Earthen Architecture as a Community of Practice: A Case Study of Neolithic Earthen Production in the Eastern Mediterranean

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This article analyses the development of Neolithic earthen architecture in the Eastern Mediterranean as a concrete example of 'communities of practice'. Recent studies on earthen architecture have highlighted its adaptability to different climates, architectural forms and craftmanship levels, focusing on the technological aspects of earthen construction. This paper explores the anthropological significance of earth as a building material. It provides evidence on the development of earthen building techniques, interactions between different communities regarding building practices and an understanding of the dynamics of chaîne opératoire *in relation to various materials. A review of archaeological case studies provides compelling preliminary evidence for the existence of early specialized architecture in Neolithic Aegean contexts.*

Introduction

> The practice of architecture is the most delightful of all pursuits. Also, next to agriculture, it is the most necessary to man. One must eat, one must have shelter.
>
> (Johnson 1979)

Sedentary architecture flourished in the Neolithic as more than a simple expedient for shelter and protection; it was a new representation of society's changing relationship between itself and the natural environment. The transition from dwellings to domestic structures was a manifestation of the socio-cultural changes that characterized societies at the passage between the Mesolithic/Epipaleolithic and the Neolithic (Banning & Chazan 2006; Hodder 1990; Watkins 2004). In turn, sedentarization also impacted the social organization of early societies, creating a complex and multi-faceted phenomenon in ways that have been extensively addressed by post-processualists, structuralists and social theorists alike (Carsten & Hugh-Jones 1995; Hodder 1990; Lévi-Strauss 1962; Rapoport 1969; Samson 1990; Watkins 2004; Wilson 1988). Neolithic 'house-forms' and their possible significance within contemporary social parameters have been the subject of lively debates, although only a limited number of scholars have focused on architectural materiality and its symbolism in Neolithic societies (Akkermans 2010; Aurenche 1993; Boivin 2004; Kotsakis 2018, 33; Wilk 1990). This discussion often tends to identify Neolithic societies' choice of building materials as only deterministic, or disregards its potential cultural significance for the community, merely focusing on the functionality of building choices. Consequently, it overlooks a key aspect of material culture—building materials—that intrinsically depends on the sharing of knowledge and possible existence of 'communities of practice' in architecture (Lave & Wenger 1991; Marchand 2011; van Vuuren 2015). The concept of 'communities of practice' implies a common interest by communities in gaining knowledge in a specific field or directing it to a problem-solving activity (Lave & Wenger 1991; Rogoff 1995; Wenger 1998; 2010).

Models developed by anthropologists investigating the transmission of knowledge indicate that learning spans a range of scales and modes (Bauer

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& Agbe-Davies 2010; Kardulias & Hall 2008; Knappett & van der Leeuw 2014). Our understanding of learning practices is clearly complicated by the diachronic nature of learning itself at both the individual and the community level. The 'communities of practice' approach considers an intermediate level of learning, showcasing how technological learning is linked to social context, motor-skill development and other forms of non-declarative learning (Gosselain 2008; Knappett & van der Leeuw 2014; Lemonnier 1993; Warnier 2007). The integration of multiple types of knowledge can be a long process, but one that is reflected in material culture and often in the kinaesthetic movements people perform during these processes (Roux & Corbetta 1989; Wendrich 2012a). Thus, a 'communities of practice' approach allows us to investigate skill transfer at the synchronic and diachronic level within the same community and between multiple sites (Abell 2020; Knappett & van der Leeuw 2014, 82).

By sharing their knowledge, members of a community can increase the general social-based knowledge and develop motor skills essential for craft specialization (Cutler 2019; Lave & Packer 2011; Lave & Wenger 1991). In their assertion that 'a community of practice is a set of relations among persons, activity and world over time and in relation to other tangential and overlapping communities of practice', Lave and Wenger (1991, 115) propounded how the learning process is not just a top-down approach but often also works horizontally within communities. In archaeology, the concept of community of practice was introduced to understand better the relationship between apprentice and master in material culture production. This concept also considers the relationship between different craft specialists and the diachronic transfer of knowledge between kin and/or different social groups within a community, creating new lenses through which material culture and the *chaînes opératoires* behind its production can be examined (Cutler 2019; Lave 2012; Miller 2013, 227–33; Minar & Crown 2001; Wendrich 2012b, 257–60). In turn, the *chaîne opératoire* can be understood as the totality of operational steps required to move from raw materials to a complete form of material culture, involving both materiality and movements (Leroi-Gourhan 1964, 323; von Rüden 2015, 36–7). Technological processes cannot be known just by the mere description of technical steps, but it is the experience of the people creating them, the 'tacit knowledge' embedded in objects, that gives them value in our debate (Lindblom *et al.* 2015; von Rüden 2015).

Earthen building materials are a human production and symbol of the community effort to use natural resources to create a man-made built environment. The manufacture of these materials undergoes a complex *chaîne opératoire* in which we assist in a complete transformation of the raw sources, such as soil, water and temper, to enable the creation of original material culture embedded with environmental and social data (Lorenzon 2021; Lorenzon *et al.* 2020; Love 2013a; Sadalla & Sheets 1993; Warnier 2009).

Building upon these approaches, this contribution aims to draw attention to the materiality and social process of constructing with earth. I argue that inferences about economic and social organization and the varying social importance of buildings are based on the degree of effort and the quality of raw material sources used in the construction process. The prominence of earth as a construction material in the eastern Mediterranean during the Neolithic period can also be connected with the increased exploitation of clay in various other forms of material culture (e.g. pottery, figurines, personal items), elevating this material to new sociocultural status connected with the development of agriculture and identity (Catapoti & Relaki 2020; Mina 2008). Therefore, any analysis of prehistoric architecture needs to overcome the attitude that building materials are not an essential part of material culture, but rather chosen for opportunistic or functional reasons (Lévi-Strauss 1962; Love 2013b; Rapoport 1969).

In the Levant and Mesopotamia, earthen building materials are typically associated with the earliest identified sedentary architecture (Kurapkat 2014; Love 2013b; Rosen 1986; Stordeur 2010). In reality, the use of earth to create permanent and semi-permanent dwellings is already attested in Mesolithic Europe (e.g. the Balkans; see Stevanović 1997) and during the Epipaleolithic in Asia (e.g. Mesopotamia, Anatolia; see Biçakçi 2003; Goring-Morris & Belfer-Cohen 2008), but it is only in the Neolithic that we have evidence of a multiscalar transformation from simple, seasonal dwellings to a more stable form of built environment (Hodder 1990; Kotsakis 2018; Watkins 2004).

Aurenche (1981; 1993) has discussed the development of earthen architecture in southeast Anatolia, Mesopotamia and the Levant from the eighth to the fourth millennium BC, featuring the main techniques employed in earthen construction in Pre-Pottery Neolithic A (PPNA), Pre-Pottery Neolithic B (PPNB) and other Neolithic sites. In the last two decades, further research conducted on Neolithic earthen architecture in southeast Anatolia, Mesopotamia and the Levant highlighted the lack

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Table 1. *Comparative chronological table (after Tomkins 2007; 2008; 2018; pers. comm.)*

Approx. date (cal. BC)	Western Anatolian and East Aegean	Greece	Crete (Knossos)
c. 7000–*c.* 6500	Aceramic/PPN/ Early Neolithic	Aceramic/Initial	Initial Neolithic Knossos I–II
c. 6500–*c.* 6000/5900	Late Neolithic Hacilar IX–VI Ulucak IV–V Kuruçay 13–11	Early Neolithic Franchthi FCP1	Early Neolithic Knossos III
c. 6000/5900–*c.* 5500	Early Chalcolithic Hacilar V–I Kuruçay 10–7	Middle Neolithic Franchthi FCP2–3	Middle Neolithic Knossos IV
c. 5500–*c.* 5000	Middle Chalcolithic Emporio X–VIII Kum Tepe IA Besiktepe Kizilbel/ Lower Bagbasi	Late Neolithic I Saliagos Franchthi FCP4	Late Neolithic I Knossos V–VI
c. 5000–*c.* 4500		Late Neolithic II Saliagos	Late Neolithic II Knossos VII–VIII
c. 4500–*c.* 4300/4200	? Middle Chalcolithic ?	Final Neolithic	Final Neolithic IA Knossos IX
c. 4300/4200–*c.* 3900	Late Chalcolithic		Final Neolithic IB Knossos X Final Neolithic IIA Knossos XI
c. 3900–*c.* 3600/3500			Final Neolithic IIB Knossos XII Subneolithic Knossos XIII

of comparative studies of earthen architecture in western Anatolia, Greece and the Aegean region (Andreou *et al.* 1996; Akkermans 2010; Banning 2010; Białowarczuk 2019; Finlayson *et al.* 2011; Goring-Morris & Belfer-Cohen 2008; Kinzel 2015; Love 2013a; Prévost–Dermarkar 2019). This is partially due to a long-standing division in the study of Neolithic archaeology between these regions in which western Anatolia has been bundled together with the rest of western Asia (i.e. Mesopotamia, the Levant, southeast Anatolia). Only recently have researchers called into question this arbitrary classification (Table 1). The connection of western Anatolia with the Aegean and Greece creates a broad, extremely stimulating archaeological context in which architecture is characterized by various influences coming from central Anatolia, the Balkans and the Levant (Demoule & Perlès 1993, 370–75; Horejs *et al.* 2015; Özdoğan 2014; Perlès 2003). Recent investigations have begun to bridge this gap, by offering a more comprehensive picture of Neolithization in the Eastern Mediterranean as an interconnected region (Broodbank 2013, 173–96; Horejs 2019; Perlès 2010; Reingruber 2011).

This paper builds on these new approaches by exploring the creation of communities of practice in Neolithic earthen architecture in the eastern Mediterranean. The difficulties of preservation and the geographical separation of Anatolia from Greece and the Aegean in the scholarship have resulted in a significant gap in the study of this material in the region. Consequently, earthen building materials in this geographical area have received little attention. This contribution aims to bring this understudied resource to the forefront for a more comprehensive examination of the process of Neolithization in the eastern Mediterranean (Guest-Papamanoli 1978; Horejs 2019; Love 2013a).

The paper first considers the implementation of different earthen techniques and provides a clearer picture of the location in which these are documented, by evaluating their use in structural architectural elements (i.e. wall elevations) over time. For this, I record the regular use of earthen architecture in the eastern Mediterranean, to be precise, western Anatolia, the Aegean islands and mainland Greece. Second, I analyse the complex *chaîne opératoire* process of these earthen building materials to gain a better understanding of Neolithic societies' relationship with earth. Finally, a focused case study at Knossos aims to ascertain evidence of synchronic and diachronic learning processes.

Figure 1. *Sites mentioned in the text. (Image: Google Map, 2021; drawing: Maija Holappa.)*

Archaeological evidence in the eastern Mediterranean

The use of earth as a building material is attested for over three millennia in most western Anatolian, mainland Greek, Cretan and other Aegean Neolithic villages (Fig. 1). Within this landscape, Stevanović (1997) conducted one of the earliest comprehensive studies of Neolithic architecture in southeast Europe, demonstrating that an anthropological approach applied to building techniques can offer comprehensive insights into the social processes of human settlements. Her research successfully extracted social information from a technological analysis of Neolithic architecture (Stevanović 1997; 2012), raising questions about the importance of clay for Neolithic cultures and the selection of clay as a key building material.

The Aegean landscape, with its heterogeneous assemblage of architecture, could be considered a melting-pot of creative Neolithic earthen practices. Numerous earthen techniques have been documented in wall structures, ceilings and foundations, thanks to the ubiquitous nature of earth, which makes it easy to employ as a binder (i.e. mud mortar), as a cover (i.e. plastic earthen materials,[1] plaster in all plaster or ceiling elements) and a structural element (i.e. wall structures in *tauf* [cob in British vernacular tradition] or mudbrick) (Aurenche 1981, 45–72; Wright 2005, 75–144).

Although recent excavations have provided more material for the analysis of construction techniques, clear limitations are posed by the re-use of building materials over time, the natural decay of buildings after abandonment, the depositional and post-depositional processes that affect earthen materials, and the instability of these materials once exposed during excavation. All these factors contribute to the fragmentary nature of the information recorded, conditioning the analysis of earthen architecture (Friesem *et al.* 2014; Stevanović 1997; 2012; Wardle 1996).

Table 2 presents a comprehensive summary of the techniques documented at Neolithic sites in the

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Table 2. *Examples of the variety of techniques in the Eastern Mediterranean. EN = Early Neolithic; MN = Middle Neolithic; LN = Late Neolithic; FN = Final Neolithic.*

Site	Period	Building type	Summary of techniques	Source	Site phasing
Ilıpınar	6000 6000–5700 5700–5500	Rectangular buildings	Ilıpınar X-IX 1. mud-slab (clay sod), wattle-and-daub, wooden floor Ilıpınar X-VIII 2. post walled buildings Ilıpınar VI and VA3. moulded mudbrick on multiple-storey building, with wooden and earthen ceiling.	Roodenberg & Alpaslan-Roodenberg 2008; Roodenberg & Thissen 1995	Ilıpınar X–V
Menteşe	5500	Rectangular/square buildings	*Tauf/pisé*, yellow mud slab, building with probable wattle-and-daub, and/or *tauf* (mud-slab); one wall mudbricks.	Roodenberg 1999, 24; Roodenberg & Alpaslan-Roodenberg 2008	Stratum 3
Barcın Höyük	6200	Rectangular buildings	Wood and loam, wattle-and-daub with no wattle (i.e. cob/ *tauf* in association with wooden post).	Gerritsen & Özbal 2019; Özbal & Gerritsen 2019	Phase IV
Hacilar	6400–6000	Rectangular buildings	Mudbrick on stone foundation, mud plaster. Hacilar VI two rows of large, plano-convex mudbricks laid on stone foundations. Possible upper storeys.	Mellaart 1961	Hacilar VI–IX
Ulucak	6000–5700	Rectangular buildings	Elaborated plaster floor; standard mould-made mudbrick walls on stone foundation (Level IVa); wattle-and-daub, no foundation (level IVb1 and IVb2); 13 buildings at Level IVb2 which also present mudbricks on stone foundation. *Pisé* in the building outer walls in Level IVb2. Sun-dried mudbrick tempered with straw; roof supported by wooden poles inside the building.	A. Çilingiroğlu *et al.* 2004, 20–22, 30–31; A. Çilingiroğlu & Ç. Çilingiroğlu 2007, 364; Ç. Çilingiroğlu & Çakırlar 2013	Building level IV
Uğurlu	5900–5700	–	Earthen floor, mud on stone foundation (*tauf*) and adobe (mudbricks).	Erdoğu 2014	Uğurlu IV–V
Knossos	EN–MN	Rectangular houses	Hand-shaped mudbricks, wattle-and-daub, *pisé modelé* laid on stone (*tauf*).	Evans *et al.* 1964	Knossos IX–VII
Sesklo	5800–5200	Rectangular House 11–12	Mudbricks, *pisé* walls and posts, stone socle. Wattle-and-daub.	Elia 1982, 128–33, 169–74, 216–33; Souvatzi 2008; Theocharis 1968; 1973	Sesklo A
Makri	Mid 6th millennium BC	Round Houses, Complex area (storage unit), Rectangular building B in Delta1	Mudbricks and daub are found in the same post-framed house B in Delta 1, with a pitched roof in thatch; plaster floors.	Efstratiou *et al.* 1998, 25–7	Makri II
Dikili Tash	5300–4800		Wattle-and-daub, earth ceiling. Two variations of the post-framed technique (Koukouli-Chrysanthaki *et al.* 1996).	Koukouli-Chrysanthaki *et al.* 1996; Malamidou *et al.* 2018, 61–6; Martinez 2001; Prévost–Dermarkar 2019	
Dimini	EN–MN	Rectangular building	Wattle-and-daub, *tauf* (= *pisé*); mudbricks on a stone foundation.	Hourmouziadis 1979; Souvatzi 2008	
Elateia	EN–MN	Rectangular House in Trench 1 and Trench 3	Mudbricks and wattle-and-daub from the building in T1, external clay coating (mud), mud plaster. Mudbrick fragments in T3.	Weinberg 1962	
Nea Makri	MN–LN	Oval and Rectangular buildings	Mudbricks on stone socle, but also dwelling with wattle-and-daub. Mud mortar created with marlish soil.	Pantelidou-Gofa 1991	MN phase 2–8 LN phase 9–12
Servia	MN–LN	28 Rectangular/square buildings (19 MN; 9 LN)	Wattle-and-daub; clay floors.	Mould & Wardle 2000	Phase 1–7

eastern Mediterranean with long occupational histories. Most of the buildings considered are forms built above ground, while pit-dwellings also provide essential information. I have privileged the former due to the available archaeological record and informative reports describing earthen techniques (Bailey 2000, 263–5; Kloukinas 2017, 169; Kotsakis 2018, 36).

At first glance, the data collected from these 14 archaeological sites exhibit a heterogeneous picture characterized by synchronic and diachronic variability of techniques both within a single site and between sites; however, as discussed in further detail, clear patterns of skill transfer between techniques become evident when the data are compared.

Archaeological work carried out at coastal sites in western Anatolia has also brought to light more evidence of Neolithic earthen architectural practices (Biçakçi 2003; Ç. Çilingiroğlu 2005; Horejs 2019). Four techniques are documented at these five selected sites (Ilıpınar, Barcın Höyük, Menteşe, Hacilar and Ulucak): wattle-and-daub, *tauf*, mudbrick—both handmade and mould-made—and earthen ceilings as structural elements in rectangular buildings. The presence of mud mortar and mud plaster was not attested but inferred (A. Çilingiroğlu *et al.* 2004, 20–39; Gerritsen & Özbal 2019; Mellaart 1961; Özbal & Gerritsen 2019, 290–93; Roodenberg 1999, 24; Roodenberg & Alpaslan-Roodenberg 2008; Roodenberg & Thissen 1995; Thissen 2010).

While the north Aegean site of Uğurlu provides some detailed evidence of Neolithic occupation, few architectural remains have been documented, making the site of Knossos, the best-known Neolithic settlement in Crete, the best source of information on earthen architectural practices (Erdoğu 2014; Evans 1971; Evans *et al.* 1964). The analysis of materials from Knossos indicated the presence of three distinctive construction techniques that, although implemented diachronically, had significant temporal overlap: wattle-and-daub, mudbrick, and what is described as *pisé*.

In mainland Greece, much of the evidence regarding Neolithic construction comes from excavations in the northern and central part of the country (including Thrace and western, central and eastern Macedonia). More than 50 sites from this region have provided basic information on construction techniques and materials. The evidence shows the use of earthen building materials either on their own or in combination with wood (Kloukinas 2014; 2017; Reingruber 2005). In this region, we see a high variability of techniques, both synchronically and diachronically. The adoption of a specific technique and its implementation depended on a combination of factors, including available resources and social considerations. For instance, during the middle of the sixth millennium BC, Makri presents both wattle-and-daub and mudbrick constructions (Efstratiou *et al.* 1998), while a fortuitous conflagration event at Dikili Tash allowed excavators to recognize the presence of wattle-and-daub as the only technique implemented at the site during the same period (Koukouli-Chrysanthaki *et al.* 1996; Malamidou *et al.* 2018, 61–6; Martinez 2001; Prévost–Dermarkar 2019). Moving south towards central Greece, Dimini, Nea Makri and Sesklo are well-known Neolithic sites that provide evidence of mudbrick architecture on top of a stone socle. This is true at least in the later phase of the Neolithic, although earlier constructions indicate the extensive use of wattle-and-daub (Elia 1983; Hourmouziadis 1979; Pantelidou-Gofa 1991; Souvatzi 2008, 81; Theocharis 1968; 1973; Wijnen 1981; 1992). At other sites, such as Elateia, we have evidence for the synchronic use of wattle-and-daub and handmade mudbrick, while Servia indicates a consistent use of the wattle-and-daub practice from the Middle Neolithic to the Early Bronze Age (henceforth EBA) (Mould & Wardle 2000, 71–105; Weinberg 1962).

A review of earthen archaeological materials identified at these sites demonstrates the use of four main building techniques and structural elements in the Aegean: 1) wattle-and-daub; 2) mud-slab; 3) *pisé* or *tauf*; 4) mudbricks. Ancillary earthen techniques such as mud plaster, mud mortar and earthen floors are also attested.

Earthen *chaîne opératoire* in the eastern Mediterranean

Earth became a major signifier in Neolithic societies. Its transformation from an agricultural by-product to building material and finally to use in architecture occurred not only as a technological process, but as a socio-cultural practice through which people created meaning communicated through a non-verbal medium, such as kinaesthetic motor movements (Lévi-Strauss 1962; van Vuuren 2015). Recent ethnoarchaeological studies showed how repetitive actions stemming from the manufacture of earthen building materials result in a multi-sensory experience that conditions the mind and help to develop kinaesthetic motor skills and tactile sensibility (Jerome *et al.* 1999; Marchand 2011). Similar studies on ceramic production have emphasized the importance of non-declarative knowledge often expressed through motor skills and implicit learning (Abell 2020; Cutler 2019; Gosselain *et al.* 2009; Squire 2004; Warnier 2007).

Studies focusing on the behavioural chain help us consider the meticulous choices that people had to make (i.e. What type of sediment? What type of temper? How much? Should the soil be sieved? How long to mix? Are the mudbricks hand-moulded? How? Mould-formed? Are they regular?). An analysis of these choices guides us through the manufacturing process, providing evidence for identifying issues in implicit learning within the same community. Implicit learning or tacit knowledge is linked to motor skills, and the continuous repetition of kinaesthetic movements during manufacturing is reflected in the created material. Furthermore, eventual differences in the *chaîne opératoire* of contemporary materials are relevant for pinpointing the presence of multiple communities of practice within the same settlement.

The attestation of multiple earthen techniques in the Eastern Mediterranean indicates the presence of different steps in the *chaîne opératoire* linked to the creation of different architectural elements (i.e. daub, plaster and mudbrick), often requiring diverse kinaesthetic movements. An analysis of these different behavioural chains provides us with primary information to assess the presence of communities of practice (Abell 2020; Chazan 2009; Roux 2016; Skibo & Schiffer 2008; Walls 2016).

All the earthen methods documented and presented in the *chaîne opératoire* involved a direct, tactile manipulation of earth during the mixing process and/or during its application, highlighting the multi-sensorial facet of earth work (Catapoti & Relaki 2020; Herva *et al.* 2014, 36; Lévi-Strauss 1962). There are several overlaps in the manufacture of earthen building-material *chaîne opératoire*: 1) the collection of raw sources; 2) the transport of materials; 3) the preparation of the soil, in which the soil is made suitable for manufacturing by removing large inclusions such as branches and big stones that are detrimental to manipulation and manufacturing; 4) the addition of organic and/or inorganic temper as well as water; and 5) the tactile manipulation by hands or feet of the mud mixture over a span of a few hours or days, highly dependent on the materials to be produced (Fig. 2). In this latter step, the *chaîne opératoire* diverged depending on the technique:

a. Daub: the mud mixture was directly applied to a wattle skeleton (Mould & Wardle 2000; Pantelidou-Gofa 1991).
b. *Tauf* (or *pisé modelé*): the wall was shaped by hand-positioning a chunk of mud mixture still wet on top of a stone socle, foundation, or directly on the ground. This technique could also be used with wooden poles, creating a basic skeleton to be filled with mud (Gerritsen & Özbal 2019). This type of vertical structure could be created by an individual or a limited number of people (Kurapkat 2014, 73–4).
c. Mud plaster: it was smoothed on top of mudbrick and wooden walls, but also on the floor for protection (Weinberg 1962).
d. Mudbrick: the mud mixture was worked for a few days to increase plasticity and allowed the fibres to ferment. Then, it was moulded by hand to create loaf-shaped bricks or pressed into a wooden mould to manufacture size-standardized bricks (Mellaart 1961; Roodenberg & Alpaslan-Roodenberg 2008). The bricks were then sun-dried for multiple days or weeks depending on the climate. In addition, this technique usually required the participation of more than one individual, since a team of a minimum of three to four peoples was required to assist in the different steps of production, including: mud working, transporting the mud and moulding the bricks.
e. Earth ceiling: the mix presented a higher clay concentration and was spread on top of the ceiling structure to cover it and make it impermeable (Malamidou *et al.* 2018, 61–6; Prévost–Dermarkar 2019).
f. Mud mortar: a mix of clay and water with minimal organic matter was used as a binder between stones or bricks.

From a *chaîne opératoire* perspective, common steps include the selection of earth/soil, its excavation, the addition of human-induced tempering (i.e. vegetal temper, sand, shells) and the plastic manipulation of the mud mixture created with the addition of water. Usually, the location of earthen building-material manufacture depends on the typology. Plastic materials such as mortar and plaster are usually created in proximity to the structure, as they require immediate use. Mudbrick required not only space for the mud mixing carried out over multiple days, but once moulded, also needed an extensive area to dry (Devolder & Lorenzon 2019). Thus, their manufacture usually occurs outside the settlements and closer to the sources of raw material. The transport of raw material or finished building materials also varies between techniques.

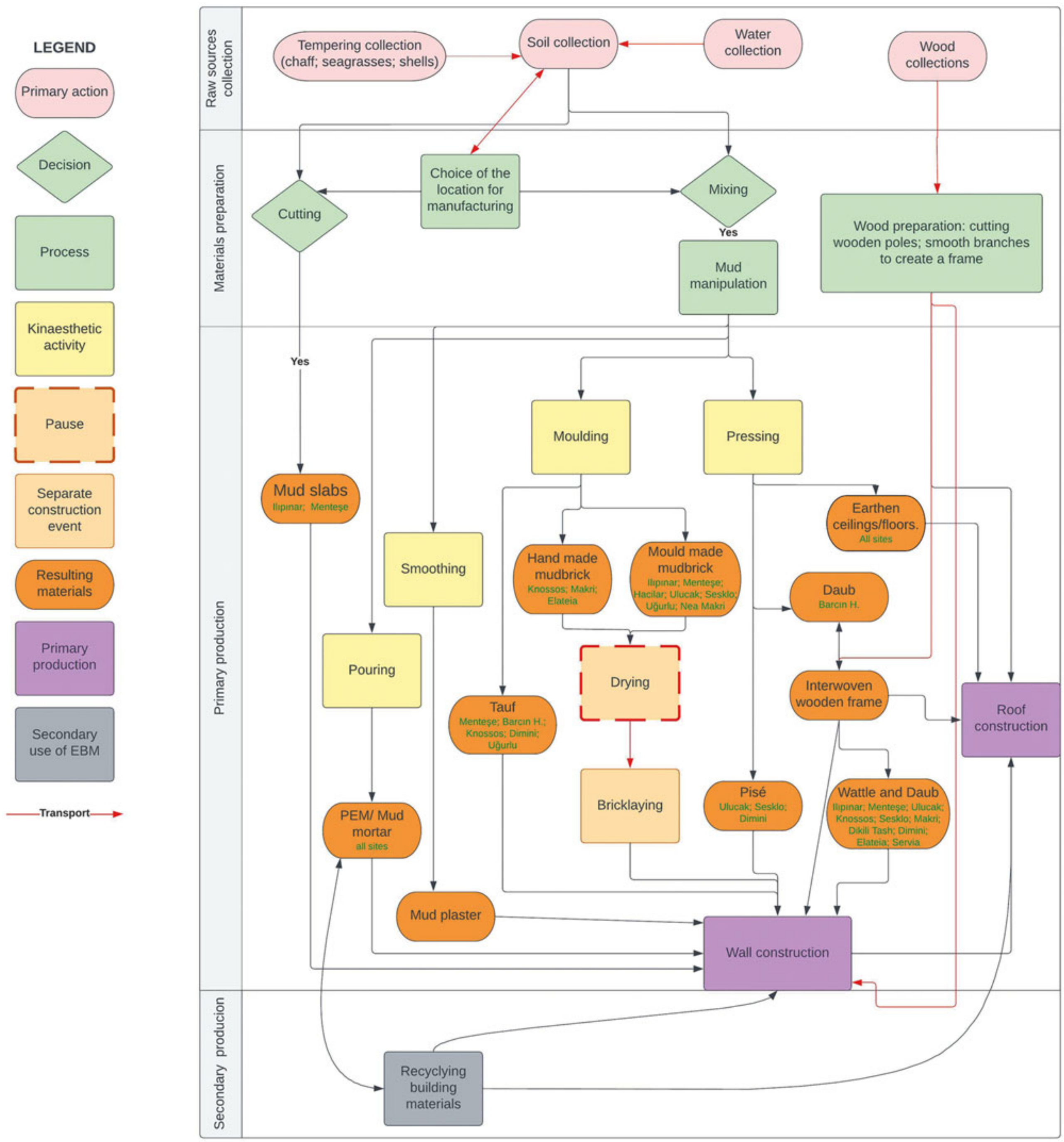

Figure 2. *Chart of earthen architecture* chaîne opératoire.

The use of agricultural by-products such as cereal chaff or straw is well evidenced in the Aegean Neolithic alongside other organic and inorganic tempering, such as dung, crushed shells and sand (Ç. Çilingiroğlu & Çakırlar 2013; Guest-Papamanouli 1978; Mould & Wardle 2000, 80; Prévost–Dermarkar 2019). Small changes in quantity and tempering determined the earthen building material to be produced; for instance, mud plaster required a higher quantity of vegetal temper than mudbrick, while *pisé* needed a smaller amount of organic material than either bricks or *tauf* (Doat *et al.* 1991; Minke 2000).

The distinctive kinaesthetic movements linked to the production of various earthen building materials bring about significant differences in the *chaîne opératoire*. Each earthen building material relates to individual motor skills and repetitive movements, which may indicate the change of specific know-how within a community in a diachronic analysis.

The problematic nature of mud-slab, a building material that was mostly used untreated causing continuous spalling and decay, may be the reason for the abandonment of this technique in the post-walled building of Ilıpınar X–VIII (Roodenberg & Alpaslan-Roodenberg 2008). Mudbricks seem to have appeared not only as a result of hand-moulded production, as recorded at Knossos and Hacilar (Evans *et al.* 1964; Mellaart 1961), but also as mould-made modular units at Ilıpınar VI–VA (Roodenberg & Alpaslan-Roodenberg 2008).

The overlapping of two techniques, *tauf* and *pisé*, in the description of archaeological walls remains a problem in the analysis of recorded data. In the *tauf* technique, the wall is shaped by hand-positioning a chunk of mud mixture still wet on top of a stone socle, a foundation, or directly on the ground. This technique can also be used with wooden poles, creating a basic skeleton to be filled with mud such as in the structures at Barcin Höyük and Knossos (Gerritsen & Özbal 2019). This type of wall elevation can be created by an individual or a small number of people (Kurapkat 2014, 73–4). On the other hand, *pisé* (i.e. *pisé moulé*), while often mentioned in the literature of the Aegean Neolithic, was not really an implemented technique. So far, studies do not provide any concrete evidence for the use of wooden formworks in this period. Consequently, a mention of *pisé* in archaeological reports often refers to *pisé modelé* (i.e. hand-shaped loam clods) and overlaps with the *tauf* technique (or 'cob' in the British vernacular tradition).

Pisé and *tauf* are differentiated by the amount and quality of vegetal temper as indicated by the analysis of the Knossian material (Fig. 3). At Knossos, the material initially described as *pisé* presents characteristics better associated with *tauf*, such as the presence of high amounts of vegetal temper, the use of long grasses and straw in the mix alongside chaff, and a small percentage of sand (Fig. 4).

The qualitative and quantitative prominence of earthen material production in the Neolithic highlights a communal effort to transform the surrounding natural environment. Earth becomes a crucial common resource that is deliberately sought, excavated and shaped to create a man-made product, shared by the whole community. But technological choices are also representative of 'social constraints'

Figure 3. Tauf *fragment from Neolithic Knossos (Middle Neolithic).*

and the agency of builders to pursue culturally significant building forms (Love 2013b, 751). Thus, the preference for one building technique over another is never only practical but may reveal the existence of practices that are meaningful to the social groups who were implementing them (Abell 2020; Knappett & van der Leeuw 2014).

A community of knowledge: Neolithic practices at Knossos

The relevant role of earth in Neolithic construction advances the hypothesis that earth work could also play a role in creating social identities. Thus, community members that have acquired a skill related to the manipulation of earth may also have acquired a distinct social status within their own communities (Fredriksen 2011; Love 2013a; Marchand 2011). The presence of more experienced builders in the Late and Final Neolithic Aegean is evidenced by the technological improvements in construction, such as a wider roof span, multiple storeys and standardization of mudbrick recipes and techniques (A. Çilingiroğlu *et al.* 2004, 30–33; Evans *et al.* 1964: 144–8; Nodarou *et al.* 2008; Roodenberg & Alpaslan-Roodenberg 2013). Knossos is a central case study in this research, as the site presents not only continuous levels of occupation but also a variety of earthen techniques implemented over time.

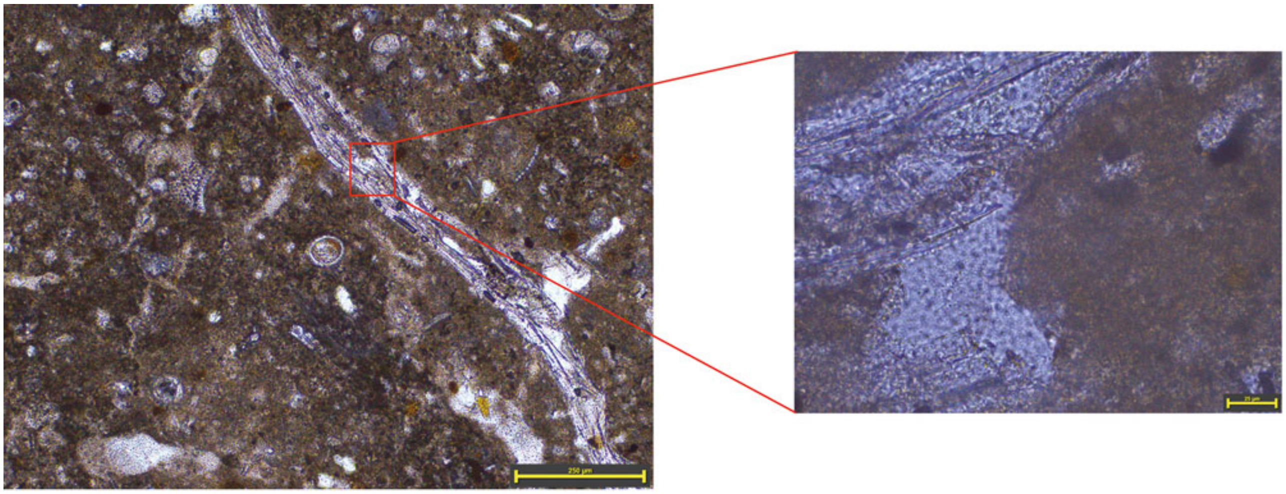

Figure 4. *Micrograph of Knossos* tauf *(Middle Neolithic) in which phytoliths associated with long grasses are visible within the silty matrix.*

Looking at the transformation of techniques between the Early Neolithic/Middle Neolithic and the introduction of new techniques in the Middle Neolithic/Final Neolithic at Knossos suggests a change from simple task-sharing activities between members of the same community to a knowledge-sharing endeavour, especially in the Late Neolithic period (Hole 2000, 205–6; Kurapkat 2014, 107–8; Love 2013a; Perlès & Vitelli 1999; for discussion on craft specialization, see Clark 1995; Costin 1991; Flad & Hruby 2007). The know-how of earthen techniques may have been part of a general communal knowledge—especially in relation to techniques such as mud-slab, *tauf* and mud mortar—acquired through observation, participation and constant connection to other earth-related activities such as agriculture and pottery production (Catapoti & Relaki 2020; Kurapkat 2014, 114–15). On the other hand, the expertise and effort required in more labour-intensive earthen techniques such as mud plaster, which requires numerous replastering events and maintenance, and standardized mudbrick production indicates: 1) the presence of multiple people engaged in these activities; 2) the commitment of societal resources from agricultural and husbandry by-products such as chaff and animal dung used for tempering; and 3) an increased knowledge-base for the selection of the soil and the collection of consistent quantities for manufacture (Aurenche 1981; Guest-Papamanoli 1978; Jerome *et al.* 1999; Kurapkat 2014, 114; Marchand 2011).

At Knossos, the analysis indicates a heterogeneous landscape in which we have different techniques that shared the initial steps of the *chaîne opératoire* but required different degrees of builder proficiency. They also present a splitting of the behavioural chain regarding earth manipulation. More importantly, these techniques do not follow one another in a deterministic fashion. For instance, wattle-and-daub (Initial Neolithic/Early Neolithic) overlapped with mudbrick architecture (Early Neolithic), followed by a phase of *tauf* construction (Middle Neolithic). Increased architectural sophistication is often the product of a slow learning process that is characterized by trial and error; thus, techniques may have overlapped for long periods while experimentation took place (Kurapkat 2014; Leroi-Gourhan 1964, 26–7; Love 2013b).

Considering the kinaesthetic movements, the *chaîne opératoire* points to a progressive development from a simple sod-cut to a more plastic working of the earth; from the creation to non-modular types of building materials (i.e. daub and *tauf*) to the manufacture of modular earthen materials (i.e. mudbricks). I agree with Kurapkat (2014, note 51) that often the lack of well-preserved remains or specificity in the twentieth-century excavation reports regarding mud or clay slabs makes it impossible to determine if in those cases we are discussing proto-mudbricks that received some kind of treatment or just mud slabs, directly cut from the earth and placed on top of a wall.

At Knossos, mudbricks made their appearance in the Initial Neolithic alongside other earthen techniques such as wattle-and-daub, and from Middle Neolithic *tauf* (recorded as *pisé*) (Evans 1971; 1994). Early Neolithic mudbricks showed evidence of circular polishing on the surface, probably carried out with a wet cloth or wet leaves after moulding and before the bricks were laid out to dry. This kinaesthetic movement can be associated with a smilar step in other earthen techniques. The repetitive circular polishing of freshly elevated surfaces is typical of mud plastering and wattle-and-daub. In a period in which both techniques were in use at Knossos, this movement seems to have been transferred between the two branches of the *chaîne opératoire*. This provides preliminary evidence of motor-skill transfer between different earthen techniques, suggesting the presence of communities of practice, or better perhaps, of communities of knowledge (Fig. 5).

A community of knowledge may actually be the more appropriate definition for a social group that shared knowledge of production but for which we cannot assess the level of craftmanship and specialization due to the limited nature of our archaeological materials. Evidence of skill transfer between mudbrick and daub techniques in the Early Neolithic can be proposed from the similarity of raw-source procurement and sediment preparation. This silty matrix with few, angular and very poorly sorted inclusions that characterized both earthen processes suggests the limited mixing of the mud and similar processing techniques (Fig. 6).

On the other hand, the diversity of vegetal temper used in the Middle Neolithic *tauf* seems to indicate a technological development in the knowledge of earthen building materials. The use of long bendable grasses is only featured in this technique, emphasizing a more marked separation between different earthen *chaînes opératoires* in this period.

When mudbricks reappeared at Knossos during the Final Neolithic/Subneolithic and Early Bronze Age, they did not present the same semi-circular striations, indicating that over time this step of the *chaîne opératoire* was progressively abandoned. Was it abandoned because it was not functional for mudbrick manufacture? Or because of the increased standardization of mudbrick architecture in the

Figure 5. *Knossos mudbrick, House E, Areas AC, Stratum IX, evidencing possible kinaesthetic movements.*

Final Neolithic/Early Bronze Age? The lack of extensive materials from multiple contexts does not permit the formulation of a more precise answer. We can, however, debate whether the introduction of additional steps (i.e. mould-moulding in EBA) in the manufacture of modular units and the long-term communal effort required incentivized a progressive standardization in production. The presence of a passive step in the mudbrick *chaîne opératoire*, the drying phase, took at least a couple of weeks. Aside from turning the drying mudbricks, this step does not require the active participation of the mudbrick maker. It is possible that this created a separation of the two key phases of mudbrick production: manufacture and construction. As the two phases

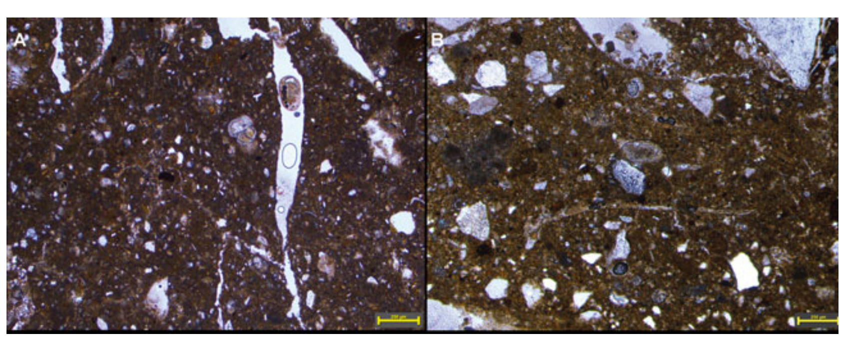

Figure 6. *Thin section of (A) mudbrick and (B) daub (plain polarized light) in which are visible the similar matrix with microfossils and limited inclusions such as rounded clay-rich granules.*

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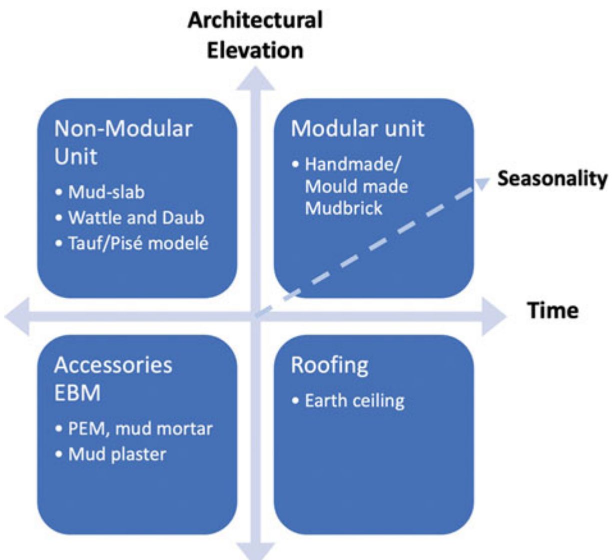

Figure 7. *Graph of modular units and time.*

could only occur at a temporal distance, they might not always have been conducted by the same people (Kurapkat 2014, 85).

The temporal element is often missing in the reconstruction of the *chaîne opératoire* for earthen building materials. The sourcing of these materials and their production may occur at different times throughout the year, still creating perfectly functional materials. For mudbrick manufacturing, this was not always the case, since the need for mudbrick to dry before construction introduced an important step that is quantifiable. For example, chaff, the main vegetal temper used, was collected after threshing and mudbrick needed a moderately dry/warm season to dry properly (Devolder & Lorenzon 2019). Temporality and seasonality are therefore two other variables that we can introduce into our analysis of the *chaîne opératoire*. Thus, when considering differences between non-modular building materials and modular units, it also becomes necessary in addition to account for the length of the manufacturing and construction processes, and their seasonality (Fig. 7).

Concluding reflections

Cognitive anthropology has explored the creation and development of communities of practice in architecture as moving beyond language-cognitive skills, but operating through motor cognition, in which the mode of learning is based on kinaesthetic representation and simulations (Cutler 2019; Marchand 2007, 193–95; Minar & Crown 2001, 375). Ethnographic studies that focus on earthen architecture have analysed the structuration of social relations during the learning process, and shown the primary importance, in the learning process, of the relationship established between an apprentice and a master; a skilled labourer and top-down relations are the backbone of this type of learning process (Fodde 2009; Jerome *et al.* 1999; Marchand 2011). At the same time, there is evidence for the establishment of horizontal connections between different communities of practice, for instance between skilled and semi-skilled labourers who share their knowledge of earthen architecture among themselves, specifically when a skilled workman is not present within the community (Fodde 2009, 152–3; Lorenzon & Sadozaï 2018).

While the limited material preserved provides preliminary evidence for the presence of communities of practices in the eastern Mediterranean from the Middle Neolithic onward, the data demonstrate a general synchronic consistency of earthen practices within each site. The heterogeneous nature of techniques among different sites supports the hypothesis that knowledge and practice were shared within Neolithic communities through the creation of a social learning context in which members of the same community participated (Minar & Crown 2001, 372; Rogoff 1990; 1995; Wendrich 2012a, 11–16). While we cannot always assess the characteristics, organization, or nature of these communities of practice, we nevertheless recognize their presence.

We may then define these as ‘communities of knowledge’, a shared know-how based on motor skills and tacit learning such as choice of raw sources over time. If the motor skills were not efficient, they were abandoned, as in the case of Knossos. For instance, the variability in wattle-and-daub techniques between Neolithic sites exemplified by diverse daub composition, fibres used and wall thickness indicates diverse manufacturing and construction traditions that reflect the variety of knowledge present in each community, which was shaped by unique environmental and social contexts (Mould & Wardle 2000; Pantelidou-Gofa 1991). Conversely, at Ilıpınar and Makri, the coexistence of different earthen architectural techniques within a single building can be linked to the presence of more than one community of knowledge within each site.

The creation of a communities of knowledge is also visible in the endurance of specific earthen techniques within the same site (i.e. Dikili Tash; Servia), proving that knowledge and expertise were being shared between members of the community over time (Koukouli-Chrysanthaki *et al.* 1996; Malamidou *et al.* 2018, 61–6; Martinez 2001; Mould & Wardle 2000; Prévost–Dermarkar 2019).

Earthen building-material manufacture is intrinsically linked to kinaesthetic movements. The repetition of specific motor activities learned over time leaves traces on these materials. Through comparisons, these traces can help us determine the characteristics of each community of knowledge. At Knossos, for instance, the few surviving mudbrick examples retained evidence of wet-polishing after hand-moulding. This is associated with a specific kind of know-how in the Early Neolithic earthen building process. Already in the Middle Neolithic the differentiation in the choice of vegetal temper indicates a clear separation between different techniques. This separation might also demonstrate the diminishing of the household-based organization of labour in favour of a community-based architectural production. Engaging in communities of knowledge—the predecessor of communities of practice—redefines earthen building production both diachronically and synchronically. Diachronically, it enables us to study skill transfer between generations; synchronically it allows us to compare production techniques between members of the same community (Abell 2020; Lave & Wenger 1991).

To grasp fully the socio-cultural impact of architecture on the building practices of past communities, investigations should consider more precisely the modalities of learning processes, their technological and social aspects and their diachronic transformation. While diverse earthen architectural practices may be the result of environmental conditions, each Neolithic community created and sustained local traditions that were clearly meaningful to them. For a more holistic understanding, I argue we need to go beyond ecological determinism and reflect upon the *Sitz im Leben* of these practices in order to make inferences about the economic, socio-cultural importance of buildings and building materials in this period.

Note

1. Plastic earthen material = PEM (see Devolder & Lorenzon 2019).

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