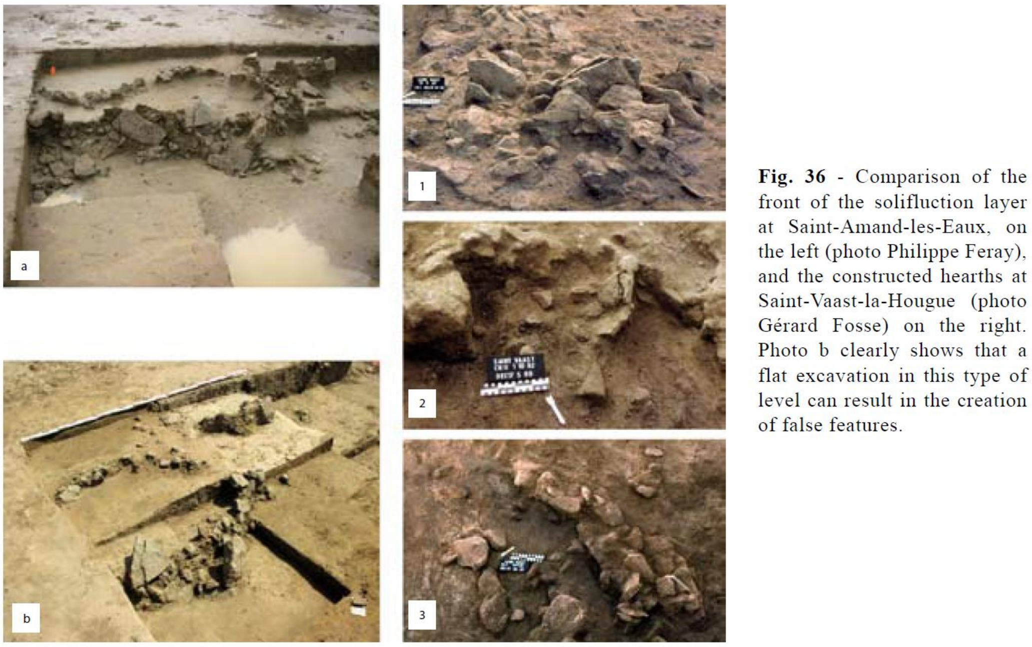


Figure 3: View of combustion features affected by solifluction post-depositional processes (from Masson 2010)

<u>Summary of contents</u>

Definition of post-depositional processes.

Physical disaggregation (e.g., bioturbation, cryoturbation, vertic processes, slumping/faulting).

Chemical alteration, namely mineral neoformation (e.g., phosphates, gypsum), solution and precipitation of carbonate, the effects of acidity/alkalinity (pH) and oxidation conditions (Eh) on the dissolution of organic material (e.g., bone dissolution windows and phosphate reaction chains).

Archaeological examples from: Hayonim Cave (Israel) for loss of bone materials; Theopetra Cave (Greece) on ash phosphatization, La Ferrassie (France) on calcite dissolution, and Montagu Cave, South Africa for neomineral formation in guano deposits.

Examples of the freeze thaw patterning combustion features at Saint-Vaast-La-Hougue

Practical Session: Analysis of micromorphological thin section under a petrographic microscope.

Specific and Further Readings

Berna, F. (2010). Bone alteration and diagenesis. In G. Artioli (Ed.), *Scientific Methods and Cultural Heritage. An Introduction to the Application of Materials Science to Archaeometry and Conservation Science* (pp. 364-367). Oxford University Press.

Hilton, M. R. (2003). Quantifying postdepositional redistribution of the archaeological record produced by freeze–thaw and other mechanisms: an experimental approach. *Journal of Archaeological Method and Theory*, *10*(3), 165-202

Huisman, H., Ismail-Meyer, K., Sageidet, B. M. & Joosten, I. 2017. Micromorphological indicators for degradation processes in archaeological bone from temperate European wetland sites. *Journal of Archaeological Science,* 85**,** 13-29.

Karkanas, P. 2022. Chemical alteration. *Encyclopedia of geoarchaeology.* Springer.

Karkanas, P. (2010). Preservation of anthropogenic materials under different geochemical processes: A mineralogical approach. *Quaternary International*, *214*(1-2), 63-69.

Karkanas, P., Bar-Yosef, O., Goldberg, P., & Weiner, S. (2000). Diagenesis in prehistoric caves: The use of minerals that form in situ to assess the completeness of the archaeological record. *Journal of Archaeological Science*, *27*(10), 915-929. http://www.scopus.com/scopus/inward/record.url?eid=2-s2.0-0033782095&partnerID=40&rel=R8.2.0

Masson, B. 2010. Combustion features and periglacial structures: a new taphonomic analysis of Mousterian combustion features at Saint-Vaast-la-Hougue. *In:* THÉRY-PARISOT, I., CHABAL, L. & COSTAMAGNO, S. (eds.) *The taphonomy of burned organic residues and combustion features in archaeological contexts.* Valbonne: Palethonologie.

Weiner, S. (2010). *Microarchaeology Beyond the Visible Archaeological Record*. Cambridge.

Lecture 3: Fire use and Pyrotechnology

Rationale

There is a vast body of literature on the topic of identifying fire in the archaeological record, as it will become clear to students during this lecture. The interest in this topic relies on the fact that control and production of fire is a hallmark of humans and has greatly shaped hominin adaptations. Fire use is linked to key aspects of our evolution as a species, namely by providing an external source of heat and light, but also as a means of external digestion, since cooking breaks down food and destroys bacteria. Fire as a technology was also key to the manufacture of new artifacts: from heat treatment of lithic tools to the manufacture of ceramics and ritual burnings. Being an obligated fire user, however, also entail some costs, namely the time spent foraging for fuel in hunter-gatherer societies (Henry, 2017). While some form of pyrotechnology has become essential in virtually all living human societies today, the question of when hominins became obligated fire users is highly debated (Sandgathe et al., 2011b, Sandgathe et al., 2011c, Roebroeks and Villa, 2011, Sorensen, 2017, Wrangham, 2006). Ethnographic studies show that, although all humans use fire, the knowledge of fire starting can be lost in a community (McCauley et al., 2020). Other animals, on the other hand, do not start fires, but a variety of animals do use and interact with fires (e.g., Bonta et al., 2017). The relevance of this topic for the present course is that fire residues, and the identification of burned artifacts and sedimentary components, is better assessed through geoarchaeological methodologies.

To understand pyrotechnology and the evolution of fire use, we first need (1) to understand the differences between fire use (non-human specific) and control/production of fire (human-specific), and (2) to define what is the evidence that can be encountered in the archaeological record. Identifying fire in the archaeological record can rely on both direct (by-products of combustion) and indirect proxies. When a fire is lit, there are materials and deposits directly produced by the combustion of fuel, such as, ashes, charcoals, or calcined bone. Yet, fire also implies a substantial raise in temperature (heat) and indirect evidence of fire are the components that are affected by this heat, such as burned sedimentary substrates and burned artifacts (lithics, bones, shells, organics, etc.) Experimental archaeological work has investigated under what circumstances heat alters underlying deposits (Aldeias et al., 2016), and a vast array of studies have established the temperature thresholds for structural changes in burned bones (Bennett, 1999, Stiner et al., 1995), shells (Aldeias et al., 2019, Villagran, 2014a), silcrete (Schmidt et al., 2013, Archer et al., 2023), flint (Goder-Goldberger et al., 2017), and other organic and mineral components (e.g., Wadley, 2009).

However, fire is not *per se* anthropogenic. Combustion is a natural phenomenon part of the geological history of the planet. Therefore, simply identifying an altered (i.e., burned) component is not enough to assign it to human agency. The identification of combustion features must be based not only on the presence of thermally altered materials, but also their geometric associations. For instance, an open campfire will generate a microstratigraphy associated with a superimposition of a white ash-rich layer, overlying a darker organic, often charcoal-rich lens, which in turn sits on top an altered, typically reddened, substrate. A powerful tool to examine pyrotechnology is, then, the use of microarchaeological techniques, particularly micromorphology coupled with infrared studies. These as well as other approaches that have investigated fire remnants are synthetized in Goldberg et al. (2017b).

As mentioned above, there is a rich body of work investigating the presence of anthropogenic fire in the archaeological record. Though, many claims for fire evidence have turned out to be wrongly assigned since there are several processes that mimic fire residues (e.g., manganese-stained bones, natural burned charcoals, carbonates erroneously interpreted as ash, etc.). Due to preservation issues, fire remnants are also easily dissolved, blown away or disturbed to the point that they become hard to detect in the field. For instance, because most fire rely on wood for fuel, acid conditions can result in the dissolution of ashes, which are almost entirely compose of calcite (Weiner, 2010, Etiegni and Campbell, 1991). In cave settings, where bat roasting is common, the accumulation of guano can also result in the loss of carbonates and consequent phosphatization of ashes (Karkanas, 2021, Karkanas, 2010). As bones are exposed to increasingly high temperatures, they go through a cascade transformation that leads to changes in color and mineralogy (Stiner et al., 1995). At temperatures above ~700ºC, bone becomes calcined and, whereas calcined bone is chemically stable, it is physically brittle. Extensive fragmentation of calcined bone then results in a lack of archaeological visibility of these components.

Recognizing evidence for use of fire, let alone control of fire is often challenging, particularly in hunter-gather occupations where fire structures are not typically formalized. Well-preserved combustion features can assume a variety of forms, and these have been categorized into the following typologies: open flat hearths; pit features, prepared surfaces, and fire installations (Mallol et al., 2017). An array of human activities can also be gleaned from the study of fire residues, namely hearth rake out, sweeping activities and ash dumps (Miller et al., 2010), which several of such activities often been associated with some degree of site maintenance.

Given this theoretical and empirical background, we can now focus on examples from the archaeological record, namely review of main claims for the first appearance of fire use, and the ongoing debate if Neanderthals were always obligated fire users. While several Neanderthal occupations show the presence of remnants associated with anthropogenic fire, at particularly two sites in SW France, there is evidence for Neanderthal occupations that are not associated with fire use during glacial environments. This has led to an ongoing debate if this evidence related to a taphonomic issue of preservation of fire remnants or if Neanderthals could have an adaptation to cold environments without the use of fire. Ethnographic studies on the consumption of putrid meat have shown to provide similar benefits as cooking (Speth, 2017), though there is currently a lack of studies on identifying putrefied bone in archaeological settings. Equally far less is known on the pyrotechnology of upper Paleolithic hunter-gatherers, as shown in a recent study by Murphree et al. (2020). In the final parts of the oral presentation, an overview will be given to students on the modalities of fire use during the European Upper Paleolithic.

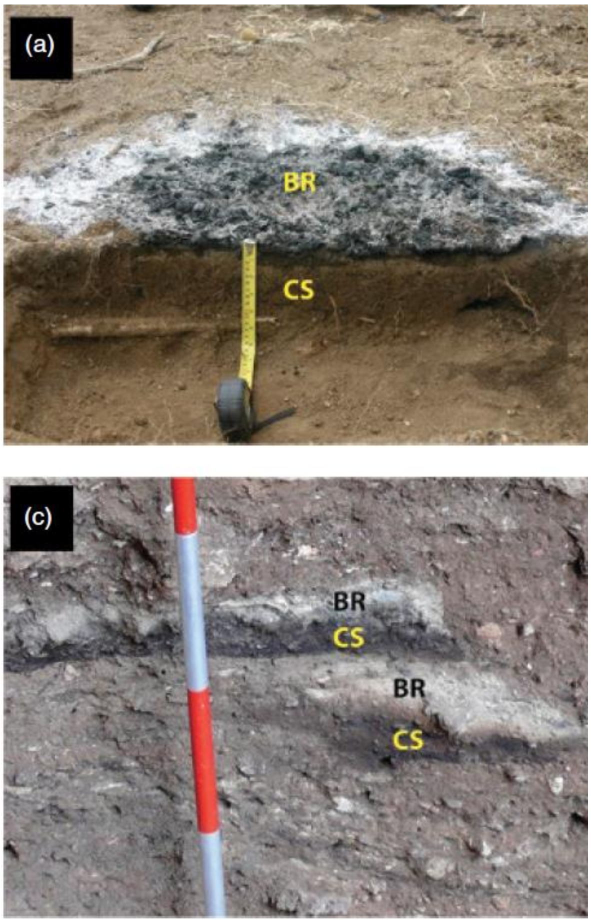


Figure 4: View of combustion features in the field in plain view (a) and in section (c). Note the superimposition of the white, ash-rich deposits with darker black bases and the presence of rubified substrates in some of the features. Adapted from (Mallol et al., 2017).

Summary of contents

Establish the conceptual differences between use of fire versus control and production of fire – examples of how animals interact and use fire, as well as ethnographic studies on human communities that do not know how to start fires.

Toolkits to identify direct (ashes, bones, shells, flint) and indirect residues of fires (burned substrates and experimental work on post-depositional burning).

Examples of pitfalls on misinterpretation of residues as relating to anthropogenic fire.

The costs and benefits of fire.

Fire as a technology and current debates on when humans started to use fire.

Review of current archaeological sites showing the earliest evidence for anthropogenic fire and how pyrotechnology changed through space and time.

Practical component – analysis of thin sections of fire features under the microscope

Specific and Further Readings

Aldeias, V. (2017). Experimental Approaches to Archaeological Fire Features and Their Behavioral Relevance. *Current Anthropology, 58*(S16), S191-S205

Aldeias, V. (2017). Experimental Approaches to Archaeological Fire Features and Their Behavioral Relevance. *Current Anthropology*, *58*(S16), S191-S205

Goldberg, P., Miller, C. E., & Mentzer, S. M. (2017). Recognizing fire in the Paleolithic archaeological record. *Current Anthropology*, *58*(S16).

Karkanas, P. (2021). All about wood ash: Long term fire experiments reveal unknown aspects of the formation and preservation of ash with critical implications on the emergence and use of fire in the past. *Journal of Archaeological Science*, *135*, 105476. https://doi.org/https://doi.org/10.1016/j.jas.2021.105476

Mallol, C., Mentzer, S. M., & Miller, C. E. (2017). Combustion features. In C. N. a. G. Stoops (Ed.), *Archaeological soil and sediment micromorphology* (pp. 299-330). Wiley Blackwell.

McCauley, B., Collard, M., & Sandgathe, D. (2020). A Cross-cultural Survey of On-site Fire Use by Recent Hunter-gatherers: Implications for Research on Palaeolithic Pyrotechnology. *Journal of Paleolithic Archaeology*, 1-19.

Mentzer, S. (2014). Microarchaeological Approaches to the Identification and Interpretation of Combustion Features in Prehistoric Archaeological Sites. *Journal of Archaeological Method and Theory*, *21*(3), 616-668

Mentzer, S. (2014). Microarchaeological Approaches to the Identification and Interpretation of Combustion Features in Prehistoric Archaeological Sites. *Journal of Archaeological Method and Theory*, *21*(3), 616-668

Roebroeks, W., & Villa, P. (2011). On the earliest evidence for habitual use of fire in Europe. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(13), 5209-5214

Sandgathe, D. M., Dibble, H. L., Goldberg, P., McPherron, S. P., Turq, A., Niven, L., & Hodgkins, J. (2011). On the Role of Fire in Neandertal Adaptations in Western Europe: Evidence from Pech de l'Azé and Roc de Marsal, France. *Paleoanthropology*, 216-242.

Sandgathe, D. M., Dibble, H. L., Goldberg, P., McPherron, S. P., Turq, A., Niven, L., & Hodgkins, J. (2011). Timing of the appearance of habitual fire use. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(29).

Sorensen, A. C. (2017). On the relationship between climate and Neandertal fire use during the Last Glacial in south-west France. *Quaternary International*, *436*, 114-128.

Speth, J. D. (2017). Putrid meat and fish in the Eurasian middle and upper Paleolithic: are we missing a key part of Neanderthal and modern human diet. *Paleoanthropology*, *2017*, 44-72.

Class 4: Burials and Inhumations

Rationale

The relationship between human societies and death is culturally ingrained. Different societies have interacted, cared for, and disposed of their dead differently through time and in different geographic settings. A rich body of literature exists on the identification of early hominin mortuary and funerary behavior, with ongoing debates on intentional ritual behaviors in the disposal or catchment of bodies in archaeological sites as Sima de los Huesos (Carbonell and Mosquera, 2006) and (more controversial) at Rising

Star Naledi karst system (Berger et al., 2023). The identification of practices of intentional burial amongst Gravettian and later hunter-gathers is well established (e.g., Pettitt et al., 2003, Formicola and Buzhilova, 2004), whereas such examples are rarer in previous upper paleolithic occupations and at times disputed among Neanderthals (Pettitt, 2002, Sandgathe et al., 2011a, Dibble et al., 2015, Rendu et al., 2014, Rendu et al., 2016, Pomeroy et al., 2020, Gargett, 1989, Gargett, 1999).

When complex rituals are in place, it is easier to identify intentional inhumation. However, in the deeper past where structured tombs and cemeteries were absence, the recognition of intentional burials relies heavily on the archaeological context and stratigraphic associations. A set of criteria has been put forward to guide in the identification of early evidence for intentional burial, as summarized in Sandgathe et al. (2011a). Specifically:

1. Was there a burial pit and was the body located at its base?
2. Were the remains covered by a unique stratum – i.e., intentional infill?
3. Are the remains covered by naturally laid deposits?
4. What is the position of the body?
5. Is the skeleton complete and articulated, or are portions disarticulated and missing?
6. Was the body accompanied by special objects – ‘grave goods’?

Of these, the first three criteria are directly related to, and can be tested by, geoarchaeological approaches. The first criterion deals with the notion that there is stronger claim to intentionality when a burial pit was anthropogenically made. There are several examples of geogenic and biogenic processes that can form pit-like depressions independently of human actions. In forested open-air sites, a natural tree-throw will form a basin-shaped depression (Waters, 1992). In cave sites, the presence of bear nests can also assume shapes and dimensions that can mimic a burial pit (Dibble et al., 2015). At the site of Roc de Marsal (France), the presence of natural karstic depressions was shown to be an analog for the described find location of the infant neanderthal unearthed at the site (Sandgathe et al., 2011a, Goldberg et al., 2017a). Also, part of this criterion is if the body rests at the base of the pit. This is because it is less parsimonious to argue that humans purposedly dug a burial pit just to immediately fill it back before depositing a body.

The second criterion mentioned above deals with the deposits that cover an intentionally buried skeleton. The human actions of covering a body entails the rapid deposition of a unique stratum. These deposits will typically lack well-developed sedimentary structures, show random fabric of the sedimentary components, and are spatially/laterally restricted to the inhumation area. The opposite is having successive stratified layers covering the body or different parts of a body. Distinguishable strata involve the gradual deposition of different sedimentary sources and components, with potential distinct depositional agents and erosional phases. Such stratigraphic differentiation implies time and not a rapid moment of accumulation of deposits to cover and protect an interred body.

A related third criterion deals with the nature of the infilling deposits. Natural depositional processes, namely those associated with rapid and low-energy sedimentation rates, can lead to the preservation of animal (and human) bones. This is why we find articulated dinosaur skeletons in the geological record, and we do not claim that dinosaurs intentionally buried their dead. In environments with high sedimentation rates, and where the energy of deposition is low, anatomical articulation of skeletons can be preserved and fossilized. Therefore, when dealing with the question if human skeletons were naturally or anthropogenically covered the basic principles of stratigraphy apply, where we would expect that naturally laid deposits would cover not only a body but also extend beyond the body location. Aspects such as the presence of sedimentary structures, fabric orientation, texture, and layer geometry will provide telltale signatures of specific natural deposition processes (e.g., water-laid deposits, loess, colluvium).

Table 1
Summary of sedimentary features, processes and their interpretation.

Sedimentary feature	Sedimentary process	Interpretation
Small lenses of clast-supported, openwork gravel that thin upslope; reverse grading, strong imbrication, and preferred orientations of clasts parallel to the slope.	Dry grain flow on sloping surfaces under the influence of gravity.	Redistribution of debris down-slope of isolated piles formed by shoveling during backfilling of tombs.
Unsorted and unstratified deposits with disorderly clast fabric; occasional normal grading.	Free rock-fall and debris fall under the influence of gravity.	Dumping material with a shovel or similar equipment during backfilling of tombs; occasional sliding and collapse of piles of debris.
Continuous planar features with abrupt changes in grain size, porosity, and compaction, often associated with stone lines with erosional, knife-sharp lower contact.	Erosion (truncation) of previous fill.	Re-opening of tomb by digging the previous fill.
Thin fine-grained layers with dense fabric and parallel horizontal orientation of the coarser elements and pores; Knife-sharp upper contacts; Groundmass consists of reacted dirty gray micrite with wavy fabric and embedded calcitic aggregates of half-reacted lime.	Lime plaster.	Man-made constructed surfaces.
Finely laminated sediment of graded silt and clay couplets with occasionally intervening sorted sandy lenses.	Sediment settled in a standing body of water.	Geogenic water-lain fill of collapsed chambers.

Figure 5: Table from Karkanas et al. (2012) showing the sedimentary features, inferred processes and archaeological interpretation of geoarchaeological investigations of Mycenean tombs in Greece.

In historic periods where funerary behavior can involve not only body internment but the construction of structures such as tombs, urns, or monumental tumuli, geoarchaeological research can also provide key data on the anthropogenic dynamics related to complex histories in the treatment and disposal of the dead (e.g., Mentzer et al., 2017, Usai et al., 2018). Reconstructing these human actions provides data on mortuary practices and dynamics involved in multi-use burials. Taking the example of Mycenean tombs, Karkanas et al. (2012) used stratigraphic and micromorphological analyses to investigate the fills in entrance corridors and chambers at the site of Ayia Sotira (Greece). These analyses revealed: the sedimentary signatures associated with tomb re-openings related to actions of digging and filling (planar erosional surfaces, sorted gravels with reversed or normal grading, changes in compaction); the identification of constructed plastered calcareous floors throughout the life history of the monuments; and different accretion modes in the chamber section, showing that the chambers were not infilled but sealed with corpses either directly laid on the chamber constructed floors or in pits dug in the substrate. A final example will be shown of the micromorphological study of a roman incineration funerary structure (*ustrina)* from Encosta de Sant'Ana (Portugal) (Angelucci, 2008). This micromorphological study investigates the formation processes of this structure showing its life history: it was built by digging a pit into the substrate and covering it with a ridge of mud-bricks; during use the firing temperatures were not always high enough to fully cremate all the corpses (bones burned below 700ºC survived); the structure was reused multiple times, not always emptied out; and, finally, that the structure had at least one moment of restoration.

From the examples provided during the oral presentation, it becomes clear that the preservation and sampling of profiles inside funerary structures can provide substantial information regarding mortuary practices and life histories of ancient complex funerary structures.

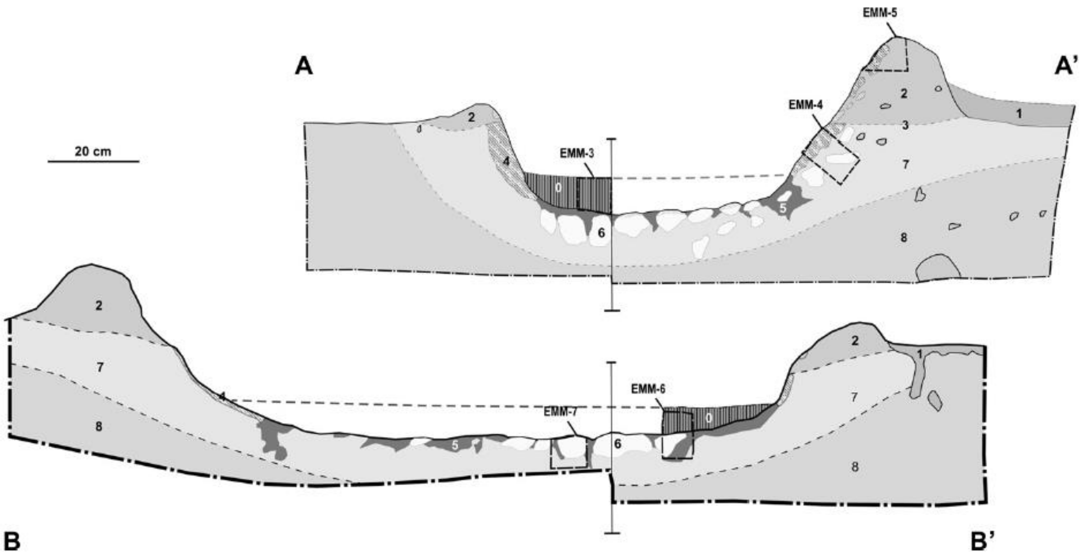


Figure 6: Profile views of the Roman ustrina sampled for micromorphology (Angelucci et al. 2008).

<u>Summary of contents</u>

Definition of geoarchaeological-based criteria for identifying intentional burials.

Geoarchaeological evidence for assessing intentionality of burials in non-constructed funerary contexts.

Examples of geoarchaeological approaches to the study of complex funerary behaviors in constructed structures – Mycenean tombs and Roman incineration structures

Practical activity:

This class will engage the active participation of the students in ongoing discussions on Neanderthal intentional burials. In the week prior to this class, two "teams" of students will be assigned – one team will take the position that Neanderthals buried their dead and the other that there is no evidence for intentional burial. Both groups will expose their arguments, detail on what evidence they see as most relevant for those arguments based on available data from the literature.

Specific and Further Readings

Angelucci, D. E. (2008). Geoarchaeological insights from a Roman age incineration feature (ustrinum) at Enconsta de Sant'Ana (Lisbon, Portugal). *Journal of Archaeological Science*, *35*(9), 2624-2633

Dibble, H. L., Aldeias, V., Goldberg, P., McPherron, S. P., Sandgathe, D., & Steele, T. E. (2015). A critical look at evidence from La Chapelle-aux-Saints supporting an intentional Neandertal burial. *Journal of Archaeological Science*, *53*, 649-657.

Gargett, R. H. (1999). Middle Palaeolithic burial is not a dead issue: The view from Qafzeh, Saint-Césaire, Kebara, Amud, and Dederiyeh. *Journal of Human Evolution*, *37*(1), 27-90.

Goldberg, P., Aldeias, V., Dibble, H., McPherron, S., Sandgathe, D., & Turq, A. (2017). Testing the Roc de Marsal Neandertal "Burial" with Geoarchaeology [journal article]. *Archaeological and Anthropological Sciences*, *9*(6), 1005-1015.

Karkanas, P., Dabney, M. K., Smith, R. A. K., & Wright, J. C. (2012). The geoarchaeology of Mycenaean chamber tombs. *Journal of Archaeological Science*, *39*(8), 2722-2732.

Macphail, R. I., & Goldberg, P. (2017). *Applied soils and micromorphology in archaeology*. Cambridge University Press.

Sandgathe, D. M., Dibble, H. L., Goldberg, P., & McPherron, S. P. (2011). The Roc de Marsal Neandertal child: A reassessment of its status as a deliberate burial. *Journal of Human Evolution*, *61*(3), 243-253

Rendu, W., Beauval, C., Crevecoeur, I., Bayle, P., Balzeau, A., Bismuth, T., . . . Lacrampe-Cuyaubère, F. (2014). Evidence supporting an intentional Neandertal burial at La Chapelle-aux-Saints. *Proceedings of the National Academy of Sciences*, *111*(1), 81-86.

Rendu, W., Beauval, C., Crevecoeur, I., Bayle, P., Balzeau, A., Bismuth, T., . . . Lacrampe-Cuyaubère, F. (2016). Let the dead speak… comments on Dibble et al.'s reply to "Evidence supporting an intentional burial at La Chapelle-aux-Saints". *Journal of Archaeological Science*, *69*, 12-20.

Pomeroy, E., Bennett, P., Hunt, C. O., Reynolds, T., Farr, L., Frouin, M., . . . Barker, G. (2020). New Neanderthal remains associated with the 'flower burial'at Shanidar Cave. *Antiquity*, *94*(373), 11-26.

Pomeroy, E., Hunt, C. O., Reynolds, T., Abdulmutalb, D., Asouti, E., Bennett, P., . . . Barker, G. (2020). Issues of theory and method in the analysis of Paleolithic mortuary behavior: A view from Shanidar Cave. *Evolutionary Anthropology: Issues, News, and Reviews, 29*(5), 263-279.

Lecture 5: Stabling and Fumiers

Rationale

With the advent of animal domestication, enclosures to contain animals appear in the archaeological record. Animal gathering enclosures, often named pens, corals, and stables, are fenced areas that bear evidence to not only animal husbandry and subsistence activities practiced by a past community, but also inform on human management activities at these sites. Stabling sites can vary from natural shelters (e.g., caves), to designated fenced locations or reuse of abandonment structures now repurposed for animal husbandry.

The main stratigraphic evidence for penning and stabling activities is the accumulation of animal dung mixed with fodder and straw bedding in strata that typically present relevant degrees of animal trampling and a microlaminated appearance. In general, stabling deposits are compacted and finely bedded layered accumulations that tend to be laterally continuous and sub-horizontal, following the underlying topography of the substrate (Karkanas and Goldberg, 2018). Different animals will produce distinguishable dung pellets and coprolites that can be identified through geochemical biomarkers (Evershed, 2008, Shillito et al., 2020, Sistiaga et al., Sistiaga et al., 2014) and micromorphological analysis (Gilbert et al., 2008, Goldberg et al., 2009a, Horwitz and Goldberg, 1989, Brönnimann et al., 2017). In addition to the shape and form of coprolites, characteristic inorganic components (e.g., phytoliths, calcium oxalates and dung spherulites) are also part of dung pellets and provide data on plant remains and the type of animals producing the excrements (Canti, 1997). Dung spherulites are produced in the intestines of certain herbivores (Brochier, 1983, Brochier et al., 1992), whereas opal phytoliths derive from plant matter and can both relate to the ingested plants by domestic animals or derive from the fodder or bedding provided to those animals.

Management practices associated with the periodic burning of the organic content that accumulates in pens and stables originates the well-known *fumiers* stratigraphies.

Burning of stabling surfaces creates distinct well stratified layers of distinct colorations. Typically, a darker brown, more organic, lower unit is overlain by whitish to gray ash-rich deposits. The basal unit relates to the deposits containing charred remains that may still preserve some altered dung pellets, whereas the white layers are composed of calcined coprolites and calcite-rich deposits. Other types of management are the addition of lime spread across the dung accumulations.

Dung complete preservation – and hence organic-rich deposits – are rare, except for waterlogged conditions or sites in arid environments (Shahack-Gross, 2011). Organic matter decay though bacterial activity under oxidizing condition is, therefore, a major post-depositional process in most stabling and pen accumulations. The presence of subproducts such as horizons of phosphate and gypsum (in arid environments) nodules can be tail tale indicators of the presence of decayed dung (Shahack-Gross, 2017, Karkanas and Goldberg, 2018). Typical phosphate minerals associated with decayed dung are apatite and vivianite, with their formation depending on the geochemical conditions at each site. The presence of urine and water leads to the development of hydromorphic processes. Dung spherulites are composed of unstable form of calcium carbonate and can dissolve under neutral to slightly acidic pH conditions but will preserve if burned as calcitic pseudomorphs (Shahack-Gross et al., 2005).

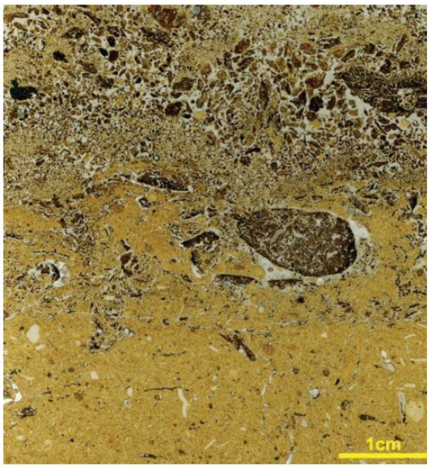


Figure 7: Example of trampled sheep/goat coprolite in a premodern Bedouin enclosures (Shahack-Gross, 2017).

Figure 8: view of a fumier at the Holocene succession at the site of El Mirador in Atapuerca, Spain (Angelucci et al., 2009)

Summary of contents

Geoarchaeological evidence for stabling and penning activities.

Identification of components of stabling deposits: dung from herbivores (cow, sheep, goat), dung from omnivores (pig, dogs), opal phytoliths and dung spherulites.

Identification of activities such as trampling and burning in thin sections.

Fumiers: their stratigraphic signatures and archaeological examples.

Ethnographic work on geoarchaeological approaches to stabling and penning sites.

Specific and Further Readings

Angelucci, D. E., Boschian, G., Fontanals, M., Pedrotti, A. & Vergès, J. M. 2009. Shepherds and karst: The use of caves and rock-shelters in the Mediterranean region during the Neolithic. *World Archaeology,* 41**,** 191-214.

Canti, M. G. 1997. An investigation of microscopic calcareous spherulites from herbivore dungs. *Journal of Archaeological Science,* 24**,** 219-231.

Burguet-Coca, A., Polo-Díaz, A., Martínez-Moreno, J., Benito-Calvo, A., Allué, E., Mora, R. & Cabanes, D. 2020. Pen management and livestock activities based on phytoliths, dung spherulites, and minerals from Cova Gran de Santa Linya (Southeastern pre-Pyrenees). *Archaeological and Anthropological Sciences,* 12**,** 148.

Gur-Arieh, S., Shahack-Gross, R., Maeir, A. M., Lehmann, G., Hitchcock, L. A. & Boaretto, E. 2014. The taphonomy and preservation of wood and dung ashes found in archaeological cooking installations: case studies from Iron Age Israel. *Journal of Archaeological Science,* 46**,** 50-67.

Lancelotti, C. & Madella, M. 2012. The 'invisible' product: developing markers for identifying dung in archaeological contexts. *Journal of Archaeological Science,* 39**,** 953-963.

Linseele, V., Riemer, H., Baeten, J., De Vos, D., Marinova, E. & Ottoni, C. 2013. Species identification of archaeological dung remains: A critical review of potential methods. *Environmental Archaeology,* 18**,** 5-17.

Shahack-Gross, R. 2011. Herbivorous livestock dung: formation, taphonomy, methods for identification, and archaeological significance. *Journal of Archaeological Science,* 38**,** 205-218.

Shahack-Gross, R. 2017. Animal gathering enclosures. *Archaeological soil and sediment micromorphology***,** 265-280.

Shahack-Gross, R. 2011. Herbivorous livestock dung: formation, taphonomy, methods for identification, and archaeological significance. *Journal of Archaeological Science,* 38**,** 205-218.

Lecture 6: Middens, Trash Pits and Latrines

Rationale

Archaeology gathers much of its information about past day-to-day lives from studding ancient trash in detail. In most modern urbanized societies, dealing with waste involves getting rid of it by swiping, cleaning, gathering and disposing of trash away from our habitations. The archaeological study of refuses provides data beyond just the material culture that was used and afterwards discarded. The way ancient societies dealt with trash is closely associated with cultural practices: was the trash burned? Was it simply taken just adjacent to the living space? Or was it put away in constructed trash pits?. Furthermore, study of middens, latrines and trash pits also provides dietary information of the site's occupants: what animals are being eaten? what vegetable foods?) as well as aspects related to past humans' health – for instance through the identification of human parasite eggs.

The study of human refuse represents the bulk of the archaeological record of early Prehistory. Anthropogenic activities specifically related to intentional dumping of debris have been identified in Paleolithic settings – e.g., intentional ash dumps (Miller, 2015, Schiegl et al., 1996, Schiegl et al., 2003, Aldeias et al., 2012). Overall, the concept of "midden" is loosely applied in archaeology as accumulation of waste, but close geoarchaeological investigations have shown that several middens infill preserve discrete laminations that relate to snapshots of distinct human activities (Brönnimann et al., 2020, Huisman et al., 2014, Yravedra and Uzquiano, 2013). Perhaps one of the most used terms for midden is that associated with “shell-midden” sites. However, given the specific complexities of shell midden stratigraphies, these will be specifically analyzed in another lecture. In this class, we will focus on later periods where formalization of waste management was in place.

Middens are large piles of material, domestic debris and animal waste thrown away by human beings in the past. The onset of designated waste refusal areas is closely linked with sedentism. Dealing with domestic debris becomes a need when human societies change from a nomadic lifestyle to spending all or large periods of time at the same location. People start pilling their trash in unused structures (e.g., former wells, abandoned houses, or storage silos), or build trash pits, pile trash in designated heaps and create latrines. Areas of designated waste management can either be private or public, and the degree into which waste was processed may vary. Middens can be formalized areas or structures (e.g., pits, wells) or unformalized areas (e.g., waste refusal areas that are not spatially bounded by structural limits). Midden structures can also be covered (or inside protected areas) or unroofed/exposed. In the latter case, natural processes related to colluvia, runoff and bioturbation can contribute to the infill. Middens with layered strata relate to gradual accretion of dumped debris, whereas massive middens indicate rapid accumulation of dumped materials. Stratigraphically, dumping activities result in sedimentary structures that can resemble gravity colluvium flows, with vertical orientation of large stones or components.

A site with several geoarchaeological studies of midden deposits is the Neolithic site of Çatalhöyük (Turkey). Some middens at Çatalhöyük preserve finely stratified layers that directly indicate successive and distinct set of human actions (Shillito and Matthews, 2013, Matthews et al., 1997). Others have been affected by post-depositional processes resulting in a homogenization of the midden infill. Pit middens have been shown to contain a variety of single-activity strata related to *in situ* burning activities with different types of ash deposits, but also lenses deriving from hearth rake out events, while other layers are rich in human coprolites pointing to the occasional use of the structures as latrines (see also Shillito et al., 2011). This case-study illustrate not only the variety of midden formation, but also that not all the sediments infilling middens are related to simple waste dumping activities.

Latrines and cesspits have been identified at several archaeological sites (Macphail, 2017, Macphail and Goldberg, 2018, De Cupere et al., 2022). The secure identification of deposits rich in human feces involves the combination of micromorphology characteristics of human coprolites (Macphail, 2017, Goldberg et al., 2009a, Shillito et al., 2011) with paleoparasitology (Bathurst, 2005, Pichler et al., 2014, Pümpin et al., 2017), sterol fecal and bile acid biomarkers (Shillito et al., 2020, Sistiaga et al.)), and ancient DNA (Gilbert et al., 2008, Søe et al., 2018). Human coprolites can incorporate dietary residues such as plant remains, phytoliths plant seeds, and small bone fragments (Macphail, 2017). Latrine fecal layers can be interfingered with other materials, namely discarded ash-rich layers, which have been interpreted as used for hygiene purposes (Deforce, 2010). The accumulation of fecal waste changes the chemical composition of soils and sediments. Secondary phosphates can be remobilized into adjacent deposits and be present as coatings in channels and voids. The case-study of the Celtic urban settlement of Swiss Basel-Gasfabrik site provides a good example of micromorphology and the identification of parasite eggs to detect the formation processes and reconstruct living conditions and health of the iron age site inhabitants (Pichler et al., 2014).

We can reasonably assume that in many permanent settlements there is a degree of waste management Ethnographic work has documented the presence of prominent refuse and dump areas in association in several forager settlements (e.g., Binford, 1078, O'Connell et al., 1991). A final example of non-formalized areas of waste disposal will be presented based on geo-ethnographic work with foragers in a tropical forest setting in southern India (Friesem and Lavi, 2017). This study documented the practices of cleaning the forest ground daily. The sweeping and dumping of debris formed a waste area just at the outskirts of the terraced area where houses were located. Due to the rapid burial and addition of calcareous components (namely, ashes), these dumped deposits have a higher archaeological visibility than the occupation surfaces where the foragers did their daily activities. As such, this case study illustrates how refusal heaps can at times be the main source of archaeological data to indirectly reconstruct ancient daily activities.

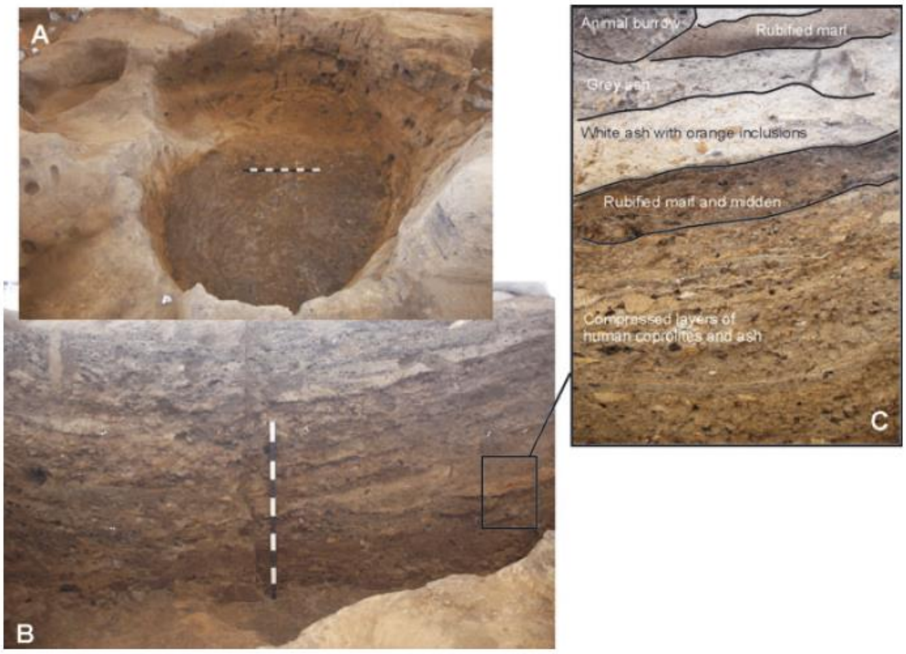


Figure 9: View of pit midden from the site of Çatalhöyük (Turkey) showing the infill with multiple episodes of in situ burning and the fine stratified nature of the midden's infill (Shillito and Mathews, 2012).

<u>Summary of contents</u>

Introduction to human refuse and its relevance for cultural, dietary, and health related inferences.

What is a midden and what is not a midden?

Definition of formalized and non-formalized waste disposal areas, trash pits and latrines.

Multidisciplinary perspectives on the studies of human refusa.

Case-studies: midden pits at the Neolithic site of Çatalhöyük, latrines at Swiss Basel-Gasfabrik, and geo-ethnographic research on waste management from southern India.

Specific and Further Readings

Brönnimann, D., Röder, B., Spichtig, N., Rissanen, H., Lassau, G., & Rentzel, P. (2020). The Hidden Midden: Geoarchaeological investigation of sedimentation processes, waste disposal practices, and resource management at the La Tène settlement of Basel-Gasfabrik (Switzerland). *Geoarchaeology, 35*(4), 522-544.

De Cupere, B., Speleers, L., Mitchell, P. D., Degraeve, A., Meganck, M., Bennion-Pedley, E., . . . Deforce, K. (2022). A Multidisciplinary Analysis of Cesspits from Late Medieval and Post-Medieval Brussels, Belgium: Diet and Health in the Fourteenth to Seventeenth Centuries *International Journal of Historical Archaeology, 26*(3), 531-572. doi:10.1007/s10761-021-00613-8

Friesem, D. E., & Lavi, N. (2017). Foragers, tropical forests and the formation of archaeological evidences: An ethnoarchaeological view from South India. *Quaternary International, 448*, 117-128.

Macphail, R. I. (2017). Privies and Latrines. In A. S. Gilbert (Ed.), *Encyclopedia of Geoarchaeology* (pp. 682-687). Dordrecht: Springer Netherlands.

Macphail, R. I., & Goldberg, P. (2018). Archaeological materials. In *Interpretation of micromorphological features of soils and regoliths* (pp. 779-819): Elsevier.

Matthews, W., French, C. A. I., Lawrence, T., Cutler, D. F., & Jones, M. K. (1997). Microstratigraphic traces of site formation processes and human activities. *World Archaeology, 29*(2), 281-308.

Miller, C. E. (2015). *A Tale of Two Swabian Caves. Geoarchaeological Investigations at Hohle Fels and Geißenklösterle*: Kerns Verlag.

Pichler, S. L., Pümpin, C., Brönnimann, D., & Rentzel, P. (2014). Life in the proto-urban style: The identification of parasite eggs in micromorphological thin sections from the Basel-Gasfabrik Late Iron Age settlement, Switzerland. *Journal of Archaeological Science, 43*(1), 55-65.

Pümpin, C., Le Bailly, M., & Pichler, S. (2017). Ova of intestinal parasites. *Archaeological soil and sediment micromorphology*, 91-97.

Shillito, L. M., & Matthews, W. (2013). Geoarchaeological Investigations of Midden-Formation Processes in the Early to Late Ceramic Neolithic Levels at Çatalhöyük, Turkey ca. 8550–8370 cal BP. *Geoarchaeology, 28*(1), 25-49.

Lecture 7: In-class presentations by students

During the previous lectures, starting by the first introductory class where the students shared what interests them in archaeology, there will be a constant interaction with students to choose a research topic to be prepared for an in-class presentation. The goal is that the chosen topics tap into already existing or emerging interests demonstrated by the student or group of students.

The in-class presentation will consist of an oral communication where a topic will be presented, providing archaeological case-studies, and critically- assessed based on the tools and skills learned in the course. The goals are for students to (1) develop their skills in public communication, (2) learn to synthesize a body of literature on a topic, and (3) apply critical thinking to the available data.

After each student or group of student's presentations, the rest of the class will be invited to provide feedback on both the clarity of the content, but also on the delivery of the oral presentations. The goal of this exercise is not only to engage all the class in productive discussions but also to provide peer constructive criticism on the presentations provided by the students.

Lecture 8: Earth Mounds and Shell Mounds

<u>Rationale</u>

Humans are builders. The planet is today punctuated by our constructions, with large infrastructure of roads, walls, houses, and monuments being part of our daily lives. We can trace human constructions in the archaeological record even in the deep past, namely with the advent of sites that were recurrently visited and, eventually, that were permanently occupied settlements associated with sedentary societies. In this class, we will focus on the use of earth and shell-rich matrix to build artificial large mounds. Mound sites are interesting case-studies for geoarchaeology since their formation is often almost entirely dependent on human agency. We will focus first on the so-called shell midden sites and then provide examples of earth mound sites.

Shell-rich sites – also called shell middens or shell mounds – are sites whose sedimentary matrix is composed by abundant, and at times entirely clast-supported, mollusk shells (Marean, 2016). The recognition of anthropogenic versus natural shell-rich deposits is, however, not always straightforward since natural shell accumulations can occur in stranded beach ridges. Human agency can be determined by the inclusion of artifacts, other faunal remains and charcoals. Natural shell-rich deposits, on the other hand, have distinct criteria related to their lateral extension, shell orientation, shell taphonomy, stratigraphic contacts, bedding, and strata dips. The interpretation of natural or anthropogenic formation is always context dependent (Bailey, 1983).

Anthropogenic shell-rich sites have commonly been interpreted as the result of refuse piles resulting from recurrent visits to the same site, or from temporally more established year-round settlements (Kelly, 1992). Ethnographic and geoarchaeological studies have shown that a vast array of activities besides simple secondary deposits of food waste can be involved in the creation of shell-rich sites (Villagran, 2014b). Historical and contemporaneous accumulation of shell middens in the Saloum Delta in Senegal are associated with processing and drying shellfish that are then traded rather than used for subsistence (Hardy et al., 2016). Stratigraphically, shell midden build up can occur both laterally and vertically, extending over several meters and forming complex stratigraphic sequences. From micromorphological investigations of these deposits, a series of human actions associated with the deposition and reworking of shellfish have been identified, with inferences of intentional accretion for building, planned dumping, individual tossing events, and association with funerary practices. Examples of purposedly constructed shell middens are the so-called shell rings that were deliberately built around the perimeter of individual huts in Tierra del Fuego (Villagran et al., 2011, Godino et al., 2011). The shell mounds of Brazil, locally named *sambaquis*, have been interpreted as intentionally constructed structures, with transport of shells to the sites where actions relating to feasting and mortuary rituals took place (Villagran et al., 2010, Klokler, 2014, Lombardo et al., 2013). In other sites, however, the non-trampled nature of the deposits has led researchers to interpret these sites as logistic processing areas and not occupational habitats (Claassen, 1992). More recent shell middens composed by Muricidae around the

Mediterranean basin are associated with the production of colorfast purple dye for textiles (Reese, 2010, Sukenik et al., 2017).

As with the type of settlement, the sedimentation rates of anthropogenic shell middens can be varied, depending on the degree of sedentism and site occupation rates, with accretion occurring either through seasonal increments, gradual accumulation rates or rapid building. While during field observations it might be difficult to identify different types of actions involved in shell midden accretion, micromorphological studies have allowed to tease out deposits associated with occupation surfaces, reworked deposits, or tossing events (Aldeias and Bicho, 2016). Independently of their formation history, however, the high porosity of shell midden sites makes them prone to taphonomic processes, namely through the percolation of water. The relative acidity of rainwater can lead to the dissolution of calcium carbonate (the main constituent of shells), with the combination of rain and atmospheric carbon dioxide to form a weak carbonic acid that reacts with the calcium carbonate of the shells to form water-soluble calcium bicarbonate (Aldeias and Bicho, 2016). This enrichment in calcium carbonate of percolating water can lead to dissolution of the shells exposed to rainwater, and the reprecipitation and calcium carbonate cementation in lower layers of the shell midden. The use of fire in shell-rich substrates has also been investigated, particularly in sites that have mollusks composed by aragonite (a calcium carbonate polymorph) that can be used to track temperatures associated with in situ hearths (Simões and Aldeias, 2022).

Turning our attention to mound sites, these types of sites are often called "tells" in the archaeological literature, as tell is the Arabic name for mound. Tell sites are widespread in several geographical areas, namely in Eastern Europe, around the Mediterranean basin and Central Asia. Tell sites are associated with intense human agency and the construction of houses and walls, often using mud bricks (Koromila et al., 2018, Namdar et al., 2011). The earliest construction of mounds and tells is often associated with the onset of sedentism, and a wide variety of settlements exist, from residential spaces, monumental buildings, or ritual areas. There is a long tradition of study of tell sites, including using geoarchaeological techniques to analyze the earthen materials used for construction (e.g., mudbricks, mortars, plasters). Besides mounds enclosing constructed structures on stone or mud bricks, there are also anthropogenic mounds constructed solely on earthen materials. Large earthen mounds are known in several continents, including along the Amazonia and across the Midwestern and Southwestern

US. The stratigraphies of earthen mounds is often extremely complex (Sherwood and Kidder, 2011, Kidder and Sherwood, 2017). Recent micromorphological research have shown that the construction of such American mounds is the result of carefully planned and engineered constructions that entailed a considerable knowledge on soil proprieties by the American Indian communities. The earth materials used for mound construction are not aleatory but show a purposed selection and transport of specific construction materials, namely different soil horizons (sod blocks from A horizons, or soil blocks from B soil horizons) and geologic materials to provide initial and loaded fills. Despite all using earth as the construction material, there is a substantial variability in mound construction depending on formation histories, rapid vs gradual construction episodes and activities linked to management of the building space (Sherwood and Kidder, 2011).

Figure 10: Stratigraphic profile of Mound A at Shiloh profil (USA) (Sherwood and Kidder, 2011).

Summary of contents

Definition of shell midden and earthen mounds

Shell-rich sites – their temporal and geographic distribution and their distinct formation histories. Ethnographic examples of shell midden accretion from Australia and Senegal. Mesolithic shell mounds in Europe.

Earthen mounds – Tell sites and American earth mound sites. The use and selection of soil and sediments to the construction of mound buildings, platforms, and structures

Case-studies: the Cabeço da Amoreira shell midden. The midwestern US earth mounds.

Practical activity: Obtain infrared spectra from experimental shells, observing the calcium carbonate polymorphic transformation from aragonite to calcite.

Specific and Further Readings

Aldeias, V. & Bicho, N. 2016. Embedded Behavior: Human Activities and the Construction of the Mesolithic Shellmound of Cabeço da Amoreira, Muge, Portugal. *Geoarchaeology,* 31**,** 530-549.

Bailey, G. N. 1983. Problems of site formation and the interpretation of spatial and temporal discontinuities in the distribution of coastal middens. *Quaternary coastlines and marine archaeology***,** 559-582.

Claassen, C. 1992. Shell mounds as burial mounds: A revision of the Shell Mound Archaic. *Current archaeological research in Kentucky,* 2**,** 1-12

Duarte, C. S., Iriarte, E., Diniz, M. & Arias, P. 2019. The microstratigraphic record of human activities and formation processes at the Mesolithic shell midden of Poças de São Bento (Sado Valley, Portugal). *Archaeological and Anthropological Sciences,* 11**,** 483-509.

Goldberg, P. & Macphail, R. 2006. *Practical and Theorectical Geoarchaeology,* Blackwell publishing.

Hardy, K., Camara, A., Piqué, R., Dioh, E., Guèye, M., Diadhiou, H. D., Faye, M. & Carré, M. 2016. Shellfishing and shell midden construction in the Saloum Delta, Senegal. *Journal of Anthropological Archaeology,* 41**,** 19-32.

Jerardino, A. 2010. Prehistoric Exploitation of Marine Resources in Southern Africa with Particular Reference to Shellfish Gathering: Opportunities and Continuities. *Pyrenae,* 41**,** 7-52.

Villagran, X. S., Balbo, A. L., Madella, M., Vila, A. & Estevez, J. 2011. Experimental micromorphology in Tierra del Fuego (Argentina): Building a reference collection for the study of shell middens in cold climates. *Journal of Archaeological Science,* 38**,** 588-604.

Villagran, X. S. 2014. A redefinition of waste: Deconstructing shell and fish mound formation among coastal groups of southern Brazil. *Journal of Anthropological Archaeology,* 36**,** 211-227.

Lecture 9: Construction Materials

Rationale

Human made materials for constructions and building are of geological and biological nature. Not only rocks or minerals were used as raw materials for construction, but also earth was commonly used as a building resource. Different parts of soil horizons used as building materials can be identified in the archaeological record, namely turf/sod blocks (i.e., intact sections of surface soils held together by fine roots), soil blocks (i.e., intact sections of soils horizons that are not the superficial A horizon), and adobe. Other common building materials are mortars and plasters (i.e., the material used for joining building stones, used for the basis of concrete and plastering). Earth construction materials can be broadly subdivided into two main categories: materials that are indirectly shaped (e.g., mud bricks) and those that are directly shaped in place, e.g., daub/taipa (Friesem et al., 2017). Here we will define each of these materials and their identification in archaeological stratigraphies, both as intact materials and their decayed products.

Turf – Turf or sods are volumes carved from topsoil that retain their network of rootlets to keep the material cohesive (Huisman and Milek, 2017). Turf blocks have been used as construction materials both for domestic structures (walls and roofs), and for earthwork structures (e.g., platforms, dikes, ramparts). As pointed out by Huismann and Milek (2017) the use of turves as building materials is particularly observed in nonwoody northern latitudes and regions. The identification of turves in archaeological stratigraphies involves knowledge of the soil and sediments locally available, and can equally provide information about ancient landscape cover at the time of site construction (MacPhail et al 2013)

Adobe – mud bricks are formed using clay-rich soils or sediments tempered with plant fragments or other non-plastic materials (e.g., sand, or fine gravel). Mudbricks can be made either by using molds or free formed. Their manufacture can involve firing in kilns or sun drying. When abandoned, mud brick structures will decay, with the original mud bricks weathering and eroding, forming colluvium like deposits that can, at times, be difficult to identify as originally coming from decayed mud bricks or separate these sediments from the intact sections of the mudbrick walls. Daub wall have similar composition to mudbricks, but not involved shaping into individual bricks. Daub can be used to form rammed earth walls by compressing daub into a framed structure (Karkanas and Goldberg, 2018). Adobe materials are very susceptible to weathering when exposed to water, with slake collapse of walls in unroofed abandoned settlements being common.

Plaster – Plasters are materials shaped in a plastic state and applied to form hardened surfaces (Karkanas, 2007, Stoops et al., 2017). Plasters can be made using lime, gypsum, or clays, often with sand or fine gravel as temper, to form floor construction, wall plastering, and as mortars. Typically, these materials are dense and indurated in nature, and retain their hardness when immersed in water (Karkanas and Goldberg, 2018). For calcitic plasters, the application of infrared spectroscopy methods can help with the distinction between geogenic and anthropogenic calcite (Chu et al., 2008).

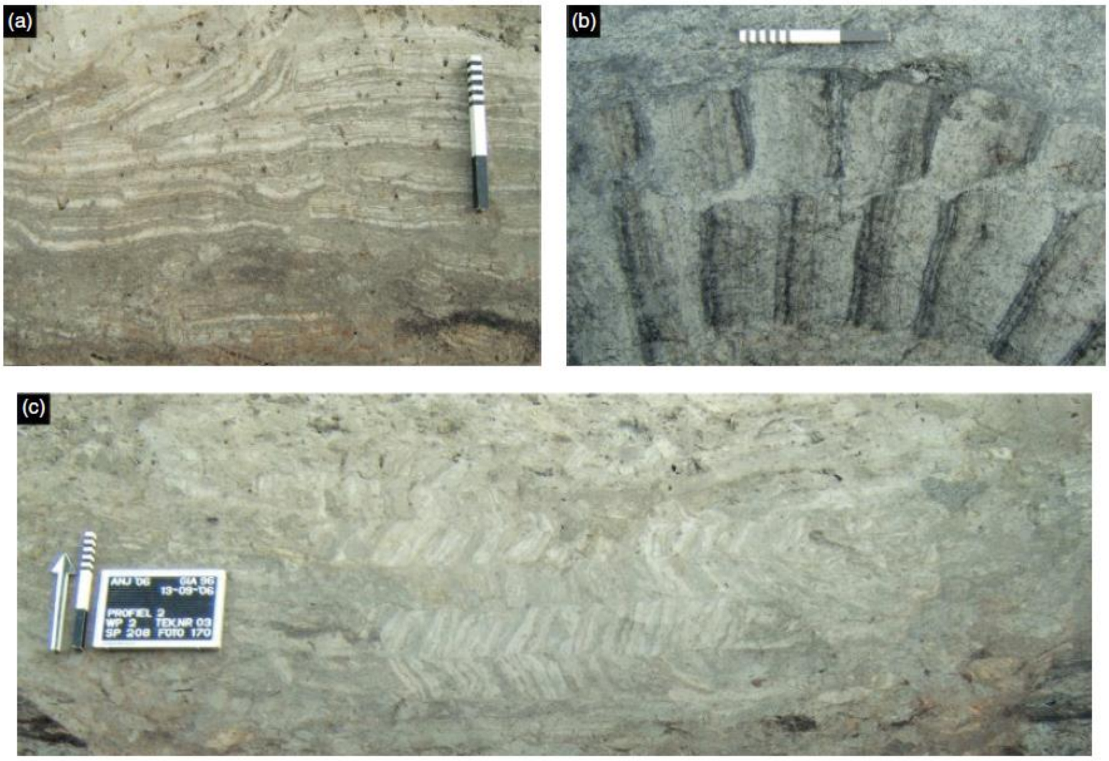


Figure 11: Examples of turf construction materials in a turf-built wall (a) and a turf-build well (b and c) from Huismann and Milek 2017.

Summary of contents

Definition and identification of common construction materials: turves, adobe, daub, plasters, and mortars.

Decaying and erosion of earthen construction materials and their (in)visibility in the archaeological record.

Case-studies: adobe bricks and plasters at the Neolithic site of Çatal Höyük, Turkey, and sod blocks from the earth mounds in the Midwest, USA.

Specific and Further Readings

Chu, V., Regev, L., Weiner, S. & Boaretto, E. 2008. Differentiating between anthropogenic calcite in plaster, ash and natural calcite using infrared spectroscopy: implications in archaeology. *Journal of Archaeological Science*, 35**,** 905-911.

Friesem, D. E., Wattez, J. & Onfray, M. 2017. Earth Construction Materials. *Archaeological Soil and Sediment Micromorphology.*

Goshen, N., Yasur-Landau, A., Cline, E. H. & Shahack-Gross, R. 2017. Palatial architecture under the microscope: Production, maintenance, and spatiotemporal changes gleaned from plastered surfaces at a Canaanite palace complex, Tel Kabri, Israel. *Journal of Archaeological Science: Reports*, 11**,** 189-199.

Huisman, D. J. & Milek, K. B. 2017. Turf as construction material. *Archaeological soil and sediment micromorphology***,** 113-119.

Karkanas, P. 2007. Identification of lime plaster in prehistory using petrographic methods: A review and reconsideration of the data on the basis of experimental and case studies. *Geoarchaeology*, 22**,** 775-796.

Macphail, R. I., & Goldberg, P. (2017). *Applied soils and micromorphology in archaeology*. Cambridge University Press.

MacPhail 2013 integrated microstratigraphical investigations of coastal archaeological soils and sediments in Norway

Stoops, G., Canti, M. G. & Kapur, S. 2017. Calcareous mortars, plasters and floors. *Archaeological soil and sediment micromorphology***,** 189-199.

Lecture 10: Occupation Surfaces and Use of Space

Rationale

In this class, we will focus on the concept of human occupations surfaces and activities derived from human agency that have affected these living surfaces. In turn, these topics will lead us to examples and pit falls when interpreting use of space in the archaeological record.

Occupation Surfaces – concerning the concept of occupation surfaces, these can be separated into two elementary categories: constructed occupation surfaces (e.g., floors, bedding) and non-constructed occupational surfaces (natural surfaces on which human activities take place). In general, constructed occupational surfaces are those that have a well-defined fabric, were intentionally made and have distinct spatial extensions, often being restricted by physical limits (e.g., inside a room, a street, etc.). It is easier to identity the human sedimentary signatures that lead to the accumulation of constructed occupation surfaces, e.g., plastered floors.

Non-constructed surfaces are more challenging to characterize as they imply a good knowledge of the original (natural) fabric of the surface and the identification of contemporaneity of the human discard left on that surface. By definition, non-constructed are surfaces in which human activities take place, but where the surface was not intentionally prepared nor manufactured. Such surfaces can be bare soils or rocky substrates. Non-constructed occupation surfaces are typical of prehistoric sites but can also exist in later periods in areas where constructed floors were absent, such as open courtyards, streets, or gardens.

Independently of constructed or non-constructed surfaces, micromorphological studies of occupational surfaces have shown that three main microstratigraphies can be discernable, from bottom to top: 1) the passive zone, 2) the reactive zone, and 3) the active zone (Gé et al., 1993). The lowermost passive unit is, in the case of constructed floors, the pugged material used for construction, with these materials having little of no physical modifications after preparation. Weak alterations can be observed in the modification of void spaces due to human trampling. In non-constructed occupation surfaces, the passive zone is the natural deposits underlying human traffic that were not significantly influenced by it or by human debris accumulation. The reactive zone is a unit that shows structural modifications due to human movement on that surface. Gé (1993) proposes three main types of mechanisms that occur simultaneously: i) disaggregation, 2) compaction, and 3) incorporation of anthropogenic constituents (namely micro-debris). In non-constructed surfaces, the nature and minerology of this reactive zone will be identical to the passive zone but can differ in terms of compaction and development of sub-horizontal fissures. The thickness of this reactive zone can vary depending on the degree of coherence and physical characteristics of the passive zone (both in terms of types and hardness of natural sediments and different floor constructions), but also depending on the intensity of human traffic on that surface. The limits between the passive and the reactive zone are commonly gradual. Finally, the active zone is understood as the upper unit that reflets the array of human activities that occur above a given occupation surface. Typically, the lower limits of this zone with the reactive unit are clear, with the active zone incorporating micro-aggregates resulting from the disaggregation of the lower units mixed with anthropogenic materials (e.g., bones, charcoals, lithics, ceramics, phytoliths, etc.) resulting from accumulation processes. Compaction and in-situ fragmentation of constituents is common and interpreted as the result of human trampling. The thickness and number of anthropogenic constituents incorporated into the active zone varies depending if the surface was continuously cleaned (e.g., swiped), if the surface was covered (e.g., matting), and depending on the number of debris produced by the human activities performed in the occupation surface (e.g., cooking, sleeping, etc.).

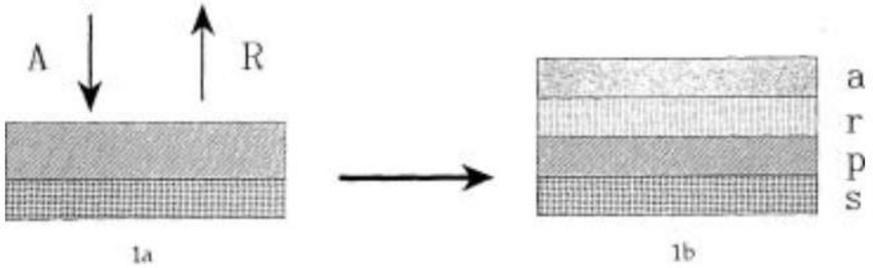


Figure 1. Schematic representation of the formation of an occupation surface from a constrttcted surface. (a) - Initial state of the constructed surface; A: actions (accumulation, redistribution, physical transformations); R: reactions (Physical transformations). (b) - The final statefound in archaeological sites; a: active zone; r: reactive zone; p: passive zone. The thickness of each layer varies between a few mm to afew cm.

Use of space – the identification of activity areas and residues of past use of space in an occupation surface are used to reconstruct space management of a settlement and the organization of daily lives in households. As clearly stated by Milek (2012) “the interpretation of activity areas is normally dependent on a clear understanding of the agents and processes behind the observed patterns in the distributions of artefacts, micro-refuse, organic residues, and/or elements that accumulated on presumed occupation surfaces”. To interpret activities areas through the lens of geoarchaeology, beyond the spatial distribution and fabric analysis of macroscopic artifacts, the study of the nature and composition of occupation deposits is key. Experimental geoarchaeological studies have investigated the effects of human actions (e.g., sweeping, bedding, rake out) in the sedimentary matrix (Miller et al., 2010), whereas geo-ethnographic work as helped to set baselines to the identification of modes of floor renovation and the recognition of matted/cover surfaces based on micromorphology.

Formation Process	Frequency and location	Archaeological evidence	Micromorphological evidence
Trampling	Heaviest in byre	Sediment very firm and platy. Concave depressions where the floor is compressed and worn	Platy or prismatic structure.
	Very heavy in entrance room, main corridor	Artefacts highly fragmented. Loose sediment and larger objects accumulate on the edges of walls and furniture	Artefacts mainly less than
	Heavy in centre of kitchen, centre of pantry, sheephouse		2 mm and are embedded in floor sediment.
Wetting	Frequent in byre, sheephouse	Compact, platy structure	Well-developed platy or massive microstructure.
	Often in entrance room, main corridor	Depletion of Fe and formation of Fe nodules or pans	Depletion of Fe and formation of Fe nodules or pans.
	Periodic throughout the house, due to roof leaks and spills		Depletion of $CaCO_3$. Secondary $CaCO_3$ pedofeatures. Presence of siderite and/or vivianite.
Sweeping	Daily throughout house	Size sorting, with larger objects swept away or to the side	Size sorting, with well-swept areas having artefacts less than 2 mm in size.
	Periodically as needed following the deposition and stamping of ash	Loose sediment and larger objects accumulate on the edges of walls and furniture	
Ash deposition	Periodically throughout the house and byre	Layers of pure ash or charcoal	Lenses of pure ash or charcoal.
	Annually in the sheephouse after shovelling out the floors in the spring	Ash/charcoal present in parts of the house where ash could not have spread accidentally by sweeping or trampling (i.e. not adjacent to hearth)	
Turf deposition	Annually in entrance room and central corridor. Every few years in pantry	“Clean” sediment layers between trampled floor surfaces.	“Clean” turf layers, which may contain evidence of original soil microstructure, between trampled floor surfaces with compaction microstructures.
Raw fuel deposition	Frequently in fuel storage area	Not identified	Layers of wood tissues, peat, coal crumbs, dung crumbs.
Dung deposition	Frequently in byre and sheephouse.	Layers of very dark brown, very compacted, highly organic sediment, but requires micromorphological id.	Layers of herbivore dung identifiable on the basis of truncated plant tissues, phytoliths.
Shovelling out	As needed throughout the house, byre, and sheephouse.	Abrupt boundaries between stratigraphic layers.	Knife-edge truncation boundaries/discontinuities. Relict slivers of truncated floors.
Turf/soil deposition during roof/wall repair	Every 10-20 years throughout the house, byre, and sheephouse	Not identified.	Potentially distinguishable as a lens of mixed turf, soil, and organic matter, but may be difficult to distinguish from intentionally laid turf.

Figure 12: Example of floor formation processes and their archaeological visibility that will be presented and discussed in class (Milek, 2012)

In general, however, even in discrete constructed occupation surfaces, the identification of use of space and spatial organization is hampered by the fact that successive human occupations are directly superimposed to each other. Indeed, the fact that archaeological stratigraphies are often palimpsests greatly hampers the goals of trying to extract different uses of spaces within a site at an ethnographic type of fine scale. While a set of geoarchaeological techniques on bulk sediment samples (e.g., spatial analysis of P or Ca concentrations) have been used to determine activity areas, the fact that these analyses rely on sediments taken in loose bulk and mixing a series of micro-residues and discrete distinct lenses of accumulations does not permit the extraction of detailed high-resolution data on possible distinct superimposed depositional events. The application of soil micromorphology for the study of occupation surfaces can provide more detailed and contextualized data on superimposed events.

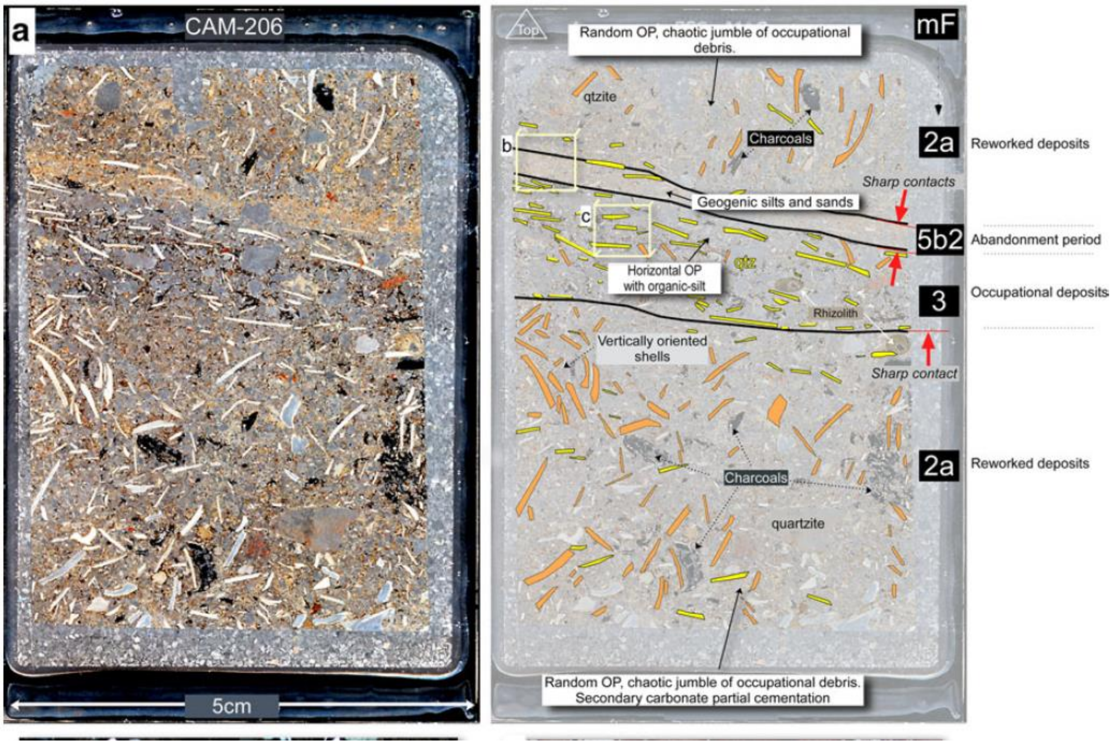


Figure 13: Example of the identification of a non-constructed surface (labelled "occupational deposits") in thin section from the shell mound of Cabeço da Amoreira (Aldeias and Bicho, 2016).

Summary of Contents

Definitions of occupation surfaces.

Geo-ethnographic studies from the sites of Thverá (Iceland), and Butser ancient Farm (UK).

Experimental geoarchaeology studies on bedding, sweeping, and cleaning.

Archaeological case-studies of floor sequences at the archeological site of Makri (Greece) and experimental floors from Butser Ancient Farm (UK). Archaeological example of bedding surfaces from Diepkloof Cave (South Africa).

Practical session:

Archaeological case-studies on non-constructed surfaces. Petrographic analysis of non-constructed occupation surfaces from the shell midden site of Cabeço da Amoreira (Portugal)

Specific and Further Readings

Aldeias, V., & Bicho, N. (2016). Embedded Behavior: Human Activities and the Construction of the Mesolithic Shellmound of Cabeço da Amoreira, Muge, Portugal. *Geoarchaeology*, *31*(6), 530-549

Banerjea, R. Y., Bell, M., Matthews, W., & Brown, A. (2013). Applications of micromorphology to understanding activity areas and site formation processes in experimental hut floors. *Archaeological and Anthropological Sciences*, 1-24.

Berna, F. (2017). Geo-ethnoarchaeology study of the traditional Tswana dung floor from the Moffat Mission Church, Kuruman, North Cape Province, South Africa. *Archaeological and Anthropological Sciences*, 1-9

Gé, T., Courty, M.-A., Matthews, W., & Wattez, J. (1993). Sedimentary formation processes of occupation surfaces. *Formation processes in archaeological context*, *17*, 149-164.

Karkanas, P., & Efstratiou, N. (2009). Floor sequences in Neolithic Makri, Greece: micromorphology reveals cycles of renovation. *Antiquity*, *83*(322), 955-967.

Macphail, R. I., & Goldberg, P. (2017). *Applied soils and micromorphology in archaeology*. Cambridge University Press.

Matthews, W. 2005. Life-cycle and life-course of buildings. *In:* HODDER, I. (ed.) *Çatalhöyük Perspectives. Reports from 1995-1999 seasons by members of the Çatalhöyük team.* Cambridge: McDonald Institute.

Matthews, W., French, C. A. I., Lawrence, T., Cutler, D. F., & Jones, M. K. (1997). Microstratigraphic traces of site formation processes and human activities. *World Archaeology*, *29*(2), 281-308.

Milek, K. B. (2012). Floor formation processes and the interpretation of site activity areas: An ethnoarchaeological study of turf buildings at Thverá, northeast Iceland. *Journal of Anthropological Archaeology*, *31*(2), 119-137.

Milek, K. B. & Roberts, H. M. 2013. Integrated geoarchaeological methods for the determination of site activity areas: a study of a Viking Age house in Reykjavik, Iceland. *Journal of Archaeological Science,* 40**,** 1845-1865.

Miller, C. E., Conard, N., Goldberg, P., & Berna, F. (2010). Dumping, sweeping and trampling: experimental micromorphological analysis of anthropogenically modifies combustion features. In I. Théry-Parisot, L. Chabal, & S. Costamagno (Eds.), *The raphonomy of burned organix residues and combustion features in archaeological contexts* (Vol. 2, pp. 25-37). Palethnologie.

Shahack-Gross, R., Albert, R.-M., Gilboa, A., Nagar-Hilman, O., Sharon, I. & Weiner, S. 2005. Geoarchaeology in an urban context: The uses of space in a Phoenician monumental building at Tel Dor (Israel). *Journal of Archaeological Science,* 32**,** 1417-1431.

Lecture 11: Anthrosols, Dark Earths and Agriculture

Rationale

Anthrosols are a formal soil classification group for soils that have been profoundly modified by long-term human activities (e.g., burial, cultivation, irrigation, manuring). These soils can develop from any parent material and their characteristics vary widely according to the type of human activity and the regions where they are found. In general, anthrosols are dark in color, with high phosphate content, incorporate anthropogenic debris – namely organic detritus (bones, charcoals) and are broadly associated with agriculture activities (Holliday, 2017). Agriculture practices associated with vegetation clearance, terracing, cultivation, manuring and plowing have been investigated from a geoarchaeological perspective (Goldberg and Macphail, 2006). However, it should be highlighted that several of the geoarchaeological and micromorphological proxies for agricultural activities are not always straightforward since natural processes can mimic these features. For instance, woodland clearance is identified through the presence of pits indicative of tree throws and by the presence of charcoals and ash in topsoil horizons in the case of 'slash and burn' practices. Nevertheless, human agency cannot be unequivocally inferred since natural tree fall and natural fires can also produce these same byproducts. Though also far from unequivocal, sedimentary features such as ard marks, plough marks and spade marks have been associated with cultivation activities (Goldberg and Macphail, 2006, but see Carter and Davidson, 1998), as well as the incorporation of botanic remains associated with domestic crops (seeds, phytoliths, cereal pollen) (Deák et al., 2017, Macphail et al., 1990b). The association of several techniques – such as micromorphology, botanical analysis, and soil geochemistry – is advised to investigate anthropogenic clearance activities, with several studies showing the application of these combined approaches to infer human agency (e.g., Gebhardt, 1993).

The term 'dark earth' is an informal expression that does not correspond to a soil classification system – with some authors considering that some dark earth deposits should be seen as sediments and not always soils (Holliday, 2017). Commonly, dark earth refers to deposits that tend to be dark in color and appear as homogeneous (lacking internal stratification) in field observations. In European contexts, the term dark earth is generally applied to urban contexts of roman or post-roman chronologies (Nicosia et al., 2017). In the Amazonia, the equivalent term is 'terras pretas' and these Amazonian dark earths refer to the top horizon associated with pre-Columbian soils whose geochemical characteristics were enhanced and modified through human activities (Arroyo-Kalin, 2017, Lehmann et al., 2006). Micromorphological studies have been widely applied in the study of European dark earths, and, to a lesser extent, in Amazonian dark earths (but see Ruivo et al., 2003). Overall, dark earths are the result of an interplay between natural (weathering), biogenic (bioturbation by soil fauna and flora) and anthropic formation processes (Nicosia et al., 2017).

Geoarchaeological studies of dark earths shows that this general designation obscures a variety of formation processes and associated archaeological activities. Therefore, while in the field urban dark earth may look similar, each context will have a different formation history: the dark earth may be weathered and bioturbated to the point that the original bedded sediments are no longer visible (Macphail, 1994, Macphail et al 2003) or was originally homogeneous, deriving from rapid accumulations from dumping or agricultural activities. Due to their high organic content, dark earth deposits are typically affected by high bioturbation activity (e.g., by roots, earthworms, and other soil microorganisms). In urban settings, these deposits can incorporate calcareous human debris (e.g., ashes, plasters), which are commonly decalcified due to humic and carbonic acids in the soils. Dumping activities are a common anthropogenic process involved in the accumulation of urban dark earths, and a careful study of the deposits can provide data on the types of activities taking place – for instance, if the debris originated from domestic cleaning activities, from emptying cesspits, from metal working workshops, or building destruction debris (Asare, 2022, Devos, Macphail, 1983). Furthermore, dark earths may develop from a mix between dumping and agricultural activities even within derelict areas in urban settings. Cultivation practices can be detected by the presence of tillage, the inclusion of botanical components (e.g., seeds, phytoliths, etc.) or manuring (Devos).

In the case of the Amazonian dark earths, these deposits tend to be geographically very extensive, commonly with human inputs (e.g., pottery sherds, bones, and charcoals) and elevated levels of phosphorous. Despite previous discussion if Amazonian dark earths were related to natural or human processes, nowadays there is a general consensus that these soils originate from anthropic activities (Holliday, 2017, Woods and McCann, 1999). They are found around and in association with pre-Columbian settlements from the onset of the first millennium AD onwards (Neves et al., 2003, Woods and McCann, 1999). However, the formation processes creating Amazonian dark earths are not well understood. Several models have been proposed, namely the house garden model, the kitchen midden model, the house model and the agricultural model (Arroyo-Kalin, 2017). Such interpretative models are probably not mutually exclusive, and a single model may not apply to the broad geographical extension of dark earths. Independently, however, the existence of Amazonia dark earths points to the strong anthropic impact of pre-Columbian communities throughout the Amazon basin.

Table 32.1 Typology and origin of dumped material commonly found in dark earth (based on Macphail 1994; Fondrillon 2007; Devos *et al.* 2011b).

Origin of the dumped material	Characteristics
Domestic waste	Mixture of ash, charcoal, charred seeds, burnt and unburnt bone, eggshell, ceramics, normal and vitrified phytoliths
Cess/latrine waste	Carnivore/omnivore coprolites, sometimes mixed with ash (as in 'nightsoiling'), parasite eggs, reworked aggregates of underlying soil, seeds (mineralized), Fe-stained vegetal residues, phosphatic nodules, crystal intergrowths and crusts; Ca-P typifies human cess, Ca-Fe/Mn-P has a broader faecal origin
Construction/destruction waste	Mortar and mortar-making byproducts, plaster, earth-based construction materials, brick and tile, stone, charcoal, turf, sediments (e.g. for ground raising)
Industrial/artisan waste (involving hearths and furnaces)	Metal and fuel-ash slags, vitrified ceramics, metal fragments and metal oxidation products (e.g., lead/lead oxide/lead carbonate), charcoal, coal, ash, burned and vitrified soil fragments, vitrified phytoliths, glass; under hydromorphic conditions iron slags can develop into amorphous iron (hydr)oxide nodules
Artisan waste (butchery, leather working etc.)	Leather, bone, phosphate nodules
Animal waste and manure	Mineralized carnivore (dog) and omnivore (human) coprolites; dominantly organic omnivore (pig) and herbivore (cattle, sheep/goat, horse) coprolites and associated stabling waste; domestic and cess/latrine waste/night-soil (see above).

Figure 14: Typology and origin of dumping material commonly found in dark earth (from Nicosia and Stoops, 2017, p. 359)

<u>Summary of Contents</u>

Definitions of Anthrasols, and of the more general terms of dark earths.

Present and discuss the sedimentary signatures of agricultural practices, pitfalls for their identification and preservation. Study case: agricultural landscapes in Brittany (France).

European (urban) dark earths: their characteristics, formation processes and inferences of associated human activities in urban settings. Study cases: Early medieval Antwerp (Belgium) urban dark earths.

Amazonian dark earths: their characteristics, formation models associated with human activities.

Specific and Further Readings

Arroyo-Kalin, M. 2017. Amazonian dark earths. *Archaeological soil and sediment micromorphology*, 345-357.

Asare, M. O. 2022. Anthropogenic dark earth: evolution, distribution, physical, and chemical properties. *European Journal of Soil Science*, 73**,** e13308.

Deák, J., Gebhardt, A., Lewis, H., Usai, M. R. & Lee, H. 2017. Soils disturbed by vegetation clearance and tillage. *Archaeological soil and sediment micromorphology*, 231-264.

Gebhardt, A. 1993. Micromorphological evidence of soil deterioration since the mid-Holocene at archaeological sites in Brittany, France. *The Holocene,* 3, 333-341.

Holliday, V. T. 2017. Anthrosols. *In:* GILBERT, A. S. (ed.) *Encyclopedia of Geoarchaeology.* Dordrecht: Springer Netherlands.

Nicosia, C., Devos, Y. & Macphail, R. I. 2017. European dark earth. *Archaeological soil and sediment micromorphology*, 331-343.

Macphail, R. I., & Goldberg, P. (2017). *Applied soils and micromorphology in archaeology*. Cambridge University Press.

Macphail, R. I. 1983. The micromorphology of Dark Earth from Gloucester, London and Norwich: an analysis of urban anthropogenic deposits from the late Roman to early Medieval periods in England. *Soil micromorphology. Vol. 1*, 245-252.

Wouters, B., Milek, K., Devos, Y. & Tys, D. 2016. Soil micromorphology in urban research: Early medieval Antwerp (Belgium) and Viking age Kaupang (Norway). *Objects, Environment, and Everyday Life in Medieval Europe.*

Lecture 12: Abandonment, Site Destruction and Decay

<u>Rationale</u>

Throughout this course, we have studied the identification of an array of human made deposits as well as the sedimentary signatures associated with maintaining living spaces. In this class, we will focus on the flipside, that is, site abandonment and collapse.

In hunter-gather societies characterized by a high degree of mobility, natural formation processes take over once a community moves away from an occupation site. Non-occupation phases are then marked by naturally laid deposits and weathering. The degree of preservation of the discarded archaeological artifacts and features will greatly depend on how quickly after abandonment the occupied surface gets buried and on the level of energy of that covering sedimentation. For instance, low energy runoff or aeolian loess will entail a higher degree of preservation than gravitational high energy debris flows. Occupation debris and features will be better preserved if they are rapidly buried, whereas exposure will enhance erosion, chemical decay, physical dispersion of artifacts across a surface and increased bioturbation levels. At the cave site of Bacho Kiro, ~45,000 years BP Initial Upper Paleolithic occupation levels were rapidly sealed by low energy water laid deposits (Hublin et al., 2020), ensuring a good preservation and cohesion of the original occupation deposits. Periodic and short-lived events of abandonment in cave settings can at times be traced by the identification of discrete accumulation of bat guano on exposed surfaces, as is the case of phosphatized uppermost levels of hearths features at the cave sites of Roc de Marsal (Aldeias et al., 2012) and Klazies River (Morrissey et al., 2023). These abandonment periods provide information to the recurrency of occupations and the palimpsest nature of the archaeological macroscopic assemblages (Karkanas et al., 2015).

In later periods associated with sedentary societies and marked by constructed habitations, abandonment can mean a localized collapse of a specific building inside a settlement that continues to be occupied, or the abandonment of the entire settlement. The latter scenario can occur both through gradual phases or through abrupt collapse. Abandonment of buildings will result in the natural decay of the roof, walls, and the fracturing of architectural features. Typically, these collapsed deposits can be layered since they decay progressively, with the development of sloped talus originating from the source area – for instance, lobes that are thicker near the original wall location and thin further away from it (Karkanas and Goldberg, 2018). The thicker accumulation of collapsed debris close to the foot of a wall will eventually bury it and protect it from complete collapse. In the case of daub walls, it is at times challenging to separate between the weathered fallen daub from the original daub wall, and many of such earth walls go unidentified in archaeological excavations. Roofs, on the other hand will sag and suffer gravitational collapse (Friesem et al., 2014b). The debris will accumulate mainly inside the originally roofed perimeter, with roof collapse being a catalyzer for quicker degradation of the now expose walls (Friesem et al., 2014a). The presence of roof tiles can be identified in archaeological strata, but organic roof materials will decay and are rarely preserved. The topography of the settlement surface will play a significant role, with gravity flows and landslides occurring at the talus slopes of the periphery of mound constructions, such as tells, or earth mounds. The distinction between natural collapse of buildings versus intentional levelling and reuse of debris as packing deposits for subsequent constructions can be gleaned from subtle changes in sedimentary structure and microagregation of the deposits, as described in detail by Karkanas and Goldberg (2018).

If abandonment occurs rapidly, namely due to a catastrophic destruction, the effects will depend on the causes of that destruction. For instance, if a conflagration took place, the identification of thermally altered materials (e.g., mudbricks) will show higher alteration of the materials closer to the flames than those further away that will be affected mainly by soot and smoke (Harrison, 2013). Relevantly, incomplete combustion (charring) can entail a better preservation of organic materials such as wood, in the form of charcoals, and carbonized seed remains. Destructions due to fire can occur due to accidental or natural fires but can also be the result of intentional burning of a settlement due to armed conflicts or associated with ritual burnings (Verhoeven, 2000). Other catastrophic events, such as earthquakes, can also lead to the structural collapse of architectural features and buildings (Stiros, 1996). In areas with recurrent tectonic activity, there can be traces of rebuilding and reconstruction phases after such events – clear examples of plaster renovations and restructuring of walls are identified at Pompeii in the months and years prior to the tragic event of 79 AD. Overall, the abandonment of a building inside a still inhabited urban setting can involve the sourcing of building materials by the site's inhabitants, with stones being repurposed for other uses. At the roman city of Baelo Claudia, for instance, geoarchaeological studies have shown that the original marbles of the bath complex were intentionally chipped away to be reused at other locations (Gutiérrez-Rodríguez et al., 2020). In fact, the sequence of events inside an abandoned structure can tell the story of the final moments of the use of that space. A domestic space can be later converted into a metal workshop or used as a silo, it can also be used as a plantation garden or a waste refusal area. This sequence of events is captured not in the architectural features – which might still be standing for decades or centuries after their original construction –, but in the sedimentary record. Eventually, however, without the continuous accretion of human made debris, an abandoned site will be subject to natural erosion and geogenic depositional processes.

Summary of Contents

Localized, gradual and abrupt settlement abandonment and collapse.

Sedimentary signatures associated with abandonment phases in non-sedentary settlements.

Sedimentary signatures and type of deposits associated with the collapse of architectural features and materials.

Case studies: Discrete non-occupation events traced in hunter-gathered sites; decay model of mud brick houses (Friesem et al., 2014a); the collapse and repurposing of the roman bath complex at Baeollo Claudia (Spain).

Specific and Further Readings

Friesem, D., Boaretto, E., Eliyahu-Behar, A. & Shahack-Gross, R. 2011. Degradation of mud brick houses in an arid environment: a geoarchaeological model. *Journal of Archaeological Science*, 38**,** 1135-1147.

Friesem, D. E., Karkanas, P., Tsartsidou, G. & Shahack-Gross, R. 2014. Sedimentary processes involved in mud brick degradation in temperate environments: a micromorphological approach in an ethnoarchaeological context in northern Greece. *Journal of Archaeological Science*, 41**,** 556-567.

Friesem, D. E., Tsartsidou, G., Karkanas, P. & Shahack-Gross, R. 2014. Where are the roofs? A geo-ethnoarchaeological study of mud brick structures and their collapse processes, focusing on the identification of roofs. *Archaeological and Anthropological Sciences*, 6**,** 73-92.

Lecture 13: Final Exam

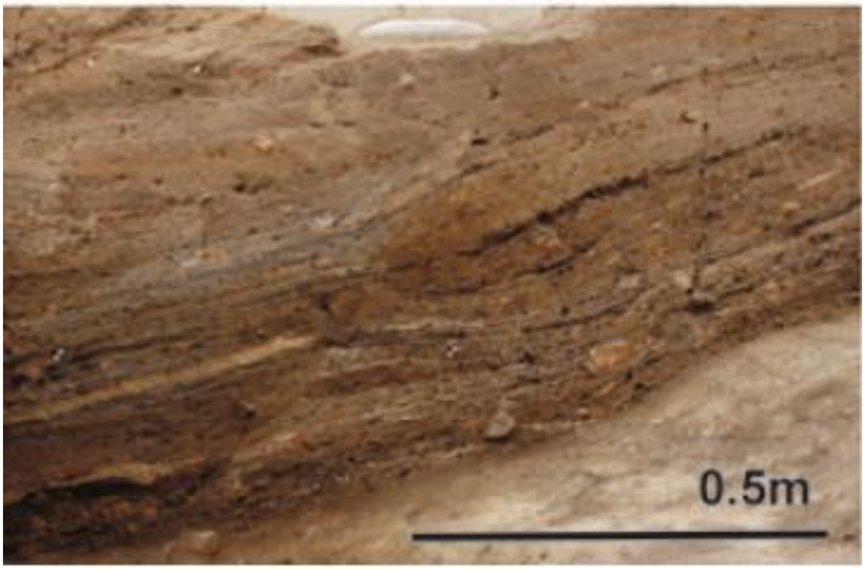
Examples of questions for final exam

- The identification of anthropogenic fire use in the archaeological record has several pitfalls. What are the proxies for fire and techniques that can be used to identify anthropogenic combustion features?

- How are constructed floors identified and characterized? Please provide examples of the application of geoarchaeological approaches to the study of archaeological floors.

- What are the main post-depositional processes that affect archaeological materials and how do these processes impact on the archaeological visibility of anthropogenic deposits?

- Analyze the stratigraphic profile provided below. What would be: 1) the set of questions that you could address within a geoarchaeological framework, and 2) what geoarchaeological methodologies would be valuable to decipher the nature of deposition processes involved in these anthropogenic accumulations?



4. Final Considerations

To finalize this report, I want to briefly analyze the challenges, but also the opportunities of having a course focusing on the geoarchaeology of human-made deposits in the academic curriculum of UAlg. For each of the challenges identified, attenuating circumstances or risk mitigation aspects are elaborated below.

Challenges

Turning first to the challenges, these can be grouped into institutional challenges and academic challenges.

This is the first time that a course on these study matters would be offered at UAlg. As mentioned in the introduction of this manuscript, a course on the geoarchaeology of human activities and deposits is also inexistent in the Portuguese academic landscape and very rare worldwide. This raises the question of how such a topic would be received by the students enrolled in the master program at UAlg. Given this novelty, it is difficult to anticipate the number of students that will choose the course as an option. However, it should be noted that, within the scope of the faculty and of the research center ICArEHB, there is a growing number of both master's and PhD students that come to the UAlg to conduct their studies. A substantial number of these students are actually developing their research in topics that are either directly related to geoarchaeology or that have a geoarchaeology component. This opens the possibility that the proposed course would then be an attractive option for students. Furthermore, given the fact that most archaeology students find employed in contract archaeology, we can also envision that the proposed course would be crucial for forming professionals that will have to deal with a large variety of fields and types of archaeological settings. The varied scope of the lectures in terms of time period and types of archaeological deposits is, therefore, a relevant option to help professionalize and capacitate the UAlg's academic formation in archaeological science approaches.

A related topic is that the master's program in Archaeology is part of the humanities and social sciences faculty (FCHS) at UALG, which means that students do not necessarily have a strong background in Geology, Geochemistry, or Minerology. Such a challenge is not unique to this course, however, but is a characteristic of any interdisciplinary field of study. Nowadays, Archaeology is intrinsically an interdisciplinary endeavor that combines expertise from a variety of other fields of study, such as Biology, Chemistry, Physics, Geology, Anatomy, etc. The constrains to bridge different areas of knowledge is, therefore, a structural issue of all modern archaeological teaching institutions. Archaeological students, also come from a variety of backgrounds – some do come from the Humanities, but many also arrive at Archaeological programs with backgrounds from the Natural Sciences. Independently, and to make sure that a level plain is drawn, the present course on the "Geoarchaeology of Human-made Deposits" was designed to mitigate these challenges of prior knowledge by:

1) providing introductory classes and hands on sessions on micromorphology, mineralogy, and spectroscopy, which are scheduled throughout the course's program.

2) focusing on examples and case studies that rely on basic knowledge of stratigraphy and archaeology and less on geochemistry, physics or mineralogy – for example, a possible lecture topic would be geoarchaeological approaches to rock paintings, but that would call upon some degree of proficiency in mineral determination and dating techniques; and

3) the course is devised as an intermediate course for students that already were enrolled in introductory classes on geoarchaeology and geology/geomorphology available in the archaeological academic programs of UAlg.

Opportunities

If we now focus on the opportunities that this course provides, there are several points that can be highlighted.

A proficiency in geoarchaeology is a *must* for every archaeologist. Repeating the words of Renfrew cited at the start of this manuscript: *'Since archaeology (…) recovers almost all its basic data by excavation, every archaeological problem starts as a problem in geoarchaeology'* (Renfrew, 1976). The lack of sustained and widespread courses on geoarchaeology on the academic formations – at UAlg and elsewhere in Europe – is a problem that directly impacts the quality of archaeological research and inferences made in our field of study. In archaeological literature, no debate is more heated than those dealing with the context of artifacts and the identification of human agency. Importantly, typically topics related to the geoarchaeology of human-made deposits are dispersed and there is a need to combine information in a cohesive course, as the one proposed here.

While in prehistoric contexts there are ongoing debates on the validity of inferring human agency in key deposits – for example, the onset of hominins as obligated fire users –, most of the commercial archaeology done in Portugal and elsewhere in the world relates to urban contexts. The lack of formation of professionals working in these realities to identify and study sedimentary artifacts as relating to human behavior tends, unfortunately, to be widespread. Therefore, having an academic course that is based on geoarchaeological studies of human deposits is not only innovative but, I believe, a crucial strength for the educational offer of any institution.

The proposed course will capacitate the UAlg's archaeology students to identify and study a variety of anthropogenic sediments. It will promote research in this topic and provide new tools for students to apply, either in their academic research or in their professional capacities as archaeologists in private enterprises. At a time that archaeological studies are increasingly interdisciplinary endeavors, this course aims to contribute to positioning UAlg at the forefront of academic formation of a new generation of well-informed and trained archaeologists.

References

ALDEIAS, V. & BICHO, N. 2016. Embedded Behavior: Human Activities and the Construction of the Mesolithic Shellmound of Cabeço da Amoreira, Muge, Portugal. *Geoarchaeology,* 31**,** 530-549.

ALDEIAS, V., DIBBLE, H. L., SANDGATHE, D., GOLDBERG, P. & MCPHERRON, S. J. 2016. How heat alters underlying deposits and implications for archaeological fire features: A controlled experiment. *Journal of Archaeological Science,* 67**,** 64-79.

ALDEIAS, V., GOLDBERG, P., SANDGATHE, D., BERNA, F., DIBBLE, H. L., MCPHERRON, S. P., TURQ, A. & REZEK, Z. 2012. Evidence for Neandertal use of fire at Roc de Marsal (France). *Journal of Archaeological Science,* 39**,** 2414-2423.

ALDEIAS, V., GUR-ARIEH, S., MARIA, R., MONTEIRO, P. & CURA, P. 2019. Shell we cook it? An experimental approach to the microarchaeological record of shellfish roasting. *Archaeological and Anthropological Sciences,* 11**,** 389-407.

ANGELUCCI, D. E. 2008. Geoarchaeological insights from a Roman age incineration feature (ustrinum) at Enconsta de Sant'Ana (Lisbon, Portugal). *Journal of Archaeological Science,* 35**,** 2624-2633.

ANGELUCCI, D. E., BOSCHIAN, G., FONTANALS, M., PEDROTTI, A. & VERGÈS, J. M. 2009. Shepherds and karst: The use of caves and rock-shelters in the Mediterranean region during the Neolithic. *World Archaeology,* 41**,** 191-214.

ARCHER, W., PRESNYAKOVA, D., HEINRICH, S. & STAHLSCHMIDT, M. C. 2023. A Predictive Model for the Non-Destructive Assessment of Stone Age Silcrete Heat Treatment Strategies. *Journal of Paleolithic Archaeology,* 6**,** 14.

ARROYO-KALIN, M. 2014. Anthropogenic sediments and soils: geoarchaeology. Springer New York.

ARROYO - KALIN, M. 2017. Amazonian dark earths. *Archaeological soil and sediment micromorphology***,** 345-357.

ASARE, M. O. 2022. Anthropogenic dark earth: evolution, distribution, physical, and chemical properties. *European Journal of Soil Science,* 73**,** e13308.

BAILEY, G. N. 1983. Problems of site formation and the interpretation of spatial and temporal discontinuities in the distribution of coastal middens. *Quaternary coastlines and marine archaeology***,** 559-582.

BATHURST, R. R. 2005. Archaeological evidence of intestinal parasites from coastal shell middens. *Journal of Archaeological Science,* 32**,** 115-123.

BENNETT, J. L. 1999. Thermal alteration of buried bone. *Journal of Archaeological Science,* 26**,** 1-8.

BERGER, L. R., MAKHUBELA, T., MOLOPYANE, K., KRUGER, A., RANDOLPH-QUINNEY, P., ELLIOTT, M., PEIXOTTO, B., FUENTES, A., TAFFOREAU, P. & BEYRAND, V. 2023. Evidence for deliberate burial of the dead by Homo naledi. *bioRxiv***,** 2023.06. 01.543127.

BERNA, F. 2017. FTIR microscopy. *Archaeological soil and sediment micromorphology***,** 411-415.

BERNA, F., MATTHEWS, A. & WEINER, S. 2004. Solubilities of bone mineral from archaeological sites: The recrystallization window. *Journal of Archaeological Science,* 31**,** 867-882.

BINFORD, L. 1078. Dimensional analysis of behavior and site structure: learning from an Eskimo hunting stand. *American antiquity,* 43**,** 330-61.

BOARETTO, E., REBOLLO, N. R., COHEN-OFRI, I., POPOVITZ-BIRO, R., BAR-YOSEF, O., MEIGNEN, L., GOLDBERG, P. & WEINER, S. 2008. Structural characterization of charcoal exposed to high and low pH: Implications for 14C sample preparation and charcoal preservation. *Radiocarbon,* 50**,** 289-307.

BONTA, M., GOSFORD, R., EUSSEN, D., FERGUSON, N., LOVELESS, E. & WITWER, M. 2017. Intentional fire-spreading by "Firehawk" raptors in Northern Australia. *Journal of Ethnobiology,* 37**,** 700-718.

BROCHIER, J. E. 1983. Bergeries et feux de bois néolithiques dans le Midi de la France. Caractérisation et incidence sur le raisonnement sédimentologique. *Quartär. Jahrbuch für Erforschung des Eiszeitalters und der Steinzeit Bonn,* 33**,** 181-193.

BROCHIER, J. E., VILLA, P., GIACOMARRA, M. & TAGLIACOZZO, A. 1992. Shepherds and sediments: Geo-ethnoarchaeology of pastoral sites. *Journal of Anthropological Archaeology,* 11**,** 47-102.

BRÖNNIMANN, D., PÜMPIN, C., ISMAIL‐MEYER, K., RENTZEL, P. & ÉGÜEZ, N. 2017. Excrements of omnivores and carnivores. *Archaeological soil and sediment micromorphology***,** 67-81.

BRÖNNIMANN, D., RÖDER, B., SPICHTIG, N., RISSANEN, H., LASSAU, G. & RENTZEL, P. 2020. The Hidden Midden: Geoarchaeological investigation of sedimentation processes, waste disposal practices, and resource management at the La Tène settlement of Basel‐Gasfabrik (Switzerland). *Geoarchaeology,* 35**,** 522-544.

BUTLER, D. R. 2020. The Anthropocene: A special issue. Taylor & Francis.

CABANES, D., WEINER, S. & SHAHACK-GROSS, R. 2011. Stability of phytoliths in the archaeological record: A dissolution study of modern and fossil phytoliths. *Journal of Archaeological Science,* 38**,** 2480-2490.

CANTI, M. G. 1997. An investigation of microscopic calcareous spherulites from herbivore dungs. *Journal of Archaeological Science,* 24**,** 219-231.

CARBONELL, E. & MOSQUERA, M. 2006. The emergence of a symbolic behaviour: the sepulchral pit of Sima de los Huesos, Sierra de Atapuerca, Burgos, Spain. *Comptes rendus palévol,* 5**,** 155-160.

CARTER, S. & DAVIDSON, D. 1998. An evaluation of the contribution of soil micromorphology to the study of ancient arable agriculture. *Geoarchaeology: an International Journal,* 13**,** 535-547.

CHU, V., REGEV, L., WEINER, S. & BOARETTO, E. 2008. Differentiating between anthropogenic calcite in plaster, ash and natural calcite using infrared spectroscopy: implications in archaeology. *Journal of Archaeological Science,* 35**,** 905-911.

CLAASSEN, C. 1992. Shell mounds as burial mounds: A revision of the Shell Mound Archaic. *Current archaeological research in Kentucky,* 2**,** 1-12.

COURTY, M. A., GOLDBERG, P. & MACPHAIL, R. 1989. *Soils and micromorphology in archaeology,* Cambridge, Cambridge University Press.

CRUTZEN, P. J. & STOERMER, E. F. 2000. Global change newsletter. *The Anthropocene,* 41**,** 17-18.

DE CUPERE, B., SPELEERS, L., MITCHELL, P. D., DEGRAEVE, A., MEGANCK, M., BENNION-PEDLEY, E., JONES, A. K., LEDGER, M. L. & DEFORCE, K. 2022. A Multidisciplinary Analysis of Cesspits from Late Medieval and Post-Medieval Brussels, Belgium: Diet and Health in the Fourteenth to Seventeenth Centuries *International Journal of Historical Archaeology,* 26**,** 531-572.

DEÁK, J., GEBHARDT, A., LEWIS, H., USAI, M. R. & LEE, H. 2017. Soils disturbed by vegetation clearance and tillage. *Archaeological soil and sediment micromorphology***,** 231-264.

DEFORCE, K. 2010. Pollen analysis of 15th century cesspits from the palace of the dukes of Burgundy in Bruges (Belgium): evidence for the use of honey from the western Mediterranean. *Journal of Archaeological Science,* 37**,** 337-342.

DEVOS, Y. Near total and inorganic phosphorus concentrations as a proxy for identifying ancient activities in urban contexts: The example of dark earth in Brussels, Belgium. *Geoarchaeology***,** n/a-n/a.

DIBBLE, H. L., ALDEIAS, V., GOLDBERG, P., MCPHERRON, S. P., SANDGATHE, D. & STEELE, T. E. 2015. A critical look at evidence from La Chapelle-aux-Saints supporting an intentional Neandertal burial. *Journal of Archaeological Science,* 53**,** 649-657.

ETIEGNI, L. & CAMPBELL, A. G. 1991. Physical and chemical characteristics of wood ash. *Bioresource Technology,* 37**,** 173-178.

EVERSHED, R. P. 2008. Organic residue analysis in archaeology: the archaeological biomarker revolution. *Archaeometry,* 50**,** 895-924.

FORMICOLA, V. & BUZHILOVA, A. P. 2004. Double child burial from Sunghir (Russia): Pathology and inferences for Upper Paleolithic funerary practices. *American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists,* 124**,** 189-198.

FRIESEM, D. E., KARKANAS, P., TSARTSIDOU, G. & SHAHACK-GROSS, R. 2014a. Sedimentary processes involved in mud brick degradation in temperate environments: a micromorphological approach in an ethnoarchaeological context in northern Greece. *Journal of Archaeological Science,* 41**,** 556-567.

FRIESEM, D. E. & LAVI, N. 2017. Foragers, tropical forests and the formation of archaeological evidences: An ethnoarchaeological view from South India. *Quaternary International,* 448**,** 117-128.

FRIESEM, D. E., TSARTSIDOU, G., KARKANAS, P. & SHAHACK-GROSS, R. 2014b. Where are the roofs? A geo-ethnoarchaeological study of mud brick structures and their collapse processes, focusing on the identification of roofs. *Archaeological and Anthropological Sciences,* 6**,** 73-92.

FRIESEM, D. E., WATTEZ, J. & ONFRAY, M. 2017. Earth Construction Materials. *Archaeological Soil and Sediment Micromorphology.*

GARGETT, R. H. 1989. Grave shortcomings: The evidence for Neandertal burial. *Current Anthropology,* 30**,** 157-190.

GARGETT, R. H. 1999. Middle Palaeolithic burial is not a dead issue: The view from Qafzeh, Saint-Césaire, Kebara, Amud, and Dederiyeh. *Journal of Human Evolution,* 37**,** 27-90.

GÉ, T., COURTY, M.-A., MATTHEWS, W. & WATTEZ, J. 1993. Sedimentary formation processes of occupation surfaces. *Formation processes in archaeological context,* 17**,** 149-164.

GEBHARDT, A. 1993. Micromorphological evidence of soil deterioration since the mid-Holocene at archaeological sites in Brittany, France. *The Holocene,* 3**,** 333-341.

GILBERT, M. T. P., JENKINS, D. L., GÖTHERSTROM, A., NAVERAN, N., SANCHEZ, J. J., HOFREITER, M., THOMSEN, P. F., BINLADEN, J., HIGHAM, T. F. & YOHE, R. M. 2008. DNA from pre-Clovis human coprolites in Oregon, North America. *Science,* 320**,** 786-789.

GODER-GOLDBERGER, M., WEINER, S., BARZILAI, O. & BOARETTO, E. 2017. Heating of flint artifacts from the site of Boker Tachtit (Israel) was not detected using FTIR peak broadening. *Journal of Archaeological Science: Reports,* 12**,** 173-182.

GODINO, I. B., ÁLVAREZ, M., BALBO, A., ZURRO, D., MADELLA, M., VILLAGRÁN, X. & FRENCH, C. 2011. Towards high-resolution shell midden archaeology: Experimental and ethnoarchaeology in Tierra del Fuego (Argentina). *Quaternary International,* 239**,** 125-134.

GOLDBERG, P. & ALDEIAS, V. 2018. Why does (archaeological) micromorphology have such little traction in (geo)archaeology? *Archaeological and Anthropological Sciences,* 10**,** 269-278.

GOLDBERG, P., ALDEIAS, V., DIBBLE, H., MCPHERRON, S., SANDGATHE, D. & TURQ, A. 2017a. Testing the Roc de Marsal Neandertal "Burial" with Geoarchaeology. *Archaeological and Anthropological Sciences,* 9**,** 1005-1015.

GOLDBERG, P., BERNA, F. & MACPHAIL, R. I. 2009a. Comment on "DNA from pre-clovis human coprolites in Oregon, North America". *Science,* 325.

GOLDBERG, P. & MACPHAIL, R. 2006. *Practical and Theorectical Geoarchaeology*, Blackwell publishing.

GOLDBERG, P., MILLER, C. E. & MENTZER, S. M. 2017b. Recognizing fire in the Paleolithic archaeological record. *Current Anthropology,* 58.

GOLDBERG, P., MILLER, C. E., SCHIEGL, S., LIGOUIS, B., BERNA, F., CONARD, N. J. & WADLEY, L. 2009b. Bedding, hearths, and site maintenance in the Middle Stone Age of Sibudu Cave, KwaZulu-Natal, South Africa. *Archaeological and Anthropological Sciences,* Volume 1, Number 2 95-122.

GUTIÉRREZ-RODRÍGUEZ, M., PÉREZ-ASENSIO, J. N., MARTÍN PEINADO, F. J., GARCÍA VARGAS, E., TABALES, M. Á., RODRÍGUEZ RAMÍREZ, A., MAYORAL ALFARO, E. & GOLDBERG, P. 2022. A Third Century AD Extreme Wave Event Identified in a Collapse Facies of a Public Building in the Roman City of Hispalis (Seville, Spain). *Historical Earthquakes, Tsunamis and Archaeology in the Iberian Peninsula***,** 267-311.

GUTIÉRREZ‐RODRÍGUEZ, M., BRASSOUS, L., RODRIGUEZ GUTIERREZ, O., MARTIN PEINADO, F. J., ORFILA, M. & GOLDBERG, P. 2020. Site formation processes and urban transformations during Late Antiquity from a high‐resolution geoarchaeological perspective: Baelo Claudia, Spain. *Geoarchaeology,* 35**,** 258-286.

HARDY, K., CAMARA, A., PIQUÉ, R., DIOH, E., GUÈYE, M., DIADHIOU, H. D., FAYE, M. & CARRÉ, M. 2016. Shellfishing and shell midden construction in the Saloum Delta, Senegal. *Journal of Anthropological Archaeology,* 41**,** 19-32.

HARRISON, K. 2013. The application of forensic fire investigation techniques in the archaeological record. *Journal of Archaeological Science,* 40**,** 955-959.

HENRY, A. G. 2017. Neanderthal Cooking and the Costs of Fire. *Current Anthropology,* 58**,** S329-S336.

HOLLIDAY, V. T. 2017. Anthrosols. *In:* GILBERT, A. S. (ed.) *Encyclopedia of Geoarchaeology.* Dordrecht: Springer Netherlands.

HORWITZ, L. K. & GOLDBERG, P. 1989. A study of Pleistocene and Holocene hyaena coprolites. *Journal of Archaeological Science,* 16**,** 71-94.

HUBLIN, J.-J., SIRAKOV, N., ALDEIAS, V., BAILEY, S., BARD, E., DELVIGNE, V., ENDAROVA, E., FAGAULT, Y., FEWLASS, H., HAJDINJAK, M., KROMER, B., KRUMOV, I., MARREIROS, J., MARTISIUS, N. L., PASKULIN, L., SINET-MATHIOT, V., MEYER, M., PÄÄBO, S., POPOV, V., REZEK, Z., SIRAKOVA, S., SKINNER, M. M., SMITH, G. M., SPASOV, R., TALAMO, S., TUNA, T., WACKER, L., WELKER, F., WILCKE, A., ZAHARIEV, N., MCPHERRON, S. P. & TSANOVA, T. 2020. Initial upper palaeolithic homo sapiens from bacho kiro cave, Bulgaria. *Nature,* 581**,** 299-302.

HUISMAN, D., NGAN-TILLARD, D., TENSEN, M., LAARMAN, F. & RAEMAEKERS, D. 2014. A question of scales: studying Neolithic subsistence using micro CT scanning of midden deposits. *Journal of Archaeological Science,* 49**,** 585-594.

HUISMAN, D. J. & MILEK, K. B. 2017. Turf as construction material. *Archaeological soil and sediment micromorphology***,** 113-119.

KARKANAS, P. 2007. Identification of lime plaster in prehistory using petrographic methods: A review and reconsideration of the data on the basis of experimental and case studies. *Geoarchaeology,* 22**,** 775-796.

KARKANAS, P. 2010. Preservation of anthropogenic materials under different geochemical processes: A mineralogical approach. *Quaternary International,* 214**,** 63-69.

KARKANAS, P. 2021. All about wood ash: Long term fire experiments reveal unknown aspects of the formation and preservation of ash with critical implications on the emergence and use of fire in the past. *Journal of Archaeological Science,* 135**,** 105476.

KARKANAS, P., BAR-YOSEF, O., GOLDBERG, P. & WEINER, S. 2000. Diagenesis in prehistoric caves: The use of minerals that form in situ to assess the completeness of the archaeological record. *Journal of Archaeological Science,* 27**,** 915-929.

KARKANAS, P., BROWN, K. S., FISHER, E. C., JACOBS, Z. & MAREAN, C. W. 2015. Interpreting human behavior from depositional rates and combustion features through the study of sedimentary microfacies at site Pinnacle Point 5-6, South Africa. *Journal of Human Evolution,* 85**,** 1-21.

KARKANAS, P., DABNEY, M. K., SMITH, R. A. K. & WRIGHT, J. C. 2012. The geoarchaeology of Mycenaean chamber tombs. *Journal of Archaeological Science,* 39**,** 2722-2732.

KARKANAS, P. & GOLDBERG, P. 2018. *Reconstructing Archaeological Sites: understanding the geoarchaeological matrix*, John Wiley & Sons.

KARKANAS, P., RIGAUD, J. P., SIMEK, J. F., ALBERT, R. M. & WEINER, S. 2002. Ash bones and guano: A study of the minerals and phytoliths in the sediments of Grotte XVI, Dordogne, France. *Journal of Archaeological Science,* 29**,** 721-732.

KELLY, R. L. 1992. Mobility/sedentism: concepts, archaeological measures, and effects. *annual Review of anthropology,* 21**,** 43-66.

KIDDER, T. R. & SHERWOOD, S. C. 2017. Look to the earth: the search for ritual in the context of mound construction. *Archaeological and Anthropological Sciences,* 9**,** 1077-1099.

KLOKLER, D. 2014. A ritually constructed shell mound. *The Cultural Dynamics of Shell-Matrix Sites. University of New Mexico Press, Albuquerque***,** 151-162.

KOROMILA, G., KARKANAS, P., HAMILAKIS, Y., KYPARISSI-APOSTOLIKA, N., KOTZAMANI, G. & HARRIS, K. 2018. The Neolithic tell as a multi-species monument: Human, animal, and plant relationships through a micro-contextual study of animal dung remains at Koutroulou Magoula, central Greece. *Journal of Archaeological Science: Reports,* 19**,** 753-768.

LEHMANN, J., KERN, D. C., GLASER, B. & WOODS, W. I. 2006. Amazonian dark earths: origin properties management.

LEIERER, L., CARRANCHO ALONSO, Á., PÉREZ, L., HERREJÓN LAGUNILLA, Á., HERRERA-HERRERA, A. V., CONNOLLY, R., JAMBRINA-ENRÍQUEZ, M., HERNÁNDEZ GÓMEZ, C. M., GALVÁN, B. & MALLOL, C. 2020. It's getting hot in here – Microcontextual study of a potential pit hearth at the Middle Paleolithic site of El Salt, Spain. *Journal of Archaeological Science,* 123**,** 105237.

LOMBARDO, U., SZABO, K., CAPRILES, J. M., MAY, J. H., AMELUNG, W., HUTTERER, R., LEHNDORFF, E., PLOTZKI, A. & VEIT, H. 2013. Early and Middle Holocene Hunter-Gatherer Occupations in Western Amazonia: The Hidden Shell Middens. *PLoS ONE,* 8.

MACPHAIL, R. I. 1983. The micromorphology of Dark Earth from Gloucester, London and Norwich: an analysis of urban anthropogenic deposits from the late Roman to early Medieval periods in England. *Soil micromorphology. Vol. 1***,** 245-252.

MACPHAIL, R. I. 2017. Privies and Latrines. *In:* GILBERT, A. S. (ed.) *Encyclopedia of Geoarchaeology.* Dordrecht: Springer Netherlands.

MACPHAIL, R. I., COURTY, M.-A. & GOLDBERG, P. 1990a. Soil micromorphology in archaeology. *Endeavour,* 14**,** 163-171.

MACPHAIL, R. I., COURTY, M. A. & GEBHARDT, A. 1990b. Soil micromorphological evidence of early agriculture in north-west Europe. *World Archaeology,* 22**,** 53-69.

MACPHAIL, R. I. & GOLDBERG, P. 2018. Archaeological materials. *Interpretation of micromorphological features of soils and regoliths.* Elsevier.

MALLOL, C., MENTZER, S. M. & MILLER, C. E. 2017. Combustion features. *In:* STOOPS, C. N. A. G. (ed.) *Archaeological soil and sediment micromorphology.* Wiley Blackwell.

MAREAN, C. W. 2016. The transition to foraging for dense and predictable resources and its impact on the evolution of modern humans. *Philosophical Transactions of the Royal Society B: Biological Sciences,* 371.

MASSILANI, D., MORLEY, M. W., MENTZER, S. M., ALDEIAS, V., VERNOT, B., MILLER, C., STAHLSCHMIDT, M., KOZLIKIN, M. B., SHUNKOV, M. V., DEREVIANKO, A. P., CONARD, N. J., WURZ, S., HENSHILWOOD, C. S., VASQUEZ, J., ESSEL, E., NAGEL, S., RICHTER, J., NICKEL, B., ROBERTS, R. G., PÄÄBO, S., SLON, V., GOLDBERG, P. & MEYER, M. 2022. Microstratigraphic preservation of ancient faunal and hominin DNA in Pleistocene cave sediments. *Proceedings of the National Academy of Sciences,* 119**,** e2113666118.

MASSON, B. 2010. Combustion features and periglacial structures: a new taphonomic analysis of Mousterian combustion features at Saint-Vaast-la-Hougue. *In:* THÉRY-PARISOT, I., CHABAL, L. & COSTAMAGNO, S. (eds.) *The taphonomy of burned organic residues and combustion features in archaeological contexts.* Valbonne: Palethonologie.

MATTHEWS, W., FRENCH, C. A. I., LAWRENCE, T., CUTLER, D. F. & JONES, M. K. 1997. Microstratigraphic traces of site formation processes and human activities. *World Archaeology,* 29**,** 281-308.

MCANANY, P. A. & HODDER, I. 2009. Thinking about archaeological excavation in reflexive terms. *Archaeological Dialogues,* 16**,** 41-49.

MCCAULEY, B., COLLARD, M. & SANDGATHE, D. 2020. A Cross-cultural Survey of On-site Fire Use by Recent Hunter-gatherers: Implications for Research on Palaeolithic Pyrotechnology. *Journal of Paleolithic Archaeology***,** 1-19.

MENTZER, S. M. 2017. Micro XRF. *Archaeological soil and sediment micromorphology.*

MENTZER, S. M., ROMANO, D. G. & VOYATZIS, M. E. 2017. Micromorphological contributions to the study of ritual behavior at the ash altar to Zeus on Mt. Lykaion, Greece. *Archaeological and Anthropological Sciences,* 9**,** 1017-1043.

MILEK, K. B. 2012. Floor formation processes and the interpretation of site activity areas: An ethnoarchaeological study of turf buildings at Thverá, northeast Iceland. *Journal of Anthropological Archaeology,* 31**,** 119-137.

MILLER, C. E. 2011. Deposits as artifacts. *TÜVA Mitteilung,* 12**,** 91-107.

MILLER, C. E. 2015. *A Tale of Two Swabian Caves. Geoarchaeological Investigations at Hohle Fels and Geißenklösterle*, Kerns Verlag.

MILLER, C. E., CONARD, N., GOLDBERG, P. & BERNA, F. 2010. Dumping, sweeping and trampling: experimental micromorphological analysis of anthropogenically modifies combustion features. *In:* THÉRY-PARISOT, I., CHABAL, L. & COSTAMAGNO, S. (eds.) *The raphonomy of burned organix residues and combustion features in archaeological contexts.* Proceedings od the round table, Valbonne, May 27-29: Palethnologie.

MORRISSEY, P., MENTZER, S. M. & WURZ, S. 2023. The stratigraphy and formation of Middle Stone Age deposits in Cave 1B, Klasies River Main site, South Africa, with implications for the context, age, and cultural association of the KRM 41815/SAM-AP 6222 human mandible. *Journal of Human Evolution,* 183**,** 103414.

MURPHREE, W. C., MALLOL, C. & ALDEIAS, V. 2020. The Evolution of Pyrotechnology in the Early to Middle Upper Paleolithic in Europe. *ESHE.*

NAMDAR, D., ZUKERMAN, A., MAEIR, A. M., KATZ, J. C., CABANES, D., TRUEMAN, C., SHAHACK-GROSS, R. & WEINER, S. 2011. The 9th century BCE destruction layer at Tell es-Safi/Gath, Israel: integrating macro- and microarchaeology. *Journal of Archaeological Science,* 38**,** 3471-3482.

NEVES, E. G., PETERSEN, J. B., BARTONE, R. N. & AUGUSTO DA SILVA, C. 2003. Historical and Socio-cultural Origins of Amazonian Dark Earth. *In:* LEHMANN, J., KERN, D. C., GLASER, B. & WODOS, W. I. (eds.) *Amazonian Dark Earths: Origin Properties Management.* Dordrecht: Springer Netherlands.

NICOSIA, C., DEVOS, Y. & MACPHAIL, R. I. 2017. European dark earth. *Archaeological soil and sediment micromorphology***,** 331-343.

O'CONNELL, J. F., HAWKES, K. & JONES, N. B. 1991. Distribution of refuse-producing activities at Hadza residential base camps: implications for analyses of archaeological site structure. *The interpretation of archaeological spatial patterning***,** 61-76.

PETTITT, P. B. 2002. The Neanderthal Dead: Exploring Mortuary Variability in Middle Palaeolithic Eurasia. *Before Farming,* 1**,** 1-19.

PETTITT, P. B., RICHARDS, M., MAGGI, R. & FORMICOLA, V. 2003. The Gravettian burial known as the Prince ("Il Principe"): new evidence for his age and diet. *Antiquity,* 77**,** 15-19.

PICHLER, S. L., PÜMPIN, C., BRÖNNIMANN, D. & RENTZEL, P. 2014. Life in the proto-urban style: The identification of parasite eggs in micromorphological thin sections from the Basel-

Gasfabrik Late Iron Age settlement, Switzerland. *Journal of Archaeological Science,* 43**,** 55-65.

POMEROY, E., HUNT, C. O., REYNOLDS, T., ABDULMUTALB, D., ASOUTI, E., BENNETT, P., BOSCH, M., BURKE, A., FARR, L., FOLEY, R., FRENCH, C., FRUMKIN, A., GOLDBERG, P., HILL, E., KABUKCU, C., LAHR, M. M., LANE, R., MAREAN, C., MAUREILLE, B., MUTRI, G., MILLER, C. E., MUSTAFA, K. A., NYMARK, A., PETTITT, P., SALA, N., SANDGATHE, D., STRINGER, C., TILBY, E. & BARKER, G. 2020. Issues of theory and method in the analysis of Paleolithic mortuary behavior: A view from Shanidar Cave. *Evolutionary Anthropology: Issues, News, and Reviews,* 29**,** 263-279.

PÜMPIN, C., LE BAILLY, M. & PICHLER, S. 2017. Ova of intestinal parasites. *Archaeological Soil and Sediment Micromorphology***,** 91-97.

RANDALL, I. 2023. Epoch or event? Defining the Anthropocene. *Physics World,* 36**,** 26.

REESE, D. S. 2010. Shells from Sarepta (Lebanon) and East Mediterranean purple-dye production. *Mediterranean Archaeology and Archaeometry,* 10**,** 113-141.

RENDU, W., BEAUVAL, C., CREVECOEUR, I., BAYLE, P., BALZEAU, A., BISMUTH, T., BOURGUIGNON, L., DELFOUR, G., FAIVRE, J.-P. & LACRAMPE-CUYAUBÈRE, F. 2014. Evidence supporting an intentional Neandertal burial at La Chapelle-aux-Saints. *Proceedings of the National Academy of Sciences,* 111**,** 81-86.

RENDU, W., BEAUVAL, C., CREVECOEUR, I., BAYLE, P., BALZEAU, A., BISMUTH, T., BOURGUIGNON, L., DELFOUR, G., FAIVRE, J.-P. & LACRAMPE-CUYAUBÈRE, F. 2016. Let the dead speak… comments on Dibble et al.'s reply to "Evidence supporting an intentional burial at La Chapelle-aux-Saints". *Journal of Archaeological Science,* 69**,** 12-20.

RODRÍGUEZ DE VERA, C., HERRERA-HERRERA, A. V., JAMBRINA-ENRÍQUEZ, M., SOSSA-RÍOS, S., GONZÁLEZ-URQUIJO, J., LAZUEN, T., VANLANDEGHEM, M., ALIX, C., MONNIER, G., PAJOVIĆ, G., TOSTEVIN, G. & MALLOL, C. 2020. Micro-contextual identification of archaeological lipid biomarkers using resin-impregnated sediment slabs. *Scientific Reports,* 10**,** 20574.

ROEBROEKS, W. & VILLA, P. 2011. On the earliest evidence for habitual use of fire in Europe. *Proceedings of the National Academy of Sciences of the United States of America,* 108**,** 5209-5214.

RUIVO, M. D. L. P., ARROYO-KALIN, M. A., SCHAEFER, C. E. R., COSTI, H. T., DE SOUZA ARCANJO, S. H., LIMA, H. N., PULLEMAN, M. M. & CREUTZBERG, D. 2003. The Use of Micromorphology for the Study of the Formation and Properties of Amazonian Dark Earths. *In:* LEHMANN, J., KERN, D. C., GLASER, B. & WODOS, W. I. (eds.) *Amazonian Dark Earths: Origin Properties Management.* Dordrecht: Springer Netherlands.

SANDGATHE, D. M., DIBBLE, H. L., GOLDBERG, P. & MCPHERRON, S. P. 2011a. The Roc de Marsal Neandertal child: A reassessment of its status as a deliberate burial. *Journal of Human Evolution,* 61**,** 243-253.

SANDGATHE, D. M., DIBBLE, H. L., GOLDBERG, P., MCPHERRON, S. P., TURQ, A., NIVEN, L. & HODGKINS, J. 2011b. On the Role of Fire in Neandertal Adaptations in Western Europe: Evidence from Pech de l'Azé and Roc de Marsal, France. *PaleoAnthropology* 216-242.

SANDGATHE, D. M., DIBBLE, H. L., GOLDBERG, P., MCPHERRON, S. P., TURQ, A., NIVEN, L. & HODGKINS, J. 2011c. Timing of the appearance of habitual fire use. *Proceedings of the National Academy of Sciences of the United States of America,* 108.

SCHIEGL, S., GOLDBERG, P., BAR-YOSEF, O. & WEINER, S. 1996. Ash deposits in Hayonim and Kebara caves, Israel: Macroscopic, microscopic and mineralogical observations, and their archaeological implications. *Journal of Archaeological Science,* 23**,** 763-781.

SCHIEGL, S., GOLDBERG, P., PFRETZSCHNER, H. U. & CONARD, N. J. 2003. Paleolithic burnt bone horizons from the Swabian Jura: Distinguishing between in situ fireplaces and dumping areas. *Geoarchaeology,* 18**,** 541-565.

SCHIFFER, M. B. 1987. *Formation Processes of the Archaeological Record,* Albuquerque, University of New Mexico Press.

SCHMIDT, P., PORRAZ, G., SLODCZYK, A., BELLOT-GURLET, L., ARCHER, W. & MILLER, C. E. 2013. Heat treatment in the South African Middle Stone Age: temperature induced transformations of silcrete and their technological implications. *Journal of Archaeological Science,* 40**,** 3519-3531.

SHAHACK-GROSS, R. 2011. Herbivorous livestock dung: formation, taphonomy, methods for identification, and archaeological significance. *Journal of Archaeological Science,* 38**,** 205-218.

SHAHACK-GROSS, R., ALBERT, R.-M., GILBOA, A., NAGAR-HILMAN, O., SHARON, I. & WEINER, S. 2005. Geoarchaeology in an urban context: The uses of space in a Phoenician monumental building at Tel Dor (Israel). *Journal of Archaeological Science,* 32**,** 1417-1431.

SHAHACK‐GROSS, R. 2017. Animal gathering enclosures. *Archaeological soil and sediment micromorphology***,** 265-280.

SHERWOOD, S. C. & KIDDER, T. R. 2011. The DaVincis of dirt: Geoarchaeological perspectives on Native American mound building in the Mississippi River basin. *Journal of Anthropological Archaeology,* 30**,** 69-87.

SHILLITO, L.-M., WHELTON, H. L., BLONG, J. C., JENKINS, D. L., CONNOLLY, T. J. & BULL, I. D. 2020. Pre-Clovis occupation of the Americas identified by human fecal biomarkers in coprolites from Paisley Caves, Oregon. *Science Advances,* 6**,** eaba6404.

SHILLITO, L. M., BULL, I. D., MATTHEWS, W., ALMOND, M. J., WILLIAMS, J. M. & EVERSHED, R. P. 2011. Biomolecular and micromorphological analysis of suspected faecal deposits at Neolithic Çatalhöyük, Turkey. *Journal of Archaeological Science,* 38**,** 1869-1877.

SHILLITO, L. M. & MATTHEWS, W. 2013. Geoarchaeological Investigations of Midden‐Formation Processes in the Early to Late Ceramic Neolithic Levels at Çatalhöyük, Turkey ca. 8550–8370 cal BP. *Geoarchaeology,* 28**,** 25-49.

SIMÕES, C. D. & ALDEIAS, V. 2022. Thermo-microstratigraphy of shells reveals invisible fire use and possible cooking in the archaeological record. *Frontiers in Earth Science,* 10.

SISTIAGA, A., BERNA, F., LAURSEN, R. & GOLDBERG, P. Steroidal Biomarker Analysis of a 14,000 Years Old Putative Human Coprolite from Paisley Cave, Oregon. *Journal of Archaeological Science*.

SISTIAGA, A., MALLOL, C., GALVÁN, B. & SUMMONS, R. E. 2014. The Neanderthal meal: a new perspective using faecal biomarkers. *PloS one,* 9**,** e101045.

SØE, M. J., NEJSUM, P., SEERSHOLM, F. V., FREDENSBORG, B. L., HABRAKEN, R., HAASE, K., HALD, M. M., SIMONSEN, R., HØJLUND, F. & BLANKE, L. 2018. Ancient DNA from latrines in Northern Europe and the Middle East (500 BC–1700 AD) reveals past parasites and diet. *PLoS One,* 13**,** e0195481.

SORENSEN, A. C. 2017. On the relationship between climate and Neandertal fire use during the Last Glacial in south-west France. *Quaternary International,* 436**,** 114-128.

SPETH, J. D. 2017. Putrid meat and fish in the Eurasian middle and upper Paleolithic: are we missing a key part of Neanderthal and modern human diet. *PaleoAnthropology,* 2017**,** 44-72.

STINER, M. C., KUHN, S. L., WEINER, S. & BAR-YOSEF, O. 1995. Differential Burning, Recrystallization, and Fragmentation of Archaeological Bone. *Journal of Archaeological Science,* 22**,** 223-237.

STIROS, S. C. 1996. Identification of earthquakes from archaeological data: methodology, criteria and limitations. *Archaeoseismology,* 7**,** 129-152.

STOOPS, G., CANTI, M. G. & KAPUR, S. 2017. Calcareous mortars, plasters and floors. *Archaeological soil and sediment micromorphology***,** 189-199.

STOOPS, G., MARCELINO, V. & MEES, F. 2018. *Interpretation of micromorphological features of soils and regoliths*, Elsevier.

SUKENIK, N., ILUZ, D., AMAR, Z., VARVAK, A. & BAR, S. 2017. New Evidence of the Purple-Dye Industry at Tel Shiqmona, Israel. *Archaeometry,* 59**,** 775-785.

USAI, M. R., PICKERING, M. D., WILSON, C., MANUNZA, M. R., GARBI, I., PITTONI, E., BROTHWELL, D. R. & KEELY, B. J. 2018. Evidence from burial sediments for prehistoric burial practice and ritual in Monte Claro chambered tombs: Micromorphology, mineralogy and geochemistry. *Journal of archaeological science,* 100**,** 139-147.

VERHOEVEN, M. 2000. Death, fire and abandonment: Ritual practice at late neolithic Tell Sabi Abyad, Syria. *Archaeological Dialogues,* 7**,** 46-65.

VILLAGRAN, X. S. 2014a. Experimental Micromorphology on Burnt Shells of Anomalocardia brasiliana (Gmelin 1791)(Bivalvia, Veneridae) and Its Potential for Identification of Combustion Features on Shell‐Matrix Sites. *Geoarchaeology,* 29**,** 389-396.

VILLAGRAN, X. S. 2014b. A redefinition of waste: Deconstructing shell and fish mound formation among coastal groups of southern Brazil. *Journal of Anthropological Archaeology,* 36**,** 211-227.

VILLAGRAN, X. S., BALBO, A. L., MADELLA, M., VILA, A. & ESTEVEZ, J. 2011. Experimental micromorphology in Tierra del Fuego (Argentina): Building a reference collection for the study of shell middens in cold climates. *Journal of Archaeological Science,* 38**,** 588-604.

VILLAGRAN, X. S., KLOKLER, D., NISHIDA, P., GASPAR, M. D. & DEBLASIS, P. 2010. STRATIGRAPHIC READING: FUNERARY ARCHITECTURE AND DEPOSITION OF WASTE IN SAMBAQUI JABOTICABA II. *LATIN AMERICAN ANTIQUITY,* 21**,** 195-216.

WADLEY, L. 2009. Post-depositional heating may cause over-representation of red-coloured ochre in stone age sites. *South African Archaeological Bulletin,* 64**,** 166-171.

WATERS, M. R. 1992. *Principles of Geoarchaeology: a North American Perspective,* Tuckson, University of Arizona Press.

WEINER, S. 2010. *Microarchaeology Beyond the Visible Archaeological Record,* Cambridge, Cambridge.

WOODS, W. I. & MCCANN, J. M. The anthropogenic origin and persistence of Amazonian dark earths. Yearbook. Conference of latin americanist Geographers, 1999. JSTOR, 7-14.

WRANGHAM, R. W. 2006. The cooking enigma. *Evolution of the Human Diet: The Known, the Unknown, and the Unknowable. Oxford University Press, Oxford***,** 308-323.

YRAVEDRA, J. & UZQUIANO, P. 2013. Burnt bone assemblages from El Esquilleu cave (Cantabria, Northern Spain): Deliberate use for fuel or systematic disposal of organic waste? *Quaternary Science Reviews,* 68**,** 175-190.

ZALASIEWICZ, J. 2015. Disputed start dates for Anthropocene. *Nature,* 520**,** 436-436.