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Micromorphology of earth building materials: Toward the reconstruction of former technological processes (Protohistoric and Historic Periods)

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ABSTRACT

Earth building materials are often identified in the field, but very few microscopic studies focus on the identification of the technological processes, which produced them, especially in temperate contexts. The identification of such processes is crucial as it is the basis of the archaeological investigations concerning both the origin and the diffusion of building technologies. The aim of this paper is to describe and expand the definitions of the microscopic features typically associated with the steps associated with the "*chaînes opératoires*" of earth building on the basis of micromorphological analyses and development of a reference collection of earthen materials. The results have identified a range of characteristics associated with past earthen construction processes (including microscopic features linked to earth moisture when mixing, degree of mixing, the moisture of the earth when applied to the walls or on the ground, as well as those related to compaction and shear stress) that are all important factors that explain former processes. Strong compaction of earth in a dry state is typical of rammed earth, medium compaction together with a higher degree of moisture is typical of cob wall, and perpendicular organization of the earth on the face of the wall indicates the use of a formwork or shuttering. Thus, the use of microscopic features identified from analysis of vernacular and ancient materials helps to characterize and identify processes such as Roman rammed earth at the site of Rirha (Morocco). It also highlights cultural specificities, such as the diversity of cob wall and earth flooring processes during the Iron Age, as on the site of *Lattara* (southern France), and the degree of compaction of rammed earth wall for the Roman Period. Analyses carried out in a robust archaeological framework reveal that each wall present a specific vertical and horizontal organization linked to the building processes at macroscopic and microscopic scales, which should be taken into account when studying and sampling earthen walls in order to correctly identify former techniques.

1. Introduction

Earth construction is widespread in various geographical, climatic and chronological contexts (Goldberg and Macphail, 2006, p. 279; Macphail and Goldberg, 2010; Cammas, 2015b). Several load bearing walling techniques are identified. Some are well known and described in archaeological and architectural papers. Cob (*bauge* for France, *tourton* for Belgium, *chamizo* for Spain, *jalous* for Soudan, see Hamard et al., 2016a, Table 2, p. 106, Hamard, 2017) corresponds to several technological processes (Chazelles, 1997; Roux and Cammas, 2010; Hamard et al., 2016a) where the walls are monolithic or load bearing and shaped with earth in a wet plastic state (Hamard et al., 2016a, b). In the case of rammed earth, (*pisé* for France, *tapia* for Spain (Font Arrellano, 2007), *tápia*, *tápi or tepa* for southern France (Baudreu, 2007), *taipa* for Portugal (Guillaud, 2007), *tapialera* (Goodman-Elgar, 2008), clods of slightly moist soils or sediments are broken and compacted in a dryer state than for cob with the help of a formwork (Cointeraux, 1791; Doat et al., 1979; Meunier, 2003; Guillaud, 2007; Hamard et al., 2016b). Another well-known and more studied building technique is mud

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brick and its alteration (see Goldberg, 1971; McIntosh, 1974; Courty et al., 1989; Kenoyer, 1998; Morgenstein and Redmount, 1998; Shahack-Gross et al., 2005; Goodman-Elgar, 2008; Friesem et al., 2011, 2014a; Homsher, 2012; Nodarou et al., 2008; Roux and Cammas, 2016a). One characteristic of earth technology is that there are a lot of local and chronological adaptations of these techniques in one geographical area, city or even the same building (Malvido, 2003; Chausserie-Laprée and Chazelles, 2003; Chazelles and Léal, 2003; Roux, 2003; Goldberg and Macphail, 2006; Roux and Cammas, 2010). Earth is widely used, and is often the main component of floors of various thickness and composition (Gé et al., 1993; Cammas, 1994; Matthews, 1992, 1995; Matthews et al., 1994; Matthews et al., 1996; Cammas et al., 1996; Matthews et al., 1997; Stordeur and Wattez, 1998; Cammas, 1999; Shahack-Gross et al., 2005; Goldberg and Macphail, 2006; Goodman-Elgar, 2008; Cammas and Wattez, 2009; Macphail and Goldberg, 2010; Milek, 2012; Shillito and Ryan, 2013; Cammas, 2015a, 2015b).

In a lot of case studies, the field characteristics of earth material are not clear. It can be quite difficult, to identify the earthen building material, especially when it is in a secondary position (Chausserie-Laprée and Chazelles, 2003; Goldberg and Macphail, 2006 p. 227, p. 279, p. 283; Macphail and Goldberg, 2010, p. 590), and also to identify the construction technique. It is especially difficult to separate cob and rammed earth on the basis of field characteristics. This leads to misidentification of techniques and gross anachronisms, especially concerning the Roman Period and the differentiation of cob and rammed earth processes (Chausserie-Laprée and Chazelles, 2003, p. 312).

Micromorphology is very efficient for reconstruction of past anthropogenic activities (Gé et al., 1993; Cammas, 1994; Matthews, 1992, 1995; Matthews et al., 1994; Matthews et al., 1996; Cammas et al., 1996; Matthews et al., 1997; Cammas, 1999; Shahack-Gross et al., 2005; Cammas and Wattez, 2009; Macphail and Goldberg, 2010, p. 599; Milek, 2012; Cammas, 2015a). Previous micromorphological studies on archaeological earthen material focused mostly on characterization of walls, floors and fragments that were identified in the field, on alteration of mud brick in an arid context (McIntosh, 1974; Shahack-Gross et al., 2005; Goodman-Elgar, 2008; Friesem et al., 2011) and in more temperate and tropical areas (Friesem et al., 2014a; Pereira et al., 2015). Micromorphological studies of earthen floors and walls were firstly developed on Neolithic and Bronze Age sites in arid and semi-arid areas (Matthews, 1995; Matthews et al., 1996, 1997; Stordeur and Wattez, 1998; Hourani, 2003; Karkanas and Efstratiou, 2009; Hubbard, 2010; Karkanas and Van de Moortel, 2014). Earthen floors are well known and studied for tells, and for sites located in arid to semi arid regions (Matthews, 1992, 1995; Matthews et al., 1994; Matthews et al., 1996, 1997; Shahack-Gross et al., 2005; Karkanas and Efstratiou, 2009; Hubbard, 2010; Karkanas and Van de Moortel, 2014), because floors are better preserved in these areas (Karkanas and Efstratiou, 2009). In contrast, there are fewer studies on temperate areas and post Bronze Age periods like that of Friesem et al. (2014a), Gebhardt and Langhor (1999), and in Goldberg and Macphail (2006). To refine the knowledge of former earth buildings, some studies focused on experimental or ethnoarchaeological case studies (e.g. Goldberg and Whitbread, 1993; Macphail et al., 2004; Goodman-Elgar, 2008; Milek, 2012; Banerjea et al., 2015; Friesem et al., 2011, 2014a, 2014b) or raw earth objects such as hearths (Germain-Vallée et al., 2011).

There are some micromorphological studies involving technological aspect of earthen material and the identification of past techniques (Hourani, 2003; Wattez, 2003; Germain-Vallée et al., 2011; Mateu et al., 2013; Mabille et al., 2014), but there is no systematic study of microscopical characteristics linked to the preparation and implementation of earth for the Iron Age and Historic Period. The research presented in this paper focuses on the use of micromorphology to study the behaviour of earth under different anthropogenic stresses in order to better understand construction techniques and to explore the relationship between techniques and cultural factors, like the use of space. This research concerns 1) the identification of microscopic key features related to the steps of earth preparation for selected techniques, and 2) the significance of the variation in techniques and pattern/rhythms of construction that can be identified. This work is based on a reference collection created for the Iron Age and Roman site *Lattara* (southern France), and further broadened to a large number of sites in various contexts. The objective of this paper is to list and update the key microfeatures linked to earth moisture, mixing and mechanical stresses typical of archaeological building material, and, secondly, to synthesize the results of research on Iron Age and Roman Period case studies, such as microlayered earthen floors and massive walls, in order to highlight their technical specificity and their cultural diversity.

2. Material and method

2.1. Reference collection

Micromorphology covers a wide range of research, and focuses on many new anthropogenic soil types and soils processes. Furthermore, soil microfeatures depend heavily on their cultural and natural environment. As a consequence, current manuals and research papers may not cover all situations, leaving micromorphologists to produce personal reference collection for each new study, thus, their interpretations are based on literature as well as reference collections.

In order to constitute a macroscopic and microscopic reference collection, pieces of earthen building materials coming from various pedo-sedimentary, climatic and chronocultural contexts were collected by the author for 25 years. This reference collection is composed of more than 1000 thin sections of archaeological and ethno-archaeological walls and floors from Iron Age to present-day, together with fragments and aggregates of earth building materials found in archaeological layers. They come from more than 34 archaeological sites, mostly from France, with a few samples from a wider area (Table 1). Clayey to loamy and sandy materials have been studied. The investigated techniques are cob, rammed earth, wattle and daub and mud brick for a wide diversity of walls and floors.

When developing a robust reference collection, a certain degree of certainty needs to be associated with interpretations of materials and techniques. In the reference collection, wall and floors types were identified on the basis of three modalities, indicated in Table 1. Some walls and their building techniques could be identified in the field via excavation. Indeed, reliable field characteristics can be identified, such as the holes that fixed the shutter for rammed earth (see the Rirha site case study), the superimposition of irregular layers, or the presence of earth blocks or earth balls deformed because of cob process implemented in a wet soft state (Roux et Cammas, 2010). For other walls, often those made of very massive and undifferentiated material, the technique was identified using a combination of field observation and micromorphology to specify the degree of wetness at the moment of implementation (see the Rirha site case study). In some case studies, building materials were identified only by micromorphological analysis, most often, this concerns thin earthen floors and fragments of building materials found in collapsed layers, in occupation layers or in colluvium. Field work and observations of earthen materials require special skill, and as samples in this reference collection come from heterogeneous archaeological and geographical contexts, the development

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