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ORIGINAL ARTICLE

The Urban Biography of a Mauritanian City: Microstratigraphic Analysis of the Eastern Quarter of Tamuda (Morocco)

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Abstract The lack of vertical stratigraphic sondages and open area excavations constitutes a challenge to understanding Mauritanian urbanism. This makes the characterization of the spatio-temporal evolution of Mauritanian towns a difficult task. Systematic excavations carried out in Tamuda by several research teams in the twentieth century provided vertical and horizontal views of Mauritanian urbanism. Our study offers, for the first time, a high-resolution geoarchaeological analysis of Tamuda's urban sequence (third through first century BC). The microfacies analysis, by means of micromorphology and µ-XRF of Spaces E18 and E20 of the Eastern Quarter revealed a complex interaction of deposits and site formation processes that resulted from changes in everyday urban life. In this respect, the overlap of different construction phases and the alternation of episodes of active use and abandonment is highly significant. This study examines the functional characterization of urban spaces, including the identification of midden activities, a roasting pit, and a milling site (possibly) linked to fish flour production. These activities leave traces on beaten floors and occupation surfaces, and several features indicate abandonment periods between short-term occupations. The result is a complex urban biography of this Mauritanian town, in which human occupation was not constant over time.

Résumé Un problème pour comprendre l'urbanisme mauritanien est le manque de sondages stratigraphiques verticaux et de fouilles à ciel ouvert, ce qui rend difficile la caractérisation de l'évolution spatio-temporelle des villes. Des fouilles systématiques menées à Tamuda par plusieurs équipes de recherche au 20ᵉ siè-

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cle ont fourni des vues verticales et horizontales de l'urbanisme mauritanien. Notre étude fournit, pour la première fois, une analyse géoarchéologique à haute résolution d'une séquence urbaine de Tamuda (3e s. av. J.-C.—1er s. av. J.-C.). L'analyse des microfacies au moyen de la micromorphologie et de la µ-XRF des espaces E18 et E20 du Quartier Est a révélé une interaction complexe des dépôts et des processus de formation du site résultant des changements de la vie urbaine quotidienne. À cet égard, l'imbrication de différentes phases de construction et l'alternance d'épisodes d'utilisation active et d'abandon sont très significatifs. Cette étude a approfondi la caractérisation fonctionnelle des espaces urbains, y compris l'identification d'activités de dépotoir, d'une fosse de torréfaction et de sous-produits de meunerie (éventuellement) liés à la production de farine de poisson. Ces activités ont laissé des traces sur les sols battus et les surfaces d'occupation, dont la technologie et la composition ont également été explorées. De plus, plusieurs vestiges archéologiques indiquent des périodes d'abandon entre les occupations de courte durée. Le résultat est une biographie urbaine complexe de cette ville mauritanienne, dans laquelle l'occupation humaine n'a pas été constante dans le temps.

Keywords Mauritanian towns · Microstratigraphy · Urban biography · Micromorphology · µ-XRF

Introduction: Stratigraphic Approaches to Mauritanian Urbanism

The origins of urbanism in northern Morocco have traditionally been associated with the influences of the Phoenician and Punic colonizations in the western Mediterranean. Traditional interpretations, mostly based on literary sources, held that urbanism began in this region in association with Phoenician foundations (Carcopino, 1949; Chifman, 1963; Cintas, 1954; Gsell, 1927; Jodin, 1966; López Pardo, 2002, 2015a, 2015b; Ponsich, 1967, 1969, 1970, 1981; Souville, 1995; Tarradell, 1954, 1960). Decades of historiographic debate and archaeological research have shown the complexity of the Hellenization phenomenon on the littoral and hinterland of the Mediterranean and Atlantic coasts of present-day Morocco. In the last five decades, there has been growing evidence suggesting that while there were colonies and trading posts, it is equally true that most of the sites were indigenous settlements where contacts and trade were carried out with Greeks, Phoenicians, and Carthaginians who were eventually physically integrated into those settlements (Bokbot, 2020; Bokbot & Onrubia-Pintado, 1995; Camps, 1979; Février, 1967; Marzoli & El-Khayari, 2010). Thus, the birth of urbanism in Morocco appears not to have been just the result of colonizing populations, or at least the role they played was not as important as traditionally assumed (Euzennat, 1965; Villard, 1960). Throughout this article, we will use the term "Mauritanian" to refer to the pre-Roman period in present-day Morocco.

There is extensive archaeological evidence that population centers in the form of agglomerations were founded between the end of the sixth and fifth century BC at several Mauritanian sites (for syntheses, see Akerraz et al., 2012; Bridoux, 2008a). These urban sites (Fig. 1A) are distributed along the Mediterranean littoral (Russadir, Emsa, Sidi Abdeslam del Behar, Kitane, Tamuda, Septem, Ksar Sghir, and Tingi), on the Atlantic coast (Zilil, Kouass, Lixus, Thamusida, Sala, and Khédis) and in the hinterland (Banasa, Rirha, and Volubilis). All the sites, except Volubilis, are located near the coast or on alluvial plains in the hinterland near a navigable river course. The preferred locations were plateaus and hills overlooking these watercourses, which acted as communication hubs with immediate access to agricultural land but, at the same time, remained unprotected from seasonal flooding. These sites underwent major urban transformations between the fifth century BC and 42 AD when powerful confederations and kingdoms were established (Bridoux, 2020). Thus, Mauritanian towns show urban features, such as Hellenistic-inspired architecture with orthogonal urban layouts (Aranegui Gascó, 2001; Aranegui Gascó & Hassini, 2010; Arharbi & Lenoir, 2006; Bokbot, 2020; Bridoux, 2008; Callegarin et al., 2016a; Callegarin et al., 2016b; Pascual & de Madaria, 2001), public spaces (Díaz y Moreno Pulido, 2021), local magistracies (Bridoux, 2020), mints (Callegarin & El Harrif, 2000) and amphora production for maritime trade (Bernal Casasola et al., 2019). These and many other indicators depict a situation in which towns were the centers of the constantly changing micro- and macro-political life, local economies, and commercial and cultural interactions (Bridoux, 2008b; Callegarin, 2005, 2008; Hassini, 2001).

However, our knowledge of urban evolution during the Mauritanian period is still limited (Bridoux,

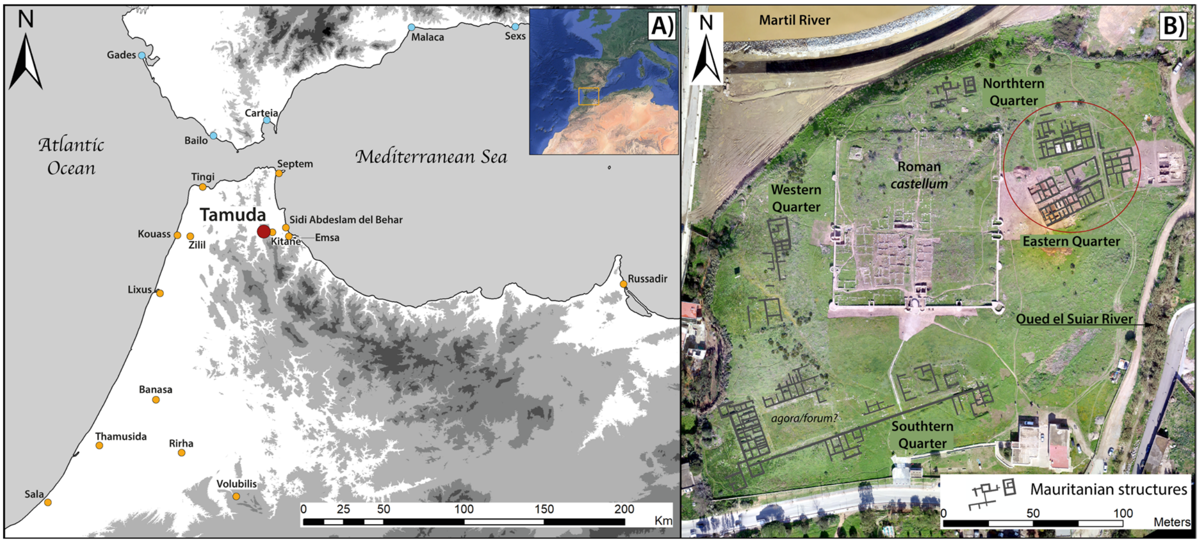

Fig. 1 Location of Tamuda (**A**) in the context of the Strait of Gibraltar (300 BC–100 AD), and the Eastern Quarter within the urban layout (**B**)

2008a, 2020). In this sense, excavations at urban archaeological sites are spatially restricted and, in most cases, relegated to small stratigraphic sondages that do not offer an overview of the site's diachronic evolution or its spatial organization. Most of them—including Lixus, Thamusida, Volubilis, and Rirha—present evidence of Roman and medieval occupations. Other sites, including Septem, Russadir, and Tingi, even show a continuous occupation up to the present day. The situation is exacerbated by the fact that some towns and regions of the former Mauritanian territory have been archaeologically investigated more than others (Bridoux, 2008a). Because of this, although there are different proposals regarding the chronological evolution of the Mauritanian period based on excavations, material culture, and historical data, there is no consensus in the archaeological community about its periodization (Akerraz et al., 2012). Part of the problem lies in assessing the role of the interactions and influences of the Phoenician and Punic colonies—especially Gadir—in the region and in the challenges deriving from the chronological phases that suggest and simplify cultural assimilation (e.g., "Phoenician" between the eighth and fifth century BC, and "Punic" between the fifth and third century BC). We do not know the social and ethnic composition of these urban sites or the significance of the Phoenician and Punic presence in them (Rebuffat, 2001), and this simplified periodization underestimates the indigenous factor in the urbanization process.

Based on the current state of research into Mauritanian urbanism, the reality is that most of the urban sites do not have a complete stratigraphic sequence covering all the phases of the Mauritanian period (Callegarin et al., 2016a, 2016b, p. 9–10). This especially affects the earlier occupation phases of these sites. In this respect, it is common at sites such as Rirha, Sidi Ali Ben Ahmed (Thamusida), and Tamuda to date archaeological finds to 700–500 BC based on surveys (Akerraz et al., 2009; Bernal Casasola et al., 2012; Bernal Casasola & Raissouni, 2013; Ichkhakh et al., 2016). However, the chronological phases of their occupation are still unknown, even though vertical sondages from the topsoil to the bedrock have been carried out at some of these sites. It is, therefore, imperative to identify the stratigraphic phases of these sites, as has been done elsewhere, such as Lixus (Aranegui Gascó, 2001, 2005; Aranegui Gascó & Hassini, 2010) and Sidi Ali Bou Jenoun, aka Banasa (Arharbi & Lenoir, 2016).

It becomes even more difficult to understand urban evolution from a stratigraphic perspective considering the geomorphological dynamics of these sites. Many of the aforementioned urban sites are situated in alluvial environments and have become permanent or semi-permanent wetlands (*merjas*). These include Rirha, Banasa, Lixus, Thamusida, Kitane, Sidi Abdeslam del Behar, and Tamuda on the Gharb and Martil plains, where erosion, seasonal flooding events, and mass movement of sediment are frequent (Aranegui Gascó, 2001, 2005; Aranegui Gascó & Hassini, 2010; Callegarin et al., 2016b; Cyril et al., 2018; Desruelles, 2018; Desruelles et al., 2012). These urban sites are located on small plateaus and hills overlooking rivers, where they benefited from the suitability of the adjacent land for crop growing, animal husbandry, and access to water resources. However, the human–environment relationship was often difficult. In this respect, natural sedimentation is sometimes found intercalated between occupation deposits in urban sites, such as Banasa (Arharbi & Lenoir, 2006, 2011; Cyril et al., 2018; Desruelles et al., 2012). It has been estimated that the inundation areas on these floodplains were even more extensive in the Mauritanian and Roman periods than today (Cyril et al., 2018). In other cases, geomorphological conditions affect the state of preservation of the urban sites. On the alluvial plains of the Rivers Sebou and Khoumane, the Mauritanian and Roman archaeological structures were sealed by overflow deposits and are currently being eroded by the undermining of the wadi banks due to the lateral migration of the meanders (Cyril et al., 2018).

Finally, other difficulties are related to the nature of the archaeological record within these urban sites. The technical systems used by the indigenous populations for the construction of buildings also influence the excavation process and interpretation of the archaeological record. Thanks to the situation of the urban sites and the settlement pattern previously described, clayey and silty alluvial deposits were easily accessible and widely used in the manufacture of earth-based construction materials, such as mudbricks and rammed earth, during the Mauritanian period (Cammas, 2018; Cammas & Roux, 2015; Roux & Cammas, 2016a, 2016b). This tradition survives in the region today. Thus, typical walls at these sites present sandstone or limestone foundations and rammed earth or mudbrick elevations. Because of this, differential erosion is particularly marked between the rammed earth or mudbrick structure and the stone foundations.

Furthermore, earth-based construction materials have mineralogical compositions similar to those of occupation and abandonment deposits. This means it is sometimes difficult to differentiate the walls during excavation, except in destruction and conflagration contexts where buildings were altered by fire (Arharbi & Lenoir, 2004, 2006, 2011, 2016; Callegarin et al., 2016a, 2016b; Girard, 1984). These construction techniques, although they are particularly noteworthy in the case of the Gharb Plain, are widespread in all the Mauritanian urban sites (Bernal-Casasola et al., 2020a; Bridoux, 2008a; Cammas, 2015, 2018). Another challenge in understanding the nature of the archaeological record is the effect of fire on site destruction and preservation and the traumatic experience of the past urban communities. The conflagration contexts with good preservation of the archaeological record reveal impressive pottery assemblages. These have been found at several sites in the Mauritanian territory, including Banasa (Arharbi & Lenoir, 2004, 2006, 2011, 2016; Girard, 1984). However, due to the limited extension of the sondages, it is difficult or even impossible to evaluate the extent and significance of such deposits. The same can be said of abandonment facies. They have been systematically identified at Mauritanian urban sites, sometimes associated with natural sedimentation processes such as flooding. However, we do not know if these abandonment, inundation, or traumatic destruction facies can be extrapolated to the whole site or among the different sites (Arharbi & Lenoir, 2011; Bernal Casasola et al., 2018; Bernal-Casasola et al., 2021c; Desruelles et al., 2012; Girard, 1981; Khayari et al., 2011).

Considering the aforementioned limitations, it is difficult to make stratigraphic and chronological comparisons between Mauritanian sites. Where similarities are described, they are usually based on the analysis of the material culture, especially pottery, as a chronological, technological, economic, or cultural indicator. However, in the last two decades, there has been a significant methodological advance from geoarchaeology regarding the characterization of site formation at urban sites, with special emphasis on the identification of floors, transit surfaces, and their associated occupation deposits, with the aim of identifying the uses of spaces and their diachronic evolution (Gé et al., 1993; Karkanas & Van de Moortel, 2014; Karkanas & Efstratiou, 2009; Matthews, 1995; Matthews et al., 1994, 1996, 1997; Shahack-Gross et al., 2005). In terms of occupation deposits, this geoarchaeological approach allows the identification of specific human activities, space maintenance practices, and discard processes (Goldberg, 1980; Karkanas & Efstratiou, 2009; Macphail et al., 2007a, 2007b; Milek, 2005; Milek & French, 2007; Sveinbjarnardóttir et al., 2007). Such a high-resolution microstratigraphic perspective is possible thanks to several methods and techniques. These include soil micromorphology, one of the most informative since it provides significant contextual information on the microscale (Courty et al., 1989; Goldberg & Berna, 2010; Karkanas & Goldberg, 2019). Micromorphology, in association with urban, chronological, and material culture studies, offers a precise reconstruction of the depositional and postdepositional environments that ultimately provide us with significant data on human behavior and social practices (Macphail & Goldberg, 2006; Karkanas & Goldberg, 2019; Gutiérrez-Rodríguez et al., 2019, 2020). Although micromorphology has already been applied in Mauritanian urban contexts, the focus of those studies was the characterization of earth-based construction materials such as mudbricks (Cammas, 2018; Cammas & Roux, 2015; Roux & Cammas, 2016a, 2016b). However, we believe that applying micromorphology from a microstratigraphic and site formation perspective, identifying the complex interaction of urban transformation processes, will provide significant data on the stratigraphic sequence and human behavior. This will ultimately provide new clues for making inferences about Mauritanian urbanism.

This study aims to carry out a stratigraphic and chronological analysis of a Mauritanian urban archaeological site in terms of site formation processes. To achieve this goal, we have applied microstratigraphic analytical techniques, such as archaeological soil, sediment micromorphology, and μ-XRF. Our case study is the archaeological site of Tamuda (Tétouan) (Fig. 1B), where, for the last 11 years, a research project has focused on the Mauritanian phases of the site. Entitled the "Economy and Craft in Tamuda" (*Economía y Artesanado en Tamuda* [EAT]) project, it is being undertaken by the Universidad de Cádiz and the Direction du Patrimoine of the Kingdom of Morocco. The excavations have provided a spatial and diachronic view of the Eastern Quarter (Fig. 1B), an area devoted to artisanal practices with a sequence dated between the late third century BC and 70–80 BC. In this article, we present the stratigraphic evolution of this sector of the Mauritanian town, highlighting its microstratigraphic dimension and how significant information about its evolution is contained in the microscale. Our specific objectives are to define the different occupational phases and their associated floors and relate them to the architectural phases identified in the field. We also focus on the technology and maintenance of floors and their associated occupation deposits, explore the different human activities and uses carried out within a building, and identify the diachronic changes and evolution of the deposits. We also attempt to characterize other kinds of occupational deposits, such as trampled accumulations and occupation surfaces. Finally, we aim to explore the complex superposition of these occupation levels and their abandonment and natural sedimentation deposits. Based on the foregoing, we propose an urban biography for the Eastern Quarter of Tamuda.

Excavations in the Eastern Quarter of Tamuda: The Economic, Craft, and Urban Evolution of a Mauritanian Town

The archaeological site of Tamuda is near Tétouan in the Martil River basin, which is part of the Rif Mountain Range. The regional geology (Fig. 2A) is very complex as large morphostructural units that can be divided into different domains converge here. They are the External Zone (consisting of Upper Cretaceous marls, Palaeocene white marls and limestones, and some Eocene flyschoid outcrops), the Internal Zone (including the Sebtid and Gomarid lithotectonic complexes, as well as the Dorsal units), Flysch units (quartz sandstones, schists, marl, etc.), and Neogene-Quaternary basins such as the Martil River, where Tamuda is located (Asebriy & Tejeda de León, 2003; Chalouan et al., 2008; Piqué, 1994; Sanz de Galdeano, 1997). The archaeological site is on a raised terrace above the river (Fig. 2B). Alluvial quaternary materials and geomorphological units of alluvial plains and small plateaus predominate in the surroundings of the site. This alluvial plain ends in a landscape of permanent marshes at the mouth of the river in the vicinity of Sidi Abdeslam. The Martil's terraces are made up of various geological materials (sands, gravels, pebbles, and conglomerates), and their

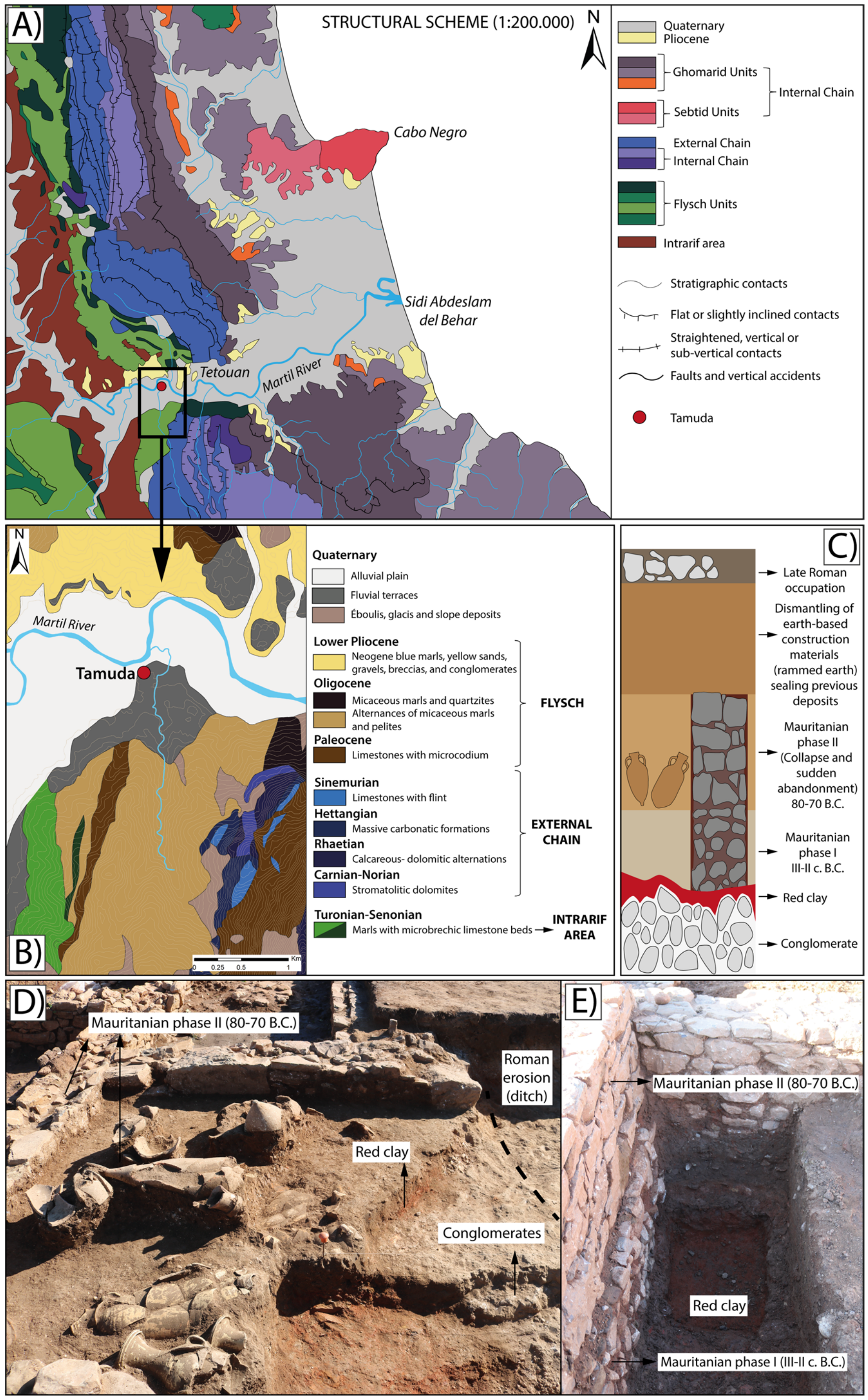

Fig. 2 Geological context of Tamuda: (**A**) structural scheme of the Tétouan region; (**B**) lithological map of the surroundings of Tamuda; (**C**) stratigraphic scheme of the geological base and human occupations in the Eastern Quarter of Tamuda; and (**D-E**) stratigraphic relations between the human occupations and the geological base

origin dates back to the end of the Pliocene (Gómez & Martín-Vivaldi, 2010). Quaternary deposits developed on these materials and are mainly composed of clays that give rise to impermeable soils. The archaeological site is built on these materials (Fig. 2C), as verified in stratigraphic sondages. In them, there is a thick basal level of cemented conglomerates with heterometric limestone clasts on which red clays have developed due to limestone dissolution. It is on top of these clays that the first archaeological strata are found (Fig. 2D, E).

The Martil Basin is highly exposed to the risk of flooding. The historical climatic series in this region shows seasonal and torrential floods that are still a source of risk for the local population. The considerable irregularity of the basin's hydrological regimes, the nature of the soil cover—often composed of impermeable clays—and the disparity between a mountainous relief upstream and a vast floodplain downstream explain the generation of runoff in the form of torrential and violent floods (Karrouchi et al., 2016).

Tamuda (Fig. 1B) is one of the most important pre-Islamic archaeological sites in Northwest Africa (today, Morocco). According to archaeological materials found in surveys, Tamuda originates in the sixth and fifth centuries BC, but this phase is still poorly known archaeologically. The earliest occupation facies are dated to the third and second centuries BC. During this period, Tamuda was characterized by orthogonal urbanism with clear Hellenistic influences in which several public and private buildings were separated by streets. Among its structures, a large *forum* or *agora* stands out (Tarradell, 1960). The town experienced a sudden abandonment process in 80–70 BC, and the site became abandoned for decades (Bernal Casasola et al., 2012; Bernal Casasola et al., 2018; Tarradell, 1960). A small military camp or *castellum* was built on the ruins of the former Mauritanian town under Claudius. It covers 1 ha and was the northernmost of the entire *Mauretania Tingitana* (Lenoir, 2011; Villaverde Vega, 2001). Its structures were abandoned in the fifth century AD during the mandate of Emperor Honorius but are exceptionally well preserved. The military camp has been the subject of recent archaeo-architectural studies (Bermejo & Campos Carrasco, 2015). During the last decade, it has been possible to specify the various phases of activity of the site, which had an active settlement for about 700 years (Bernal Casasola et al., 2012).

Since 2010, the Moroccan-Spanish EAT (Economy and Craft in Tamuda) project has focused its attention on the study of the *chaînes opératoires* of various craft activities, ranging from pottery to cereal grinding (Bernal-Casasola et al., 2020a). It has also looked at the palaeoenvironment and primary production, including local/regional amphora production (Bernal Casasola et al., 2019). In the case of the Mauritanian town, research has focused on the Eastern Quarter (Fig. 3), a large area excavated by M. Tarradell in the 1950s that had remained unpublished until the recent publication of the handwritten notes from Tarradell's archive (Bernal-Casasola et al., 2021a, 2021b). Various excavation campaigns have been carried out on the so-called Oriental Buildings 7 (EO7) and 8 (EO8), located close to the eastern gate of the Roman military camp. These large buildings are organized in elongated *insulae* (blocks) separated by streets. They suffered a traumatic abandonment in the early first century BC, perhaps when Sertorius came to help the Mauritanian kings in the late 80s BC (Bernal Casasola et al., 2018). A re-study of the earlier excavations and the new stratigraphic sondages of the EAT project has verified that the town was subjected to an intentional sudden abandonment, at least in this entire sector of 2 ha. This is confirmed by the finds of many personal belongings and objects used for grinding and storage, especially amphorae, in several rooms (Fig. 4). The amphorae were found in primary positions below the ceilings and on the occupation floors. There is also evidence that these structures were intentionally demolished (Bernal-Casasola et al., 2020b). This was one of the various episodes of destruction that the Mauritanian town suffered throughout its history and continued during the Roman occupation, as evidenced by various inscriptions and destruction levels with signs of conflagration. These archaeological contexts constitute an exceptional arena for studying construction techniques, material culture and many other aspects of Mauritanian society, given that the structures and finds are exceptionally well preserved.

For this study, we have focused on the geoarchaeological analysis of the complete stratigraphic sequence obtained in Room E-18 and some of the deposits from Room E-20. Room E-18 presented a complex stratigraphic sequence resulting from changes in everyday urban life, especially the overlap of different constructions and alternating episodes of active use and abandonment (Fig. 5). From bottom to top, the sequence begins with the stratigraphic units (henceforth SU) 2824, 2822, and 2820. They are clast-supported deposits composed of beds of rounded gravels in a red clay sedimentary matrix (SU 2824 and 2820) and a red clayey layer (SU 2822) that corresponds to the geological substrate of the site. These are followed by the earliest

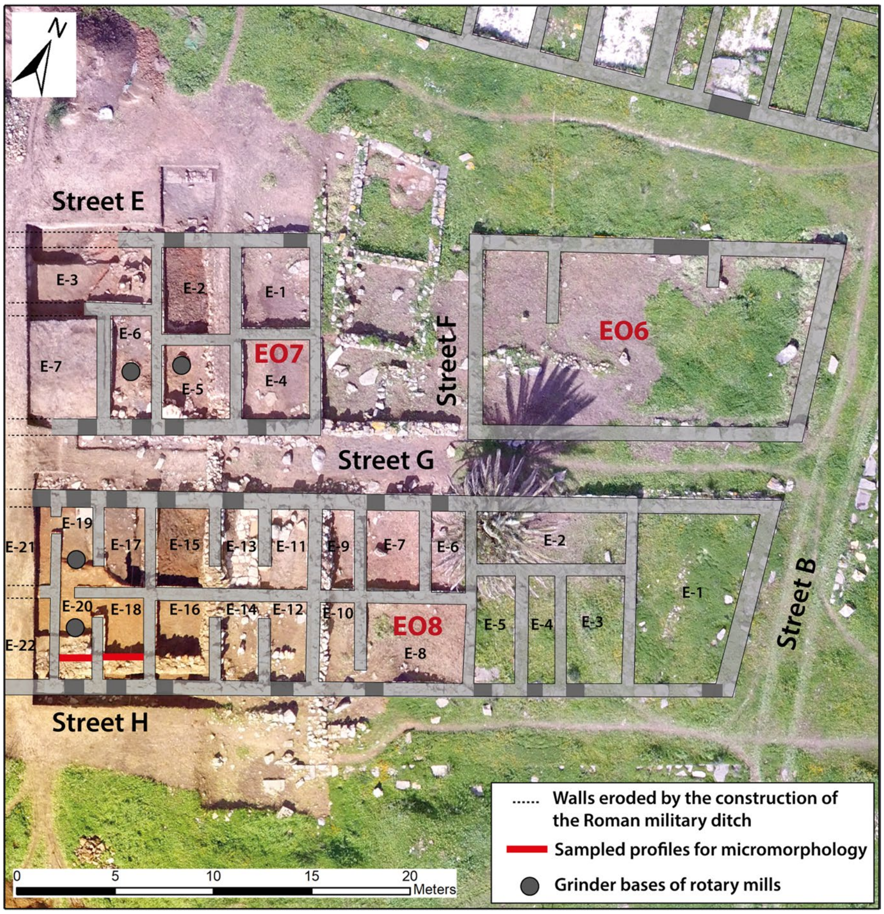

Fig. 3 Aerial view of Buildings EO6, EO7, and EO8 in the Eastern Quarter of Tamuda indicating the profiles sampled for micromorphology

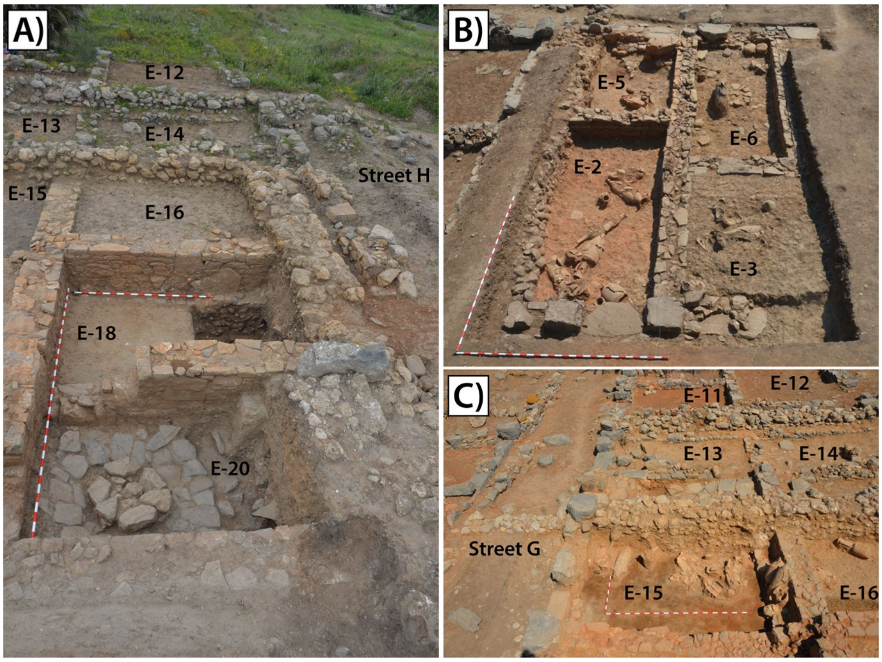

Fig. 4 Excavated units in Buildings EO7 and EO8 in the Eastern Quarter of Tamuda

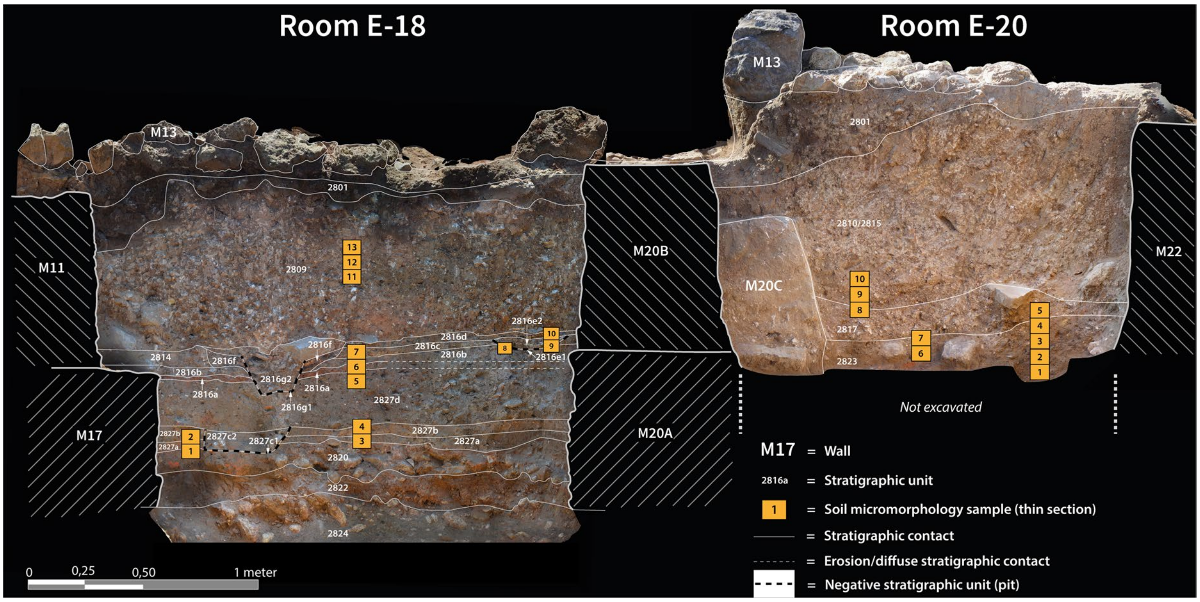

Fig. 5 Stratigraphic sequence of Rooms E-18 and E-20 (Eastern Quarter of Tamuda) indicating the provenance of the soil micromorphology samples

occupation deposits documented in the excavation area, SU 2827a and 2827b, which are brownish and yellowish clay beds with clay aggregates from earth-based building materials. These deposits, stratigraphically associated with Walls M17 and M20A, are sealed by Pit SU 2827c, and SU 287d, a clayey layer with abundant anthropogenic materials filling the space. All these deposits define Mauritanian Phase I and are dated to the third and second centuries BC. A selection of finds from one of the strata (SU 2816a) belonging to this construction and occupation phase (SU 2820, 2822, 2824, 2827) clearly illustrates that we can date this phase to the second century BC or, at the earliest, the final years of the third century BC. This date is obtained from the presence of Roman black-glazed ware-Campanian A (Fig. 6: 1) together with an amphorae assemblage characteristic of that period: Ramon T-12.1.1.1/2 of possible Bay of Málaga production (Fig. 6: 1), a T-8.2.1.1 Punic-Gaditan amphora (Fig. 7: 2), and Mauritanian amphorae typologically related to late Greek-Italic or Dr. 1A forms (Fig. 6: 3–5). Type T-9.1.1.1 Punic-Gaditan amphorae are also common in these strata. The rest of the material culture fits perfectly with the second century BC. This includes the fusiform unguentaria (Fig. 6: 2), an abundant number of pottery painted with horizontal red bands (Fig. 6: 3–9); wheel-thrown common ware of different types (Fig. 6: 10–11); and mortars with an internal groove and an over-fired external base that were possibly made locally in Tamuda (Fig. 6: 12–13).

Above Mauritanian Phase I is a new occupation phase, corresponding to a succession of anthropogenic deposits and clayey/calcareous beaten floors and reflected in SU 2816 and all its subunits. These occupation deposits are characterized by a new architectural phase defined by Walls M11 and M20. This building phase is attributed to the first century BC, and more specifically to 80–70 BC. This moment of general abandonment of Buildings EO9 and EO8 has been dated to the first decades of the first century BC. These material contexts have already been published (Bernal Casasola et al., 2018; Bernal Casasola et al., 2019; Bernal-Casasola et al., 2020a, and 2020b). We refer to those studies for greater detail since the sequence and material culture are very similar to those discovered in Rooms E-18 and E-20, the focus of this study—i.e., late forms of Roman black-glazed ware, wheel-thrown Mauritanian common ware, painted pottery, Italic cookware, gray pottery, and Mauritanian and Punic-Gaditan amphorae (SU

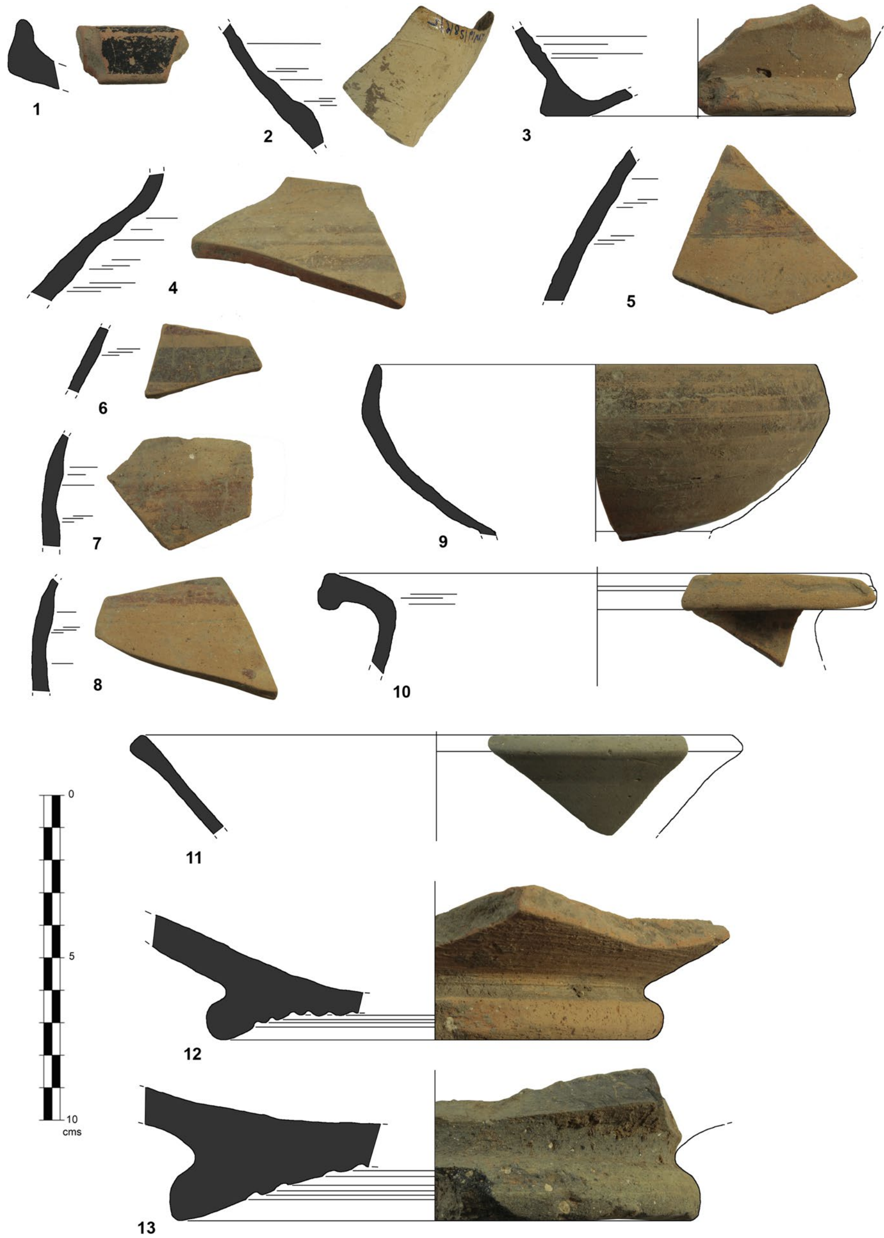

Fig. 6 A selection of pottery finds identified in the stratigraphic unit 2816: (1) possible black-gloss Lamboglia 5 (Campanian A); (2) fusiform unguentarium, possibly Italic; (3-–8) decorated potteries, showing painted horizontal red bands; (9) wheel-thrown bowl with re-entrant rim, showing painted horizontal brown bands, both on the inside and outside surfaces; (10) common ware: wheel-thrown cooking-pot; (11) common ware: wheel-thrown dish; (12 and 13) common wares: mortars with an internal groove and an over-fired external base that were possibly made locally in Tamuda

2809, 2810, 2814–2817, and 2823). The pavements of this reflooring sequence are truncated by pits and reworking processes, limiting their lateral continuity in the profile. Firstly, we find SU 2816a, a red clayey beaten floor. This is followed by SU 2816b, a grayish brown clayey layer very similar to SU 2827. On it, there is a brownish dark clayey deposit with a complete amphora in horizontal position (SU 2814) and a yellowish beaten floor, SU 2816c, which is stratigraphically associated with two combustion structures. The first is an excavated pit with a concave morphology (SU 2816e1) filled with finely bedded ash lenses, rubified clayey spots, and discrete charcoal lenses (SU 281,632). These 37-cm diameter stratigraphic units were identified as a pit combustion structure (Bernal-Casasola et al., 2020a). The second combustion structure associated with SU 2816c is a truncated combustion structure of unknown use (SU 2816f) that represents the last human occupation recorded in this room. Some of these deposits are

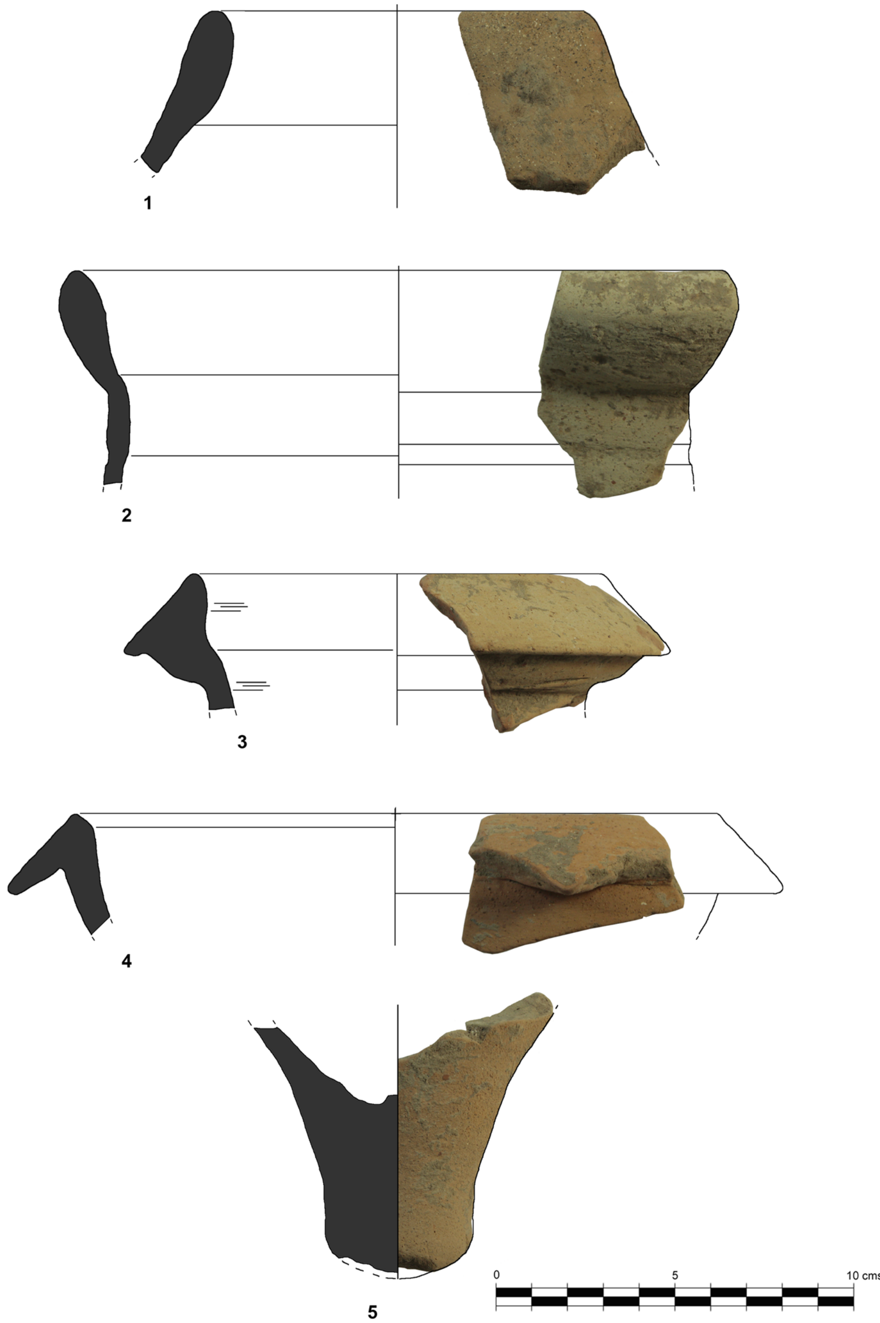

Fig. 7 A selection of amphorae finds identified in the stratigraphic unit 2816: (1) rim of T-12.1.1.1/2 amphora of possible Malacitan production (2816/14); (2) Punic-Gaditan amphora rim, form T.8.2.1.1; (3–4) Amphorae rims of Mauritanian production, typologically related to late Greek-Italic forms and Dressel 1A amphorae; (5) Indeterminate Mauritanian amphora pivot

sealed by SU 2816d, a dark brown silty clay deposit with anthropogenic features, including charcoal, pottery, and earth-based building materials. Other deposits are truncated by a pit (SU 2816g1) filled with a clayey deposit containing abundant anthropogenic materials and building debris (SU 2816g2). Finally, the Mauritanian sequence of Room E-18 is sealed by SU 2809. This is a massive brownish-gray sandy clay deposit, 50–60 cm thick, that contains archaeological materials, including small pottery fragments and some iron objects. These lead us to hypothesize that its origin was the degradation of earth-based architecture and metallic roof elements. Finally, there is a hiatus in the sequence, and the next stratigraphic units are dated to Late Antiquity. Thus, SU 2801 is the sedimentary base of M13, a very degraded wall of which only the stone foundation remains.

The other stratigraphic sequence analyzed is in Room E-20. It has not been fully excavated and only reflects the 80–70 BC phase. The only documented occupation deposits in this room are represented by SU 2823, a dark gray clayey deposit associated with a circular rotary mill structure that preserves the millstone base and a stone floor used during the milling process (Bernal-Casasola et al., 2020a). The fill of this space is very similar to that of Room E-18, with degraded earth-based building material deposits (SU 2817 and 2810/2815) and late Roman occupation on top (SU 2801 and M13).

In order to understand the site formation processes and reconstruct the urban biography of Tamuda during the Mauritanian period in this sector of the town, it was necessary to describe the aforementioned occupation deposits and delineate their chronological phases. Although the floors associated with the two building phases were evident in the field (Fig. 5), it was difficult to macroscopically define their associated occupation deposits during the excavation process. In this respect, the floors and occupation deposits locally showed sharp and diffuse contacts, with quite a lateral variability. This was especially significant in those deposits affected by later occupations, such as Pit 2816g, that affected the previous deposits in Room E-18. In contrast to these layered and finely stratified occupation deposits, the genesis of the thick deposits, such as SU 2827 in Room E-18, was difficult to interpret in the field. Thus, to define purpose-built floors and their relationship with the architectural phases, as well as the changes in the construction and maintenance of floors, the possible remains of the activities carried out on them, and the genesis of the thick deposits, we undertook an extensive microstratigraphic sampling of these two sequences.

Materials and Methods

Archaeological Soil and Sediment Micromorphology

Undisturbed soil and sediment micromorphology samples were taken from chronostratigraphic profiles exposed during the 2018 excavation season. The sampling strategy was systematic, covering all the stratigraphic units identified in the field. Blocks stabilized with plaster of Paris bandages were oven-dried for one day at 50°C. Impregnation was carried out under vacuum with polyester resin (Palatal P4-01), styrene monomer, and MEK catalyst. A total of 23 thin sections were studied. They were analyzed under plane-polarized (PPL), cross-polarized (XPL), and oblique incident (OIL) lights. Standard descriptive criteria were followed (Courty et al., 1989; Karkanas & Goldberg, 2019; Stoops, 2003; Stoops et al., 2010).

Here, we use the Flügel's microfacies concept to refer to the arrangement of sedimentary constituents by distinct and recurrent groups of similar composition and organization within a particular thin section (Flügel, 2004). Thus, through microfacies analysis, it was possible to group similar characteristics of the lithological composition, geometric association, and post-depositional change. This allows us to recognize patterns in different thin sections. This is based on the principle that distinct events, depositional environments, and post-depositional processes produce a particular set of microfacies units that, in turn, can be associated with a specific microfacies type (Courty, 2001; Flügel, 2004; Goldberg et al., 2009).

In terms of sampling and micromorphological documentation, the site was included in a global reference system (UTM ETRS89-30 N) using a total station. Photographic data from the profiles were collected with a Canon 750D, using control points to provide scale and orientation to the 3D modeling according to the local coordinates system. SfM technology (commercial software, Agisoft Photoscan) was used to produce volumetric models from the photographs. The studied thin sections were scanned using MWSI (Gutiérrez-Rodríguez et al., 2018). This technique acquires the image directly from the microscope through a camera and Microvisioneer desktop software (http://www.microvisioneer.com/). All the studied samples were uploaded to the GeoDig platform (http://geodig.es), a collaborative database specifically designed for geoarchaeological research by one of the authors of this study (M.G.-R.). This supplementary material will provide the reader with further spatial contextualization and dynamic visualization of the studied samples (Table 1).

μ-XRF

The elemental composition of the thin sections was explored using μ-XRF. The analyses were conducted

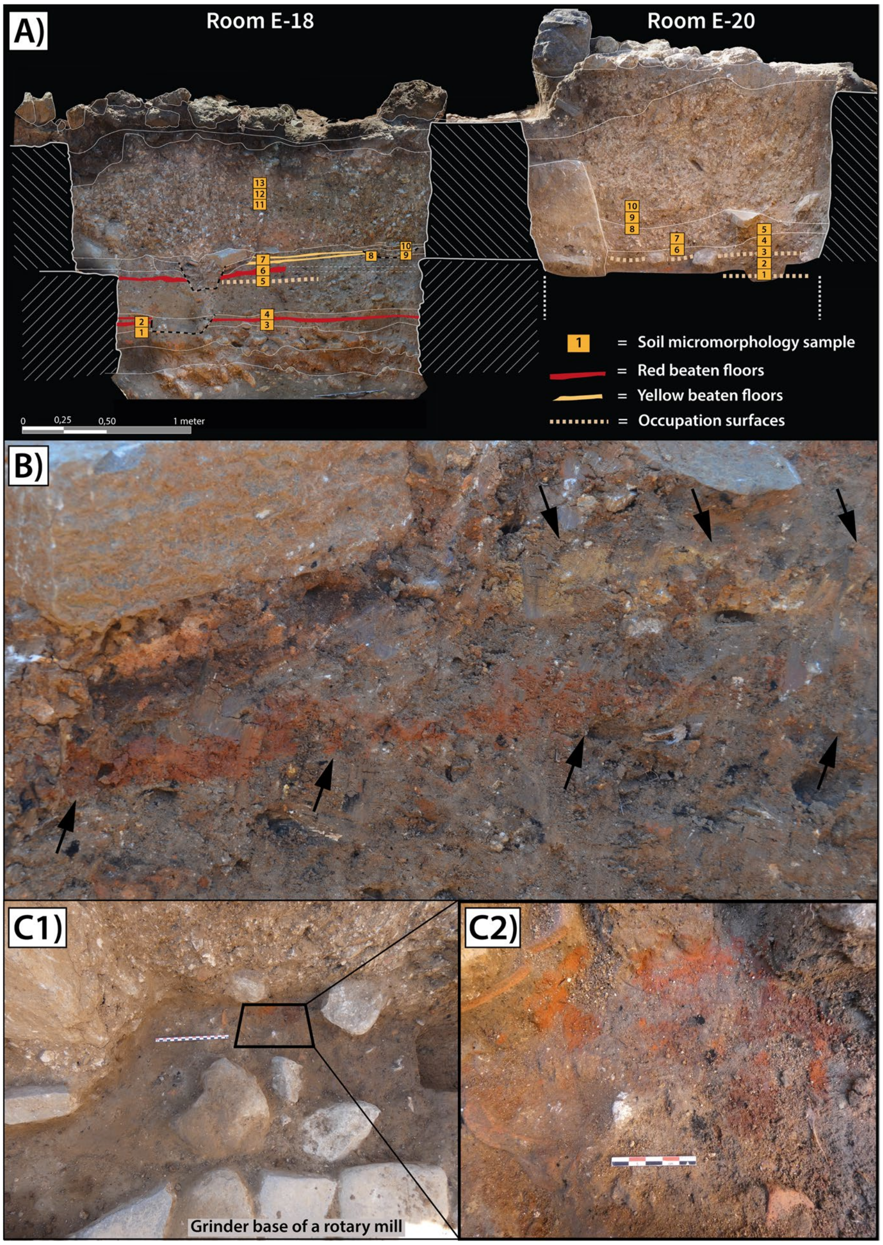

Fig. 8 Macroscopic characterization of beaten floors and occupation surfaces: (**A**) floors and occupation surfaces identified within the Mauritanian sedimentary sequence; (**B**) macroscopic view of red and yellow beaten floors (black arrows); (C1) occupation surface associated with the grinder base of a Pompeian-style rotary mill; (**C2**) detail of the occupation surface (note the abundance of horizontally disposed pottery sherds and burnt clay aggregates)

with a Horiba XGT-7000 μ-XRF spectrometer at the University of Leicester School of Archaeology and Ancient History. Measurements were taken under full vacuum conditions. This spectrometer was equipped with a microfocus X-ray tube with an Rh anode, a monocapillary lens for X-ray focusing, and a Peltier-cooled Silicon Drift Detector (SDD) calibrated to the Kα1 line. The sample chamber (300×300×80 mm) incorporated an XYZ motorized stage for sample positioning. A high-resolution microscope was used to position the sample at the desired distance from the monocapillary. To increase the sensitivity of the low Z elements, the sample chamber was brought under a vacuum. For the mapping analysis of the samples, a spot size of 100 μm was chosen at an operating X-ray tube voltage of 50 kV, an acquisition time of 2000s, a processing time of 6 s, and a current of 1 mA. Mappings and concentration values were obtained with INCA software (Version 5.05).

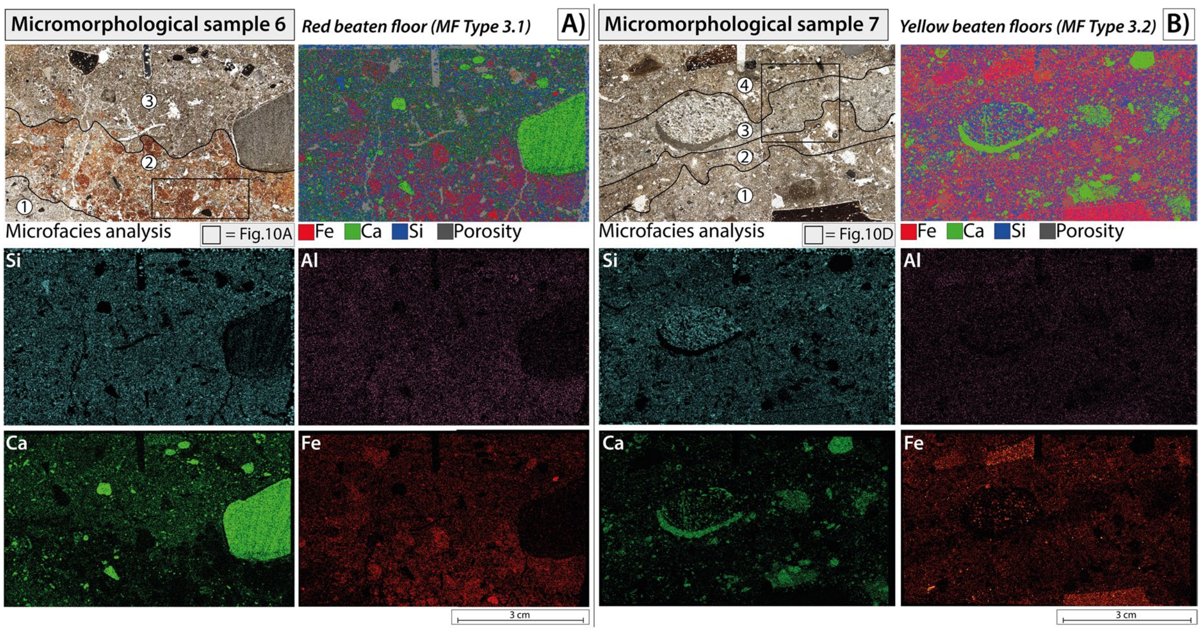

Fig. 9 Contextual micromorphological and μ-XRF characterisation of beaten floors: (**A**) red clayey beaten floors with an Al-, Si-, and Fe-rich composition; (**B**) yellow calcareous beaten floors with a Si- and Ca-rich matrix

Results

The most discriminating factor in defining microfacies is the nature of the different geogenic materials that can be related to their former geomorphological and sedimentary environments and their geometric and spatial relationships to the many different anthropogenic materials. The different microfacies types broadly coincide with the stratigraphic units visible in the field. However, different geometric patterns and assemblages are observed only in thin sections. Six main microfacies types were identified in the thin sections, some with subtypes. Microphotographs of each can be found in Figs. 10, 11, 12, 13, 14, and 15. Descriptions and significant aspects for the interpretation of the formation processes of each microfacies type are provided in Table 2.

Discussion: Site Formation Processes and Urban Evolution

Floors and Occupation Surfaces

During the excavation process, human occupation deposits and material culture associated with beaten floor pavements were identified. However, the microstratified nature of these pavements made it difficult to macroscopically individualize them and, consequently, to characterize their associated occupation deposits. This last point was important not only to differentiate the material culture assemblages, but also to define the biography of Building E08. In this respect, the microstratigraphic and diachronic studies of the succession of beaten floors provide significant information about different uses of the urban space and the patterns of architectural maintenance activities (Gutiérrez-Rodríguez, 2018). With this aim, using micromorphology and μ-XRF, we characterized the different beaten floors of these rooms as intentionally-made occupation surfaces prepared from sedimentary materials (Gé et al., 1993).

Following decades of geoarchaeological research, beaten floors have been characterized in different chronological and cultural contexts (e.g., Gé et al., 1993; Karkanas & Efstratiou, 2009; Karkanas & Van de Moortel, 2014; Lisá et al., 2020; Macphail & Goldberg, 2018; Rentzel et al., 2017). Under the microscope, beaten floors (when well preserved) present three different parts: passive, reactive, and active layers (Gé et al., 1993, expanded by Macphail & Goldberg, 2018). The passive layer is composed of

Table 1 The thin sections analyzed in this study, with chronological and contextual information

Sample	Sampling area	Chronology	Field description	Link to GeoDig platform
1	E-18	III–II C. B.C.	SU 2820: Geological substrate. A clast-supported deposit composed of beds of rounded gravel in a red clay sedimentary matrix. This unit contains very few archaeological finds, which were found in contact with the upper stratigraphic unit SU 2827a and 2827b: Brownish and yellowish clay beds with abundant red clayey aggregates from earthen building materials. Contains some late Punic amphorae fragments	http://geodig.es/section/552
2	E-18	III–II C. B.C.		http://geodig.es/section/555
3	E-18	III–II C. B.C.		http://geodig.es/section/561
4	E-18	III–II C. B.C.		http://geodig.es/section/563
5	E-18	III–II C. B.C.	SU 2827: Massive greyish brown clay deposit approx. 30 cm thick with yellow and red clay aggregates from earth building materials. Abundant archaeological finds, among which amphorae, red painted ware and Roman black-glazed ware are common	http://geodig.es/section/565
6	E-18	80–70 B.C.	SU 2816a: Red clay deposit. A homogenous bed approx. 5 cm thick with truncated lateral continuity. It is a beaten floor associated with Wall M20 SU 2816b: Greyish brown clay deposit approx. 5 cm thick on top of the 2816a beaten floor	http://geodig.es/section/569
7	E-18	80–70 B.C.	SU 2816c: Yellow clay deposit. A homogeneous bed approx. 3 to 5 cm thick with truncated lateral continuity. It is a beaten floor associated with Wall M20 SU 2816d: Greyish brown clay deposit approx. 3 cm thick on top of the 2816a beaten floor	http://geodig.es/section/572
8	E-18	80–70 B.C.	SU 2816e: Finely bedded ash lenses, rubified clayey spots and discrete charcoal lenses infilling a 37-cm-diameter concave morphology pit. It is a combustion structure	http://geodig.es/section/574
9	E-18	80–70 B.C.		http://geodig.es/section/575
10	E-18	80–70 B.C.	SU 2809: Massive brownish grey sandy clay deposit 50–60 cm thick. Contains small pottery fragments and some iron artifacts. This kind of deposit is common in Tamuda, sealing pottery assemblages with complete amphorae in several rooms of the Eastern Quarter (Bernal-Casasola et al., 2020a). Because of this, it has been interpreted as a sudden rammed earth collapse that sealed occupation deposits	http://geodig.es/section/576
11	E-18	80–70 B.C.		http://geodig.es/section/577
12	E-18	80–70 B.C.		http://geodig.es/section/578
13	E-18	80–70 B.C.		http://geodig.es/section/579
1	E-20	80–70 B.C.	SU 2823: Dark grey clayey deposit. Stratigraphically associated with a circular rotary mill structure (Bernal-Casasola et al., 2020a)	http://geodig.es/section/584
2	E-20	80–70 B.C.		http://geodig.es/section/586
3	E-20	80–70 B.C.		http://geodig.es/section/589
4	E-20	80–70 B.C		http://geodig.es/section/590
5	E-20	80–70 B.C.	SU 2817: Stratigraphic unit similar to SU 2809	http://geodig.es/section/591
6	E-20	80–70 B.C.	SU 2823: Described above	http://geodig.es/section/592
7	E-20	80–70 B.C.	SU 2817: Described above	http://geodig.es/section/593
8	E-20	80–70 B.C.		http://geodig.es/section/594
9	E-20	80–70 B.C.	SU 2810/2815: Stratigraphic unit similar to SU 2809	http://geodig.es/section/595
10	E-20	80–70 B.C.		http://geodig.es/section/596

sedimentary materials constructed by human action that presents no deformation or incorporation of human residue related to accumulation events; human activities carried out on the occupation surface; and previously formed inherited materials, such as soil, sediment, or urban waste (Lisá et al., 2020; Macphail & Goldberg, 2018). The reactive layer is formed by the mechanical deformation of the passive layer due

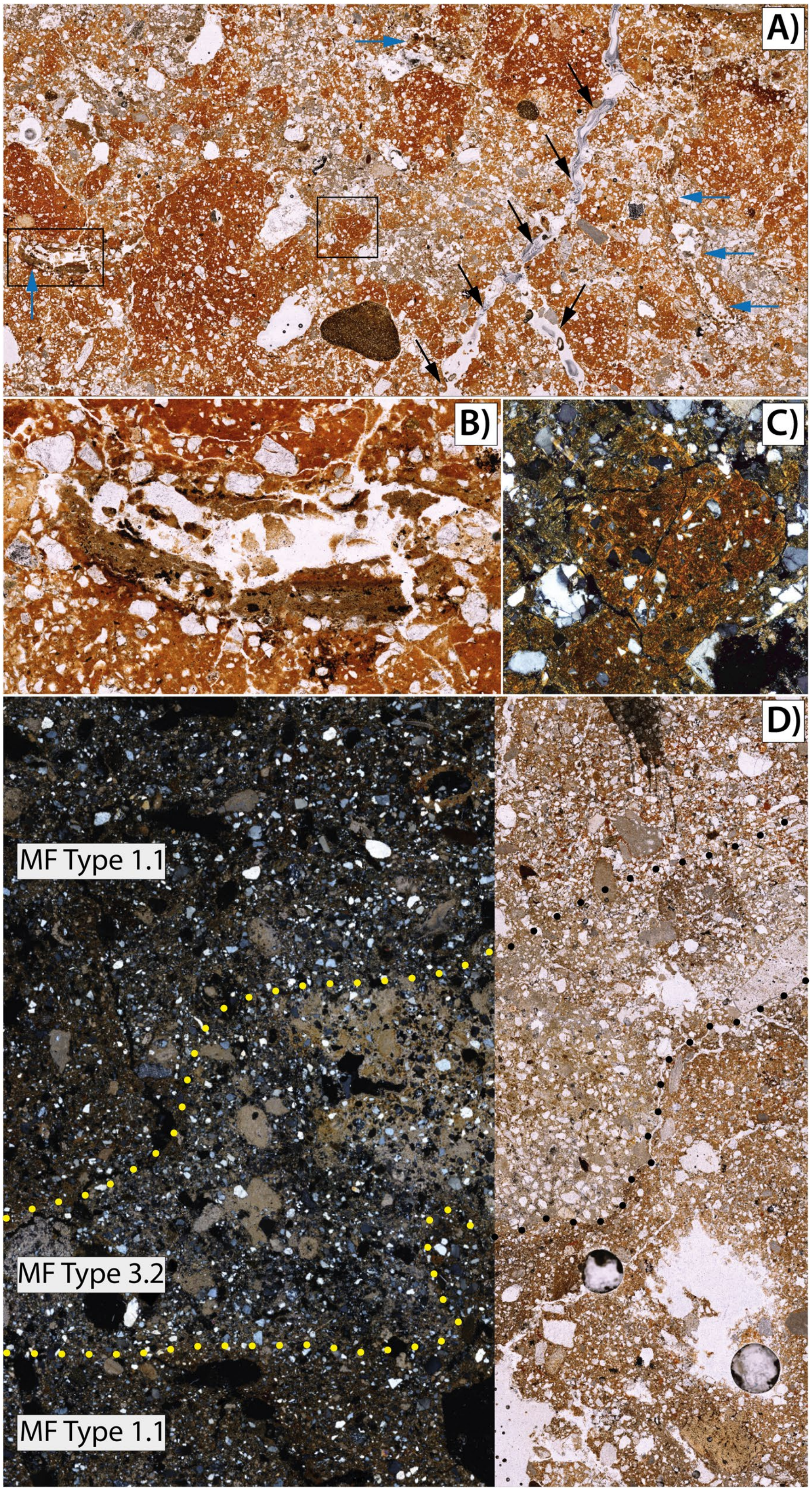

Fig. 10 Red and yellow beaten floors: (**A**) brownish red clay with quartz sand; (**B**) post-depositional channels and passage features; (**C**) detail of the red clays, showing a cross-striated b-fabric; (**D**) yellow floors, showing a diffuse basal contact between the passive layer and the underlying deposits at the bottom of the pavement, as well as an irregular surface of the active layers at the top of the floor (dotted lines)

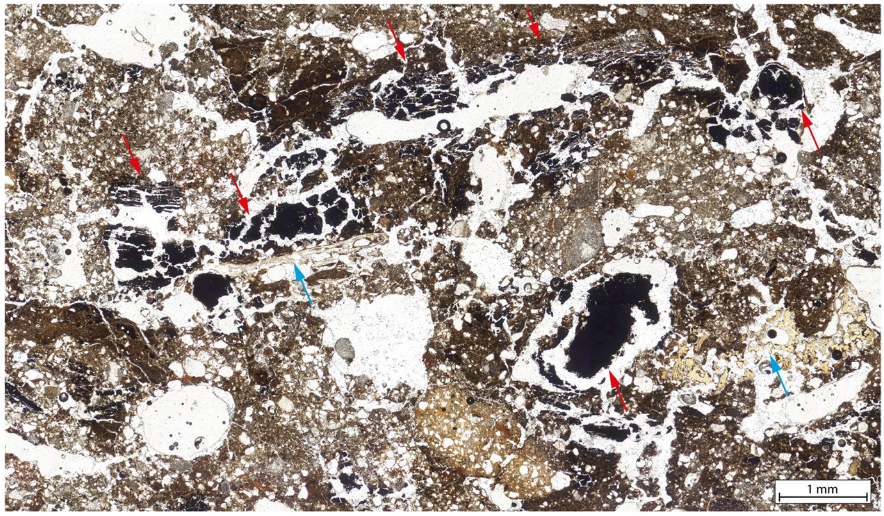

Fig. 11 Occupation surface, showing a clayey micromass rich in anthropogenic residues such as charcoal, charred organic tissue (red arrows), bones and fishbones (blue arrows)

to trampling and human residue. Finally, the active layer results from trampling and is a heterogeneous mix of rounded microaggregates and residue from human activities.

At Tamuda, we identified two beaten floor types that are discernible microscopically due to their colors: red (Microfacies Type 3.1) and yellow (Microfacies Type 3.2) (Figs. 8 and 9). Micromorphology revealed that the first-floor type (Fig. 10A–C) is common in both Mauritanian phases I (third and second century BC) and II (80–70 BC). They are composed of a brownish red (PPL) to reddish-orange (XPL) clay with silt to fine sand-size quartz (20%). Other coarse mineral constituents include minor amounts of sand to fine gravel-size, rounded fragments of flint (5%), and weathered bioclastic calcarenite (10%). While clay and quartz can be attributed to a similar soil source, the local clayey substrate formed after limestone dissolution (Fig. 2), flint, and bioclastic calcarenite have been identified as intentionally added mineral tempers. These lithologies are common in the External Chain units of the study area to the south of Tamuda, where there is a predomination of calcareous and dolomitic formations with flint (Fig. 2). These floors are very sandy, presenting a single-spaced porphyric c/f related distribution. They show densely compacted subrounded aggregates with subangular fissures that make up a weakly developed pedality. These features were formed during the floor construction by mechanical deformation, indicating that these red floors were heavily trampled and pugged in wet/dry conditions (Macphail & Goldberg, 2018). They present a sharp basal contact revealing a clear difference between the underlying deposits and the passive layer. However, the active layer is always heterogeneous and macroaggregated, presenting a loose packing porosity resulting from human trampling in dry conditions during the activities carried out on this floor. The floors show no evidence of coating or reflooring, indicating an absence of floor maintenance practices. Finally, regarding their postdepositional history, bioturbation features are present in the red floors. In this respect, channels are very common, with both parallel and vertical preferred orientations, drilling the floors. These channels present layered silt infillings with microcharcoal particles and abundant impregnated Fe/Mn oxide nodules. All these features depict a scenario of plant growth and subsequent in situ decay, following which silt and water infilling took place and Fe/Mn features were formed due to the poor evapotranspiration properties of the clay. These bioturbation and Fe/Mn features formed after the primary use of this space ceased, and it was subsequently colonized by plants and soil fauna.

Floors of the second type, those with a yellow color (Fig. 10D), have been characterized as calcareous floors. They were identified in the Mauritanian Phase II (80–70 BC), making a sequence barely visible in the field with respect to the overlying and underlying deposits (Fig. 8). It was also impossible to macroscopically distinguish between the floors, making a microstratigraphic study necessary. There are significant differences in their composition with respect to the red floors since they are composed of

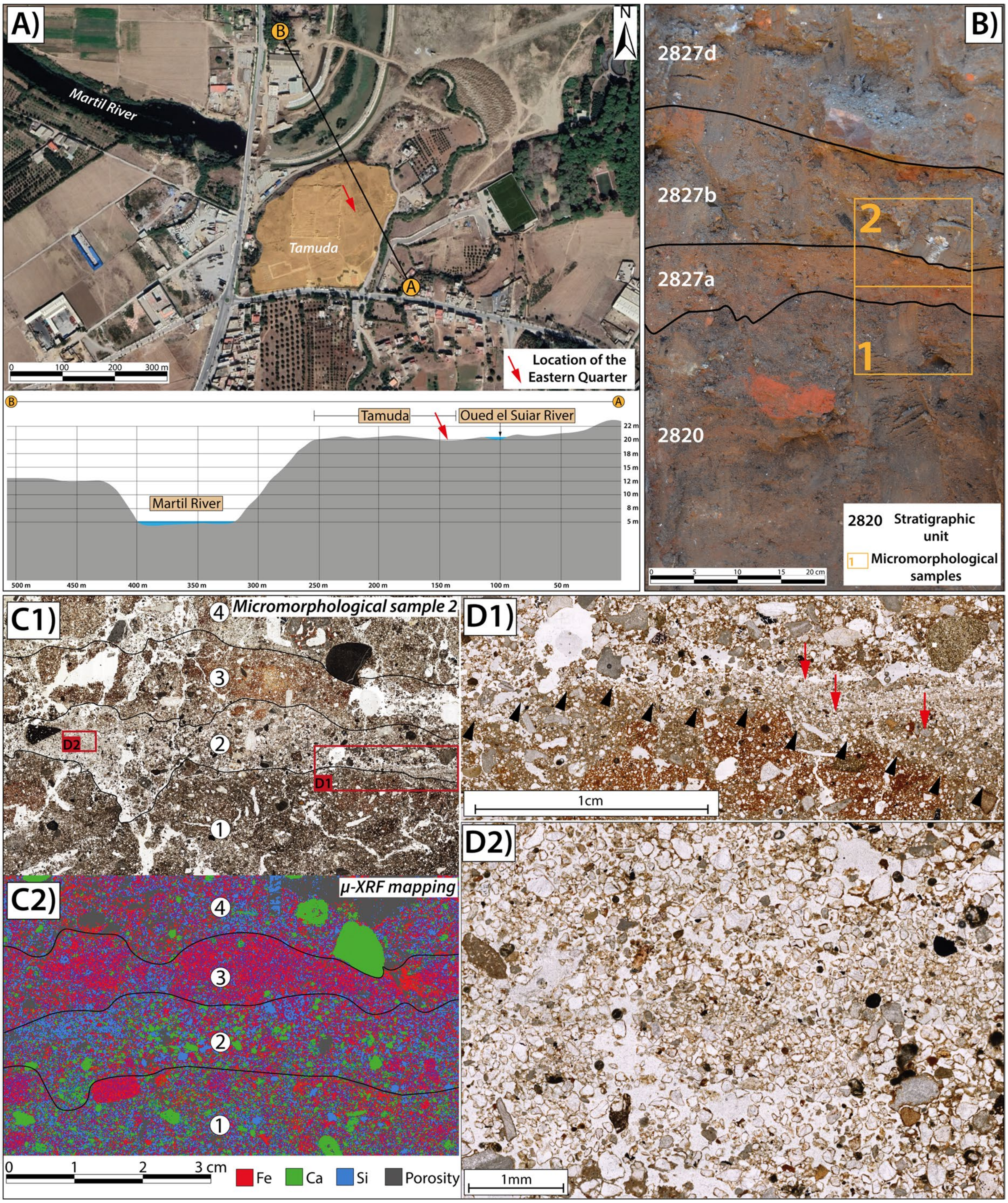

Fig. 12 Macroscopic and microstratigraphic evidence of overbank levee deposits within the Mauritanian sequence of Tamuda: (**A**) plan and section of Tamuda in relation to the Oued el Suiar River, the source of the levee deposits; (**B**) detail of the stratigraphic sequence where such deposits have been identified; (**C1**) microfacies analysis of micromorphological Sample 2 showing 4 microfacies; (**C2**) μ-XRF mapping of the sample, showing the richer Si and Ca content in the levee deposit; (**D1**) contact between the beaten floor and the levee deposit (black triangles), red arrows indicate bedding and fining-upwards beds; (**D2**) detail of the siliciclastic levee deposit

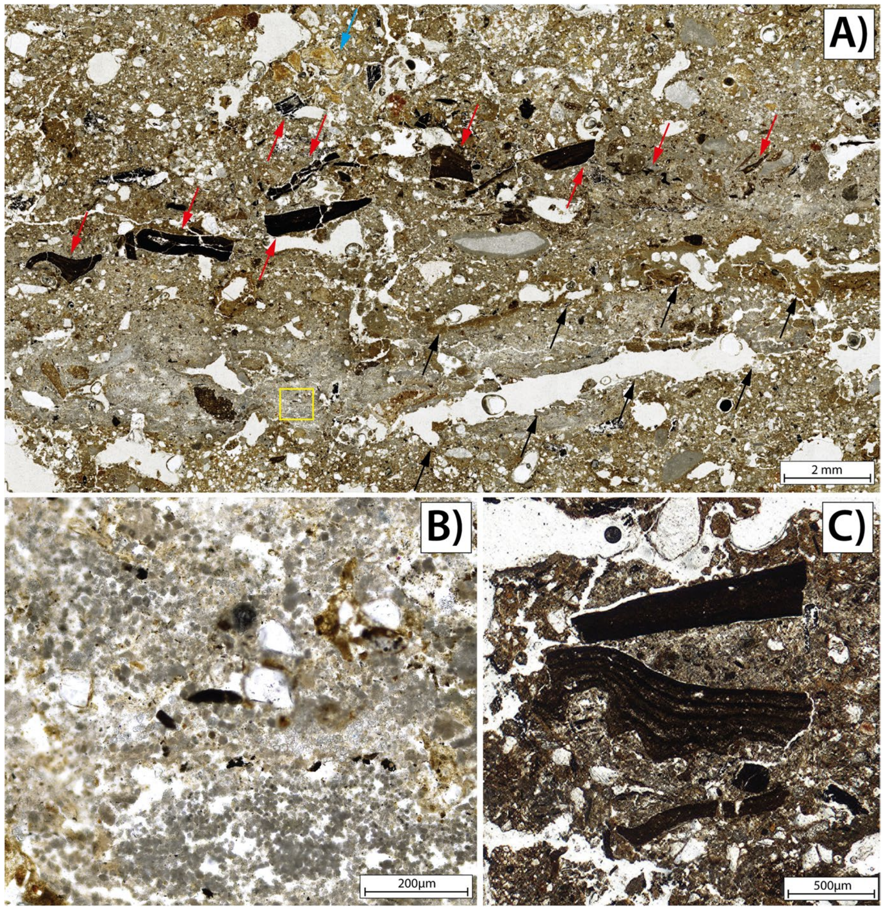

Fig. 13 (**A**) Finely bedded bioturbated combustion by-products corresponding to a combustion structure. (**B**) Micromass composed of rhombic shaped crystals of calcitic ash. (**C**) Detail of some of the abundant charred organic remains

a Si- and Ca-rich matrix (Fig. 9). In this respect, the fine material is a marly material composed of micritic calcium carbonate and minor amounts of clay. Coarse mineral fraction comprises silt to fine sand-size smooth angular quartz and sand to fine gravel-size bioclastic calcarenite and flint. While the origin of the bioclastic calcarenite and flint can also be identified as intentionally added temper and is also attributed to the External Units to the south of the site (Fig. 2), the origin of the marl and quartz is more difficult to assess. Tentatively, we highlight the similarities of these floors to the local Flysch units of the north bank of the Martil River, which are composed of diverse lithologies, among which marls and yellow sands are common (Fig. 2). These floors present a sandy texture and a close porphyric c-f distribution relatively analogous to the red floors. However, yellow floors, in contrast to red floors, present a massive microstructure indicating intense trampling. Another difference is that they show diffuse basal contact between the passive layer and the underlying deposits. In addition, the active layer shows a dense packing and incorporates anthropogenic materials such as charcoal and, in minor quantities, earth-based building materials. Yellow floors present an irregular surface of the active layers, and microaggregates mixed with anthropogenic materials in the overlying deposits are common. Again, these floors show no coatings, replastering, or evidence of any other maintenance practices. Bioturbation features are also present but are significantly less common than in red floors, indicating that soil exposure and bioturbation were less intense or had a shorter exposure time.

Particularly interesting is the identification of clayey occupation surfaces in Mauritanian Phase II, 80–70 BC (Fig. 8). They were not intentionally manufactured but were the result of human occupation and trampling on a bare surface (Fig. 11). These occupation surfaces present a clayey micromass rich in anthropogenic residues such as charcoal, charred

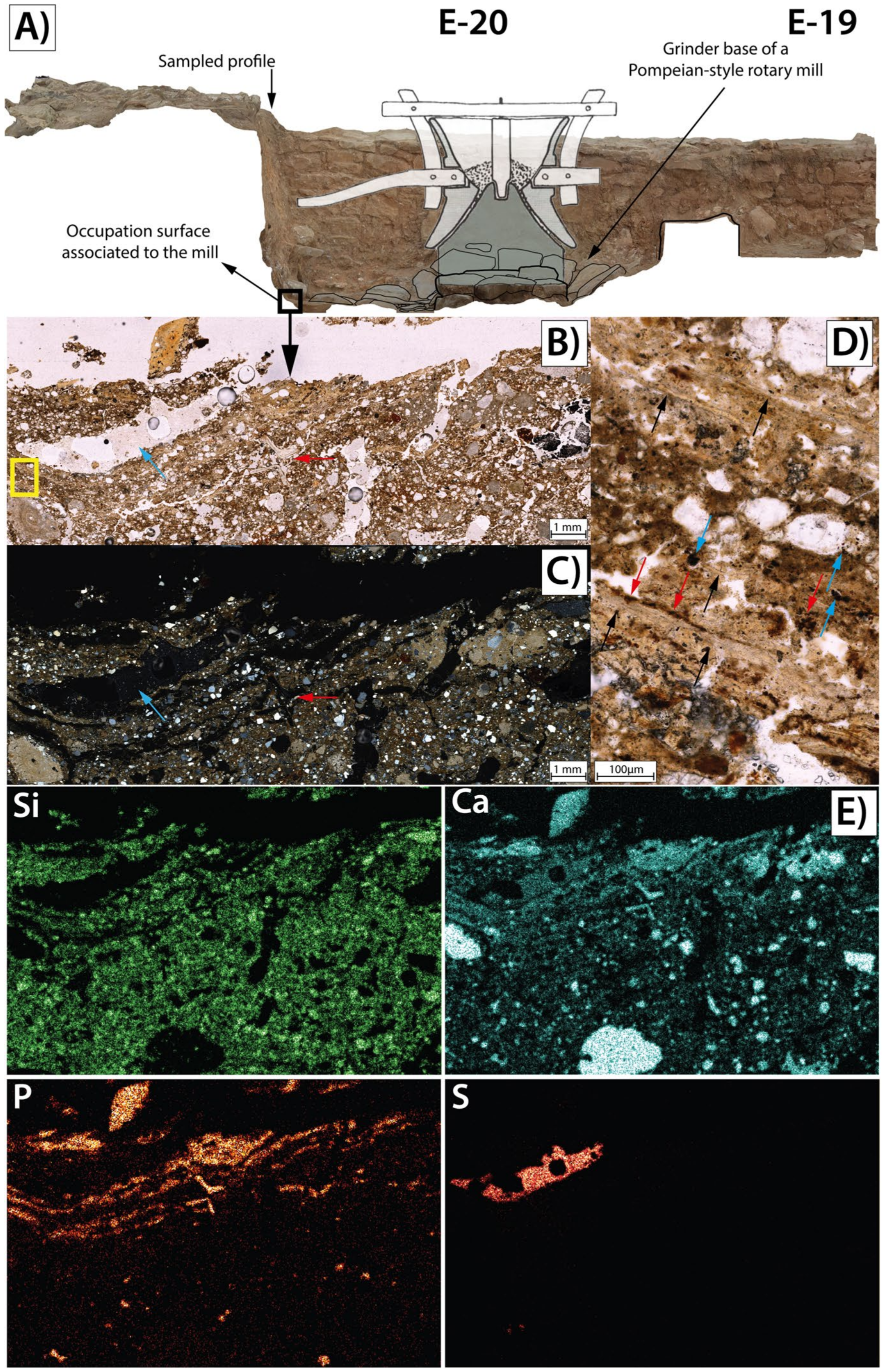

Fig. 14 (**A**) Occupation surface stratigraphically associated with a Pompeian-style rotary mill in Room E-20. (**B**) Relict Ca-P crusts and nodules with a gypsum crust (blue arrow) and fishbone fragments (red arrow) under plane polarised light. **C** The same in cross polarised light. (**D**) Anatomically connected phytoliths (black arrows), Fe–Mn staining features (red arrows), microcharcoal (blue arrows), and comminuted fishbone fragments. (**E**) µ-XRF characterization of the occupation surface

organic material, bones, and fishbones. Both coarse and fine materials are well-bedded and present horizontal preferred distributions. Anthropogenic materials show in situ cracks, suggesting trampling. However, they are poorly preserved due to the action of bioturbation processes, and show limited lateral continuity. Earthworm channels with silt coatings produced by soil- and charcoal-ingesting species are common. These post-depositional features were generated after the burial of these surfaces.

In terms of their technology and manufacture, the microstratigraphic analysis of the beaten floors and

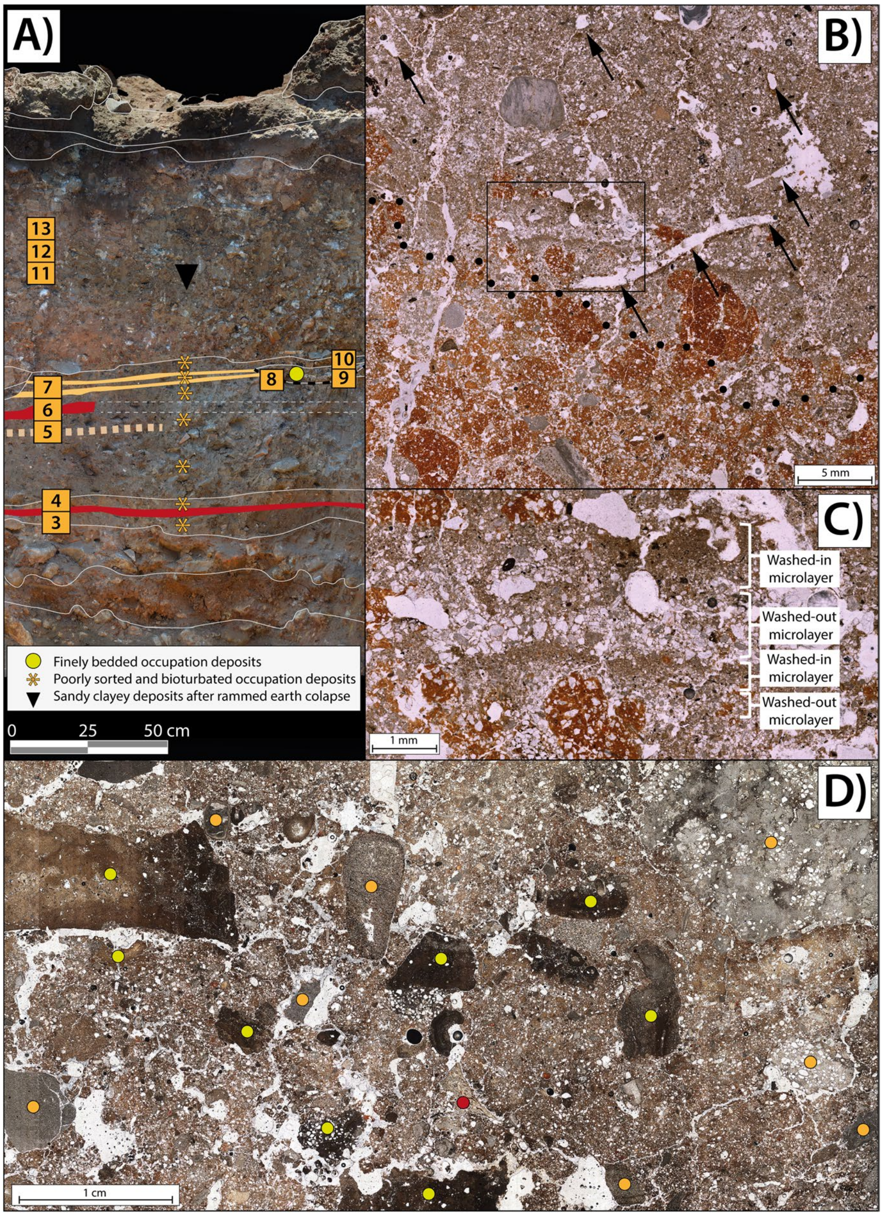

Fig. 15 (**A**) Occupation deposits. (**B**) The top of a red clayey beaten floor, showing bioturbation features such as channels (black arrows), drilling previously formed structural crusts (black rectangle). (**C**) Detail of the structural crusts, where the washed-in and out microlayers are visible. (**D**) Poorly sorted bioturbated sandy clay deposit showing gravel-size bones (red points), burnt mortar fragments (green points), and limestone fragments (orange points) generated after the intentional and rapid collapse of the upper part of the rammed earth walls

occupation surfaces in Tamuda reveals that the source of the mineral components of Floor Types 1 (red) and 2 (yellow) appears to be the same as for the added coarse mineral tempers: flint and bioclastic calcarenite from the External Units. The fine mineral fraction, however, is different. While Floor Type 1 (red) presents red clays, the marls used in Floor Type 2 (yellow) can be preliminarily attributed to the Flysch lithologies from the north bank marls of the Martil River, where yellow sands are common. Despite this difference, the floor technology seems very similar, with both types having been trampled in dry or limited wet conditions. In addition, neither type shows any evidence of maintenance features, such as coating or re-flooring. However, both were affected by post-depositional bioturbation.

Natural Sedimentation Events: Overbank Levee Deposits

Natural sedimentation deposits are commonly found in urban settlements intercalated with anthropogenic

Table 2 Microfacies analysis

Microfacies type	Subtypes	Description	Genetic interpretation	Figures in which this microfacies is represented
1. Poorly sorted bioturbated sandy clay deposits	1.1. Poorly sorted bioturbated sandy clay with household waste and degraded earth-based construction materials	Coarse mineral composed of silt- to fine sand-size smooth angular quartz (35%), silt- to sand-size rounded micritic limestone with sparite veins (5%), silt to sand-size angular flint (5%), silt-size muscovite (5%), and fine sand-size smooth angular calcite (2%). Coarse anthropogenic material is composed of silt- to gravel-size bone, silt- to sand-size charcoal and charred organic material, and silt- to sand-size rounded clayey beaten floor/wall coating aggregates. Fine material composed of a greyish yellow (PPL) to golden yellow (XPL) clay with relatively abundant microcharcoal particles presenting a random fabric pattern distribution. These components show a close porphyric c/f-related distribution. Porosity is mainly composed of planar voids and channels. This deposit presents a subangular blocky to massive microstructure and a crystallitic to cross-striated b-fabric. As pedofeatures, there are micritic calcite hypocoatings and passage features showing clay arrangement within the pore walls	Dumping and middening of household waste, followed by postdepositional bioturbation, progressive decay of earth-based construction materials and sediment homogenisation	Figure 15B and C
	1.2. Poorly sorted bioturbated sandy clay with household waste, degraded earth-based construction materials and phosphatic features	Coarse mineral material composed of silt-size smooth angular quartz (30%), silt to sand-size rounded micritic limestone with sparitic veins (10%), silt to sand-size angular flint (5%), silt-size muscovite (5%) and fine sand-size smooth angular calcite (2%). Coarse anthropogenic material composed of sand-size bone and fishbone, silt to sand-size charcoal and charred organic material. Fine material composed of a greyish brown (PPL) to dark grey (XPL) clay with microcharcoal particles and ash spots. Both coarse and fine materials show a parallel preferred distribution pattern. These components present a close porphyric c/f related distribution. Porosity is mainly composed of channels showing horizontal and oblique preferential orientations, few chambers and planar voids. This deposit presents a massive microstructure and a crystallitic to undifferentiated b-fabric. As pedofeatures, there are abundant bioturbation-related features such as channels and passage features presenting charcoal-rich micritic carbonate infillings and clay rearrangements in the walls. It is noteworthy that this deposit presents horizontally distributed thick calcium-phosphate and microcrystalline gypsum crusts that have also been identified with µ-XRF as shown in P, Ca and S distribution. These crusts present the same coarse mineral components as the groundmass, some silt-size charcoal fragments and vertical planar voids. Anatomically connected phytoliths showing a parallel distribution are common	The sedimentary source of this microfacies is the in situ degradation of protein-rich organic matter from grinding by-products from a rotary mill. The nature of the grinding by-products leads us propose that this structure was used not only for the cereal milling, but also for the production of fish flours	Figure 14B–E

Table 2 (continued)

Microfacies type	Subtypes	Description	Genetic interpretation	Figures in which this microfacies is represented
	1.3. Poorly sorted bioturbated sandy clay with gravel-size coarse mineral fraction and household waste	Coarse mineral composed of silt- to fine sand-size smooth angular quartz (30%), silt to gravel-size rounded micritic limestone with sparite veins (10%), silt to gravel-size angular flint (5%), silt-size muscovite (5%) and fine sand-size smooth angular calcite (5%). Coarse anthropogenic material is composed of silt- to gravel-size bone, very little silt- to sand-size charcoal, sand-size angular shell fragments, sand to gravel-size subrounded aggregates of burned mortar and sand-size rounded clayey beaten floor/wall coating aggregates. Fine material is composed of a greyish yellow (PPL) to golden yellow (XPL) clay with relatively abundant microcharcoal particles and a random fabric pattern distribution. These components show a close porphyric c/f-related distribution. Porosity is mainly composed of channels. This deposit presents a massive microstructure and a crystallitic to cross-striated b-fabric. As pedofeatures, there are micritic calcite hypocoatings	This microfacies type was formed with the input of earth-based construction materials: the collapse of rammed earth walls. Its formation was rapid, sealing the last occupation surface of the site and its associated assemblages. Later, postdepositional bioturbation processes such as soil fauna colonisation and plant growth occurred, promoting sediment homogenisation	Figure 15D
2. Moderately sorted and bedded quartz sand		Coarse mineral material composed of silt to fine sand-size smooth angular quartz (50%), silt to sand-size rounded weathered bioclastic calcarenite (5%), silt to sand-size rounded micritic limestone with sparitic veins (2%), silt to sand-size angular flint (2%), and fine sand-size smooth angular calcite (2%). Fine material is composed of minor amounts of greyish yellow (PPL) to golden yellow (XPL) clay. These components show a chitonic to concave gefuric c/f related distribution. Porosity is mainly composed of simple packing voids and few channels. This microfacies shows a pellicular to bridged intergrain microstructure and an undifferentiated b-fabric. As pedofeatures, there are micritic calcite hypocoatings and passage features presenting clay arrangement within the pore walls. When not affected by bioturbation, this microfacies presents locally preserved laminae grading to a micritic limestone-rich very fine silty sand	This microfacies type was generated by overland flows in rainfall events that exceeded soil absorption capacity. It presents rapid formation and postdepositional bioturbation processes, suggesting a subaerial exposure and soil fauna/vegetation colonisation	Figure 12C1, C2, D1, and D2
3. Beaten floors	3.1. Clayey beaten floor (red)	Coarse mineral material composed of silt-size smooth angular quartz (20%), silt to sand-size rounded bioclastic calcarenite (10%), silt to sand-size angular flint (5%) and silt-size muscovite (2%). These rock fragments were used as a mineral temper. Fine material is composed of a pale orange (PPL) to reddish orange (XPL) clay. These components show a single spaced porphyric c/f related distribution. Porosity is mainly composed of channels with a preferential vertical distribution, but this microfacies also shows subangular fissures. In this respect, this microfacies shows a weakly developed pedality with unaccommodated and moderately separated subangular blocky peds. This microfacies shows a granular microstructure and a cross-striated b-fabric	Pavements made by dumping, trampling and compacting clay aggregates sourced from the clayey substrate on which the Mauritanian town is located. Minor amounts of sand to gravel-size rounded fragments of weathered bioclastic calcarenite were used as a temper. This microfacies type shows a rapid formation	Figure 10A, B, and C

Table 2 (continued)

Microfacies type	Subtypes	Description	Genetic interpretation	Figures in which this microfacies is represented
	3.2. Calcareous beaten floor (yellow)	Coarse mineral material composed of silt-size smooth angular quartz (40%), silt to sand-size rounded micritic limestone with sparitic veins (15%), silt to sand-size angular flint (5%) and fine sand-size smooth angular calcite (2%). µ-XRF presents an Si enrichment in this deposit corresponding to quartz sand. Coarse anthropogenic material consists of few rounded fine sand-size clayey beaten floor/wall coating aggregates. Fine material is composed of moderately bedded micritic calcium carbonate and clay. Both coarse and fine materials present a preferred horizontal distribution and bedding. These components show a close porphyric c/f related distribution. Porosity is composed of few channels. This microfacies presents a massive microstructure and a crystallitic to granostriated b-fabric	Pavements made by dumping, trampling and compacting calcareous rocks. Minor amounts of sand to gravel-size rounded fragments of weathered bioclastic calcarenite, micritic limestone and flint were used as a temper. This microfacies type shows a rapid formation	Figure 10D
4. Clayey occupation surfaces		Coarse mineral material composed of fine sand-size smooth angular quartz (30%), silt to sand-size rounded weathered bioclastic calcarenite (10%), silt to sand-size rounded micritic limestone with sparitic veins (5%), silt to sand-size angular flint (5%), silt-size muscovite (5%) and fine sand-size smooth angular calcite (2%). Coarse anthropogenic material is composed of silt to sand-size bone and fishbone, silt to sand-size charcoal and charred organic material. Anthropogenic materials, especially charcoal, show a horizontal preferential orientation and in situ cracks, suggesting intense trampling. Fine material is composed of a greyish yellow (PPL) to golden yellow (XPL) clay. Both coarse and fine materials are well bedded and horizontally distributed. These components show a close porphyric c/f related distribution. Porosity is mainly composed of channels and vesicles showing a horizontal parallel preferential distribution. This microfacies presents a channel microstructure and a cross-striated b-fabric. This microfacies shows few fresh organic tissues inside pores. As pedofeatures, there are bioturbation-related features such as channels and micritic calcite hypocoatings, and silt infillings within pores are common	This microfacies type was generated by traffic and trampling upon pre-existing deposits. Anthropogenic materials are common. This microfacies type shows a slow formation and postdepositional bioturbation processes, suggesting a subaerial exposure and soil fauna/vegetation colonization	Figure 11

Table 2 (continued)

Microfacies type	Subtypes	Description	Genetic interpretation	Figures in which this microfacies is represented
5. Well sorted and finely bedded bioturbated combustion by-products		Coarse mineral material composed of silt-size smooth angular quartz (10%), silt to sand-size rounded micritic limestone with sparitic veins (2%), silt to sand-size angular flint (2%), silt-size muscovite (2%) and fine sand-size smooth angular calcite (2%). Coarse anthropogenic material consists of silt (dominant) to sand-size charcoal and charred organic matter (sometimes showing oxalate rhombic crystals), sand-size silicified plant fruit shells, as well as sand-size burned bones and fishbones. Silicified plant fruit shells are relatively common and bedded, especially in the upper part of the deposit. They show dark reddish brown (PPL) to dark brown (XPL) and reddish interference colours. These pericarps are massive and present a complex layered anatomy with resin ducts cells. Also, while most of them present a tabular shape, others are concave. All these combustion by-products are finely bedded and show in situ cracks suggesting trampling. Coarse and fine components show an open porphyric c-f related distribution. Fine mineral material is composed of calcitic ash rhombic crystals and minor amounts of clay, as shown by Ca and Fe distribution in the μ-XRF mappings. This microfacies also shows few, dispersed rubified clayey aggregates. Both coarse and fine materials are finely bedded and present a horizontal parallel preferred distribution pattern. Porosity is mainly composed of channels showing horizontal preferential orientations. This deposit shows a massive to channel microstructure and a crystallitic b-fabric. As pedofeatures, there are bioturbation-related features such as channels and passage features with silt infillings. Also, there are few phytolith clusters in anatomical connection	This microfacies type corresponds to a well preserved but partially reworked combustion structure. Charred remains show a horizontal preferred distribution pattern and in situ cracks, suggesting trampling. This microfacies type shows a rapid formation, but there are postdepositional bioturbation features suggesting subaerial exposure and soil fauna/vegetation colonisation	Figure 13

layers. While in some cases, these can be appreciated with the naked eye, they are sometimes discrete mm-thick layers that, after being reworked by later human occupations, do not show lateral continuity. Thus, most evidence of such processes is reflected on the microscale. In these scenarios, it is difficult to identify natural deposits during the excavation process, although their identification through microstratigraphic analysis is key to understanding urban biographies. In this respect, natural deposits intercalated with urban deposits tell us of the presence of abandoned spaces within the urban layout or the effects and extent of natural sedimentation events.

Natural sediments have been identified in Mauritanian Phase 1 of Tamuda in Micromorphological Samples 1 and 2 (Fig. 5), where moderately sorted and bedded quartz sand deposits are found. These correspond to Microfacies Type 2 in this study (Table 2) and are found on top of red-beaten floors and occupation deposits. Such quartz sand sediments were almost imperceptible during the excavation (Fig. 12B). However, under the microscope, they present smooth angular fine sand-size quartz (50%) with sporadic rounded sand-size fragments of bioclastic calcarenite (5%), micritic limestone with sparitic veins (2%), and flint (2%). There are also minor amounts of clay limited to silt bridges and irregular coatings around grains. Thus, it is a siliciclastic sandy deposit with a chitonic to concave gefuric c-f related distribution and a pellicular to bridged intergrain microstructure (Fig. 12D). In addition, locally, these microfacies present a well-developed bedding with fining-upwards beds (Fig. 12D1: red arrows). We identify this microfacies type with overland flow deposits generated during intensive rain events when a fluvial channel overflowed, and soil absorption capacity was exceeded. Therefore, these slightly laminated deposits were washed-out of fine particles during the rainfall events, making way for deposits composed of loosely to densely packed mineral grains (Karkanas & Goldberg, 2013, 2019). Silt bridges and irregular clay coatings reflect the translocation of fine particles by water percolation (Karkanas & Goldberg, 2019; Texier & Meireles, 2003). These microfacies show a rapid formation and subsequent postdepositional bioturbation processes, suggesting subaerial exposure and fauna/vegetation colonization after the site's abandonment. These features specifically allow the identification of these microfacies with levee deposits, as fine-grained suspended load sediments during submergence by the major flooding of an active channel. Considering the site's topography, these levees probably correspond to the Oued el Suiar or Soueyeur River, which is 60 m from the study area. Tamuda is just one meter below the channel level of the Oued el Suiar River, on a gentle slope towards the Martil Basin (Figs. 2 and 12A). This is also supported by the lithological assemblage of these microfacies, which presents the bioclastic calcarenites, micritic limestone, and flint typical of the External Units upstream of this channel. The channel comes from a mountainous relief south of the site and contributes, along with other streams, to the considerable irregularity of the hydrological regimes in the Martil Basin with its seasonal torrential and violent floods. In this respect, the site of Tamuda is located in an inundation-risk area exposed to violent floods, as are many of the Mauritanian urban sites. The repeated identification of this fine-grained sandy microfacies type in Mauritanian Phase I (third and second century BC) reveals the effects and extent of floods, at least in the Eastern Quarter of the town during this period.

Occupation Deposits and Repeated Abandonment Processes

In urban areas, human-made deposits are predominant. These clastic sediments result either from human activities carried out on the different occupation surfaces or from the degradation of anthropogenic materials, such as earth-based construction materials like mudbrick or rammed earth walls. The macroscopic archaeological record is ambiguous, partial, and fragmentary. Thus, it is difficult to attribute individual sedimentary bodies of occupation deposits to specific human actions in the past. In most cases, hypotheses on this relationship are due to the archaeologist's instinct more than geoarchaeological empirical data. However, as Karkanas and Goldberg stated (2018, p. 99): "[…] human activities produce unique combinations of fabrics, depositional body geometries, stratigraphic contacts, and associations." There is a growing literature on the microstratigraphic study of occupation deposits that aims to characterize the diachronic evolution of urban space usage, the frequency of use of such environments, and the construction of urban biographies (Gutiérrez-Rodríguez et al., 2019; Macphail & Courty, 1985; Matthews, 1995, 2012; Matthews et al., 1997; Milek, 2012; Milek & Roberts, 2013; Shahack-Gross et al., 2005; Wouters, 2020). This has been made possible by applying high-resolution geoarchaeological and microstratigraphic analytical techniques, among which micromorphology stands out.

In Tamuda, we identified two broad categories of occupation deposits. A few of these deposits are finely bedded, reflecting the primary use of the architectural spaces. At the same time, the vast majority shows intensive postdepositional bioturbation and a more complex syn- and post-depositional evolution. The first category, the finely stratified deposits, is represented by Microfacies Type 5 of this study— *well-sorted and finely-bedded bioturbated combustion by-products* (Table 2, Fig. 13). These deposits were identified in Room E-18 and were comprehensively described in a previous publication (Bernal-Casasola et al., 2020a). They correspond to a combustion structure identified in Samples 8 and 9 dated to Mauritanian Phase II (80–70 BC; Fig. 7: SU 2816e1 and 2816e2). Macroscopically, the structure has a concave morphology with finely-bedded ash lenses, rubified clayey spots, and discrete charcoal lenses (Fig. 13A). Under the microscope, it was possible to individualize the lower deposits, the combustion structure itself, and the sediments covering the hearth (Fig. 13A). The combustion structure presents a micromass composed of rhombic-shaped crystals of calcitic ash (Fig. 13B) and abundant charred organic remains from fuel ignition (Fig. 13B). Charred silicified plant fruit shells stand out among the organic combustion by-products. They show layered anatomy with resin duct cells similar to hazelnuts (Fig. 13C). However, this identification is only tentative in the absence of anthracological and carpological analyses. This combustion structure evidences a slight biological reworking, with biogalleries infilled with clay and channels. Thus, this deposit corresponds to a rapidly buried combustion structure that was used for roasting nuts.

Microfacies Type 1.2. of this study— *poorly-sorted bioturbated sandy clay with household waste, degraded earth-based construction materials, and phosphatic features* (Table 2)— also belongs to the first category of finely-bedded occupation deposits. Stratigraphic analysis shows that this deposit, located in Room E-20 (Fig. 5: SU 2823), is synchronous with the previously described combustion structure in Room E-18 (Bernal-Casasola et al., 2020a). This deposit corresponds to an occupation surface stratigraphically associated with a Pompeian-style rotary mill with an exceptionally well-preserved base. Under the microscope (Fig. 14), the deposits associated with this mill present relict Ca-P crusts and nodules presenting planar voids and fissures, as well as multiple layers of anatomically connected phytoliths, comminuted organic matter and relatively abundant fishbone fragments, among which a vertebra is clearly visible (Bernal-Casasola et al., 2020a; Fig. 14). These crusts also present Fe/Mn staining features, few diatoms, and microcrystalline gypsum infillings. As Bernal-Casasola et al. (2020a) discussed, all these features indicate the in situ degradation of protein-rich organic matter from grinding by-products processed in the rotary mill. The nature and microcontextual association of the grinding by-products leads us to propose that this structure was used not only for milling cereals but also for the production of fish flour.

In this respect, the previously described deposits show that the human activities identified were “invisible” to the macroscopic archaeological record. Moreover, in this specific period of the human occupation (Mauritanian Phase II: 80–70 BC), the architectural space in the Eastern Quarter of Tamuda was devoted to the installation of mills and the establishment of a complex cycle of food processing, specifically cereals and vegetables (Bernal-Casasola et al., 2020a).

However, most of the occupation deposits identified on the floors and occupation surfaces belong to the second category and present intensive postdepositional bioturbation with a more complex syn- and post-depositional story. They correspond to Microfacies 1.1 of this study— *poorly sorted bioturbated sandy clay with household waste and degraded earth-based construction materials*. This microfacies type has been identified in both Rooms E18 and E20. These are sandy loam deposits with a coarse mineral fraction composed of silt to sand-size smooth angular quartz (30%) and sand-size rock fragments of flint (5%) and micritic, limestone with sparitic veins (5%). Coarse anthropogenic materials such as bone, charcoal, charred organic matter and sand-size aggregates of earth-based building materials are common in these microfacies. The micromass presents clay and silt with abundant microcharcoal particles. All these anthropogenic components show a random preferred distribution. In addition, this microfacies type shows intensive bioturbation evinced in the abundance of passage features and channels presenting calcitic hypocoatings around pore walls and organic tissues. These features result from calcium carbonate precipitation due to root metabolism (Wieder & Yaalon, 1982) and point to ruderal vegetation growth and the absence of cleaning and maintenance activities in these rooms once their primary use had ceased. This would imply, at least during the formation of these deposits, that Rooms E18 and E20 had no roof and were exposed to open air conditions. This situation is also evident in the presence of structural crusts in this microfacies type. These crusts resulted from in situ alterations of the soil surface after raindrop impact, as well as wetting and drying cycles. More specifically, these structural crusts are disruptional (Williams et al., 2018) since they formed when soil aggregates were disrupted or disintegrated on raindrop impact. They present different microlayers: a sandy one with most of the fine material removed (the washed-out microlayer) and a compacted silty/sandy layer below with reduced porosity that was formed after the settling of fine particles from suspension (the washed-in microlayer). In this microfacies type, structural crusts are found both in situ and reworked by bioturbation processes. They indicate natural formation processes in open-air conditions followed by local reworking. Also, silt to sand-size rounded aggregates of earth-based construction materials are common in this microfacies type. They have sedimentary components and features similar to Microfacies Type 3.1. (red floors) and, macroscopically, are very similar to the red clay coatings visible on the Mauritanian walls. These aggregates have been interpreted as the result of the progressive decay and weathering of the clayey wall coatings. Thus, they would indicate an absence of architectural maintenance practices. In summary, Microfacies Type 1.1— *poorly sorted bioturbated sandy clay with household waste and degraded earth-based construction materials*— shows a slow formation in an open-air environment where surface modification due to rainfall, soil fauna, and plant colonization took place in a household waste midden with low discard frequencies. The intensive bioturbation of these subaerially exposed deposits would have homogenized the sediment.

Finally, there are massive, thick sandy, clayey deposits on top of both stratigraphic sequences in Rooms E18 and E20 (Fig. 5: SU 2809, 2823, 2817, and 2810/2815). These deposits correspond to Microfacies 1.3— *Poorly sorted bioturbated sandy clay with gravel-size coarse mineral fraction and household waste* (Table 2; Fig. 15D). They are stratigraphically associated with the final occupation of the site during Mauritanian Phase II (80–70 BC), sealing impressive pottery assemblages consisting of complete amphorae in vertical and horizontal positions in situ on the occupation surfaces (Bernal Casasola et al., 2018; Bernal-Casasola et al., 2020a, 2021). These deposits present a coarse mineral fraction very similar to Microfacies 1.1. However, the carbonatic grains are gravel-size and more abundant. Within the coarse fraction, anthropogenic materials are mainly composed of gravel-size burnt mortar fragments and other features such as bones, shells, or charcoal fragments, which are less frequent. These deposits show bioturbation features such as channels. Their stratigraphic association with the walls of Mauritanian Phase II, their thickness, the coarser size of the inclusions, and the fact that they seal in the last occupation identified at the site, lead us to conclude that they correspond to the intentional and rapid collapse of the upper part of the walls built of rammed earth. The source of the rammed earth would have been an alluvial sandy clay deposit, perhaps collected from the clayey banks of the Martil alluvial plain. Coarse anthropogenic materials were intentionally added to this deposit, specifically burnt mortar fragments and gravel-size rock fragments from lithologies originating in the External Units. Bioturbation occurred following the collapse of these walls, and this space became an abandoned area in front of the Roman military *castellum* built in 40 AD on the ruins of the former Mauritanian town.

Urban Evolution and Biography of the Eastern Quarter of Tamuda

The systematic sampling of the stratigraphic sequences excavated in Rooms E-18 and E-20, along with the microfacies analysis, allowed the diachronic reconstruction of the depositional and postdepositional processes that led to the genesis of the archaeological record (Fig. 16). This area of the archaeological site shows the first signs of human occupation during the Mauritanian Phase I (third and second century BC). This first occupation was built directly on the geological substrate (Fig. 5: SU 2824 and 2822).

Here we found Walls M17 and M20A and their associated occupation deposits (SU 2820, 2827a, and 2827b) directly on the red clays of the geological substrate (SU 2822). In this respect, there is no evidence of archaeological deposits before the third century BC. This either means that this area of the plateau was uninhabited from the seventh to the fifth centuries BC or that the traces of previous occupations had been systematically dismantled. This association of human occupations with red clayey surfaces is typical of this stratigraphic sequence. In fact, red clayey beaten floors and pavements are common in urban sites in North Africa. Thus, apart from the optimal geographic characteristics of the Tamuda plateau for human habitation, the presence of the clayey substrate seems to have played a role as a source for earth-based construction materials. Mauritanian Phase I presents a succession of red clayey beaten floors and overbank levee deposits, showing a rapid formation of the archaeological record and revealing a complex human–environment interaction. These levee deposits were generated during torrential rainfall events that produced overflows and flooded the site. Microfacies analyses revealed that this situation was reiterative (Fig. 16). The space was subsequently abandoned for a long period and became an open-air intramural midden with low frequencies of discard and a slow formation of the deposit. Crust formation due to rainfall occurred together with soil fauna and plant colonization. The progressive decay of the buildings is evidenced by the presence of weathered aggregates of earth-based construction materials. This scenario suggests that the Eastern Quarter became a marginal urban settlement area.

During the Mauritanian Phase II (80–70 BC), the architectural space was remodeled (Fig. 16). The upper part of Walls M17 and M20A was dismantled, and new walls were built directly on the earlier stone foundations. In this phase, the new walls (M11 and M20B) reveal a different building technique that used medium-size clay-bonded masonry instead of the clay-bonded pebbles typical of the previous occupation phase (similarly to Fig. 2E). However, in both phases the walls present a red clay coating. Mauritanian Phase II shows a reflooring sequence composed of red (SU 2816a) and yellow (SU 2816c) beaten floors intercalated with occupation deposits. This reiterative sequence reveals an occupation dynamic defined by the laying of pavements, active uses of the space, and short-term abandonments between occupations. Human actions, such as floor laying, led to the rapid formation of the archaeological record, while the abandonment periods are defined by slow sedimentation rates. In these abandonment periods, low-frequency discard of household waste, bioturbation, and degradation of earth-based architecture was constant. It is interesting to note the color differences between the floors. The previously described mineralogical and technological differences may be due to functional differences in the use of the space. Yellow floors are stratigraphically and chronologically associated with circular rotary mills and combustion structures. These features are frequently found in the buildings excavated in the Eastern Quarter of Tamuda during the Mauritanian Phase II. In this chronological horizon, impressive pottery assemblages with complete amphorae are found. This space has thus been defined as an artisanal area within the town during the 80–70 BC phase. Perhaps the yellow floors were built for this specific purpose using different construction techniques with optimal properties for the activities undertaken in the rooms. The occupation deposits associated with these yellow floors reveal a rapid formation of the archaeological record. They are dominated by combustion structures such as the one sampled and described with Microfacies Type 5 and occupation surfaces associated with circular mills. In each case, the microstratigraphic approach was effective in the identification of their function. In the case of the combustion structure identified in Room E18, the combustion by-products suggested a possible use as a roasting pit for nuts.

Regarding the circular mill excavated in Room E20, identifying Ca-P crusts with layers of anatomically connected phytoliths, comminuted organic matter, and relatively abundant fishbone fragments could be linked to fish flour production. Thus, the synchronic association between these features and the abundant circular mills and amphorae identified in this phase reveal not only an artisanal dedication of the Eastern Quarter of Tamuda but also a complex cycle of food processing, which is also supported by pollen analysis (Bernal-Casasola et al., 2020a). This occupation phase was sealed by SUs 2809 and 2810/2815. Microfacies analysis has allowed us to identify these deposits with the sudden and intentional collapse of the rammed earth walls that resulted in a long-term abandonment of this area of the site. The

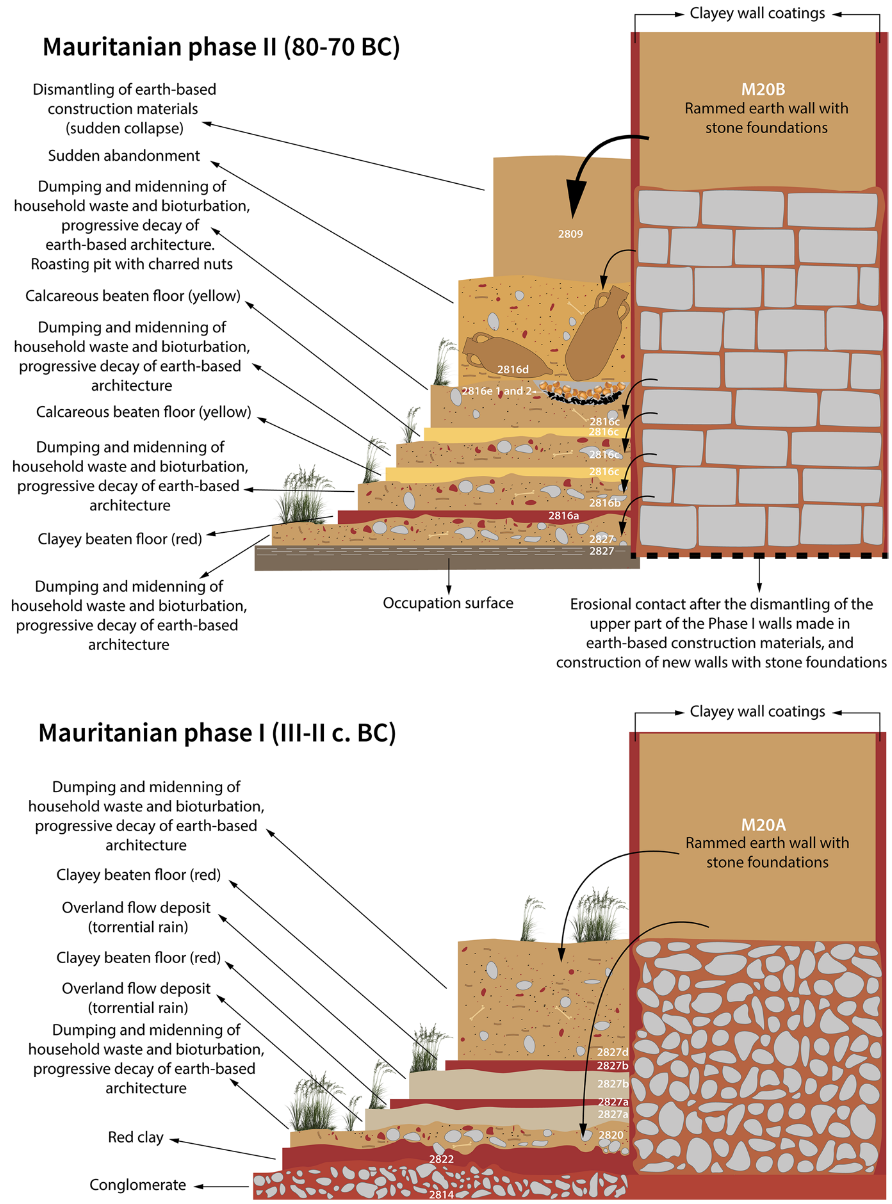

Fig. 16 Reconstruction of the urban biography of Room E-18 in the Eastern Quarter of Tamuda based on the site formation processes identified after microfacies analysis (the white numbers show the correspondence between the stratigraphic units and microfacies analysis)

Eastern Quarter became an open, abandoned space until it was reinhabited centuries later when a building corresponding to SU 2801 and Wall M1 was built during the fifth century AD. The absence of overflow deposits in Mauritanian Phase II (80–70 BC) was perhaps due to a more benevolent human–environment dynamic or the construction of an urban wall that ended the seasonal flooding. Although Mauritanian towns always have urban walls (Bridoux, 2008a), those of Tamuda have yet to be found. This difficult relationship with seasonal and torrential flooding of the Oued el Suiar River has been constant at this location, even until very recently. In this regard, the recent historiographic review of Miquel Tarradell's archive chronicling his research and excavations at the site revealed photos of a huge infrastructure built in 1948 to channel the overflows of the Oued el Suiar River (Bernal-Casasola & Moujoud, 2021).

The occupation phases and dynamics identified in the stratigraphic sequence show several similarities

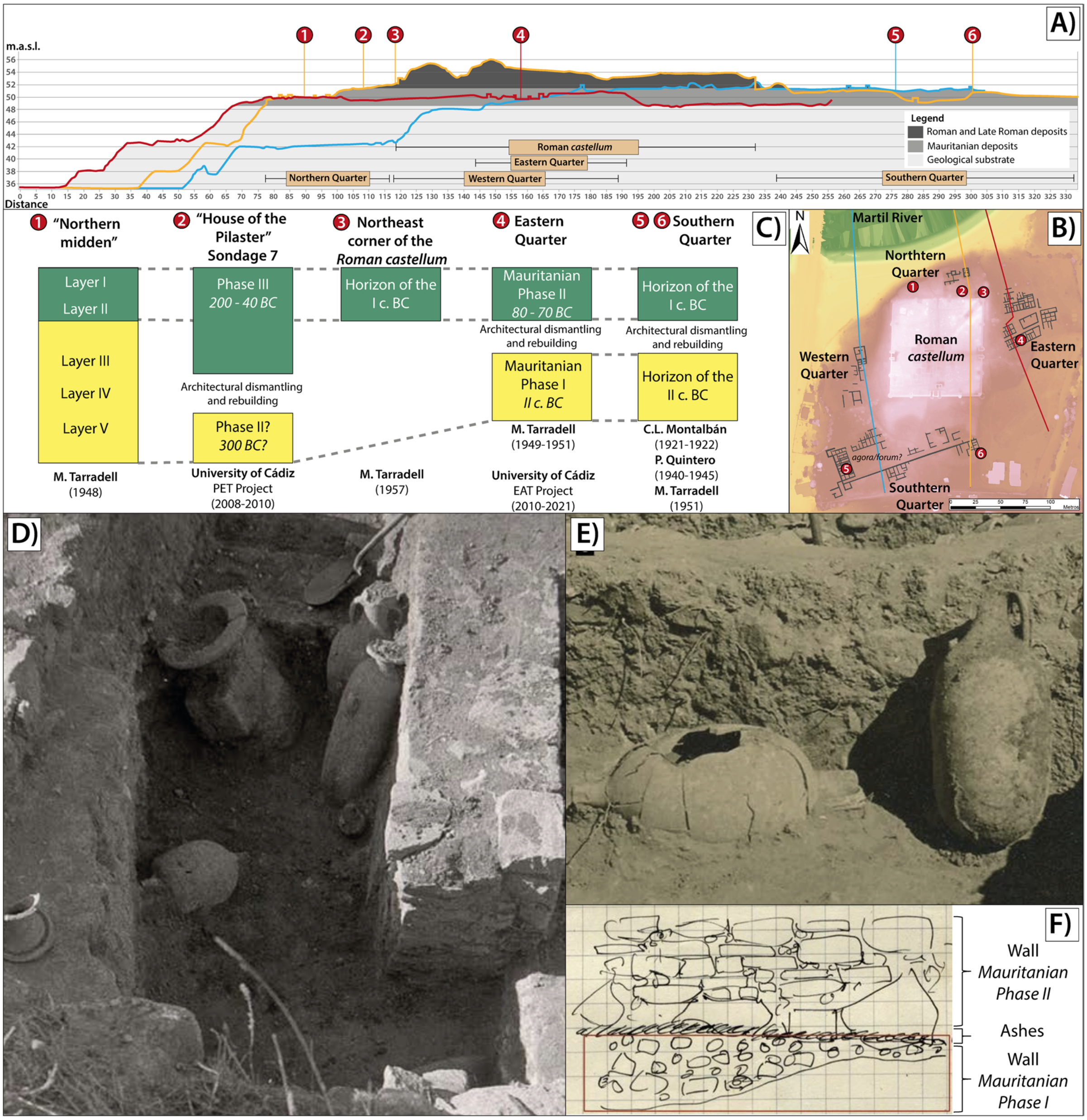

Fig. 17 Spatial and chronological correlation among the different Mauritanian stratigraphic contexts and phases in Tamuda: (**A**) topographic sections of the site showing the Mauritanian contexts mentioned in the text; (**B**) topographic plan showing the location of the topographic sections; (**C**) chronological correlation among the different Mauritanian contexts; (**D-E**) the destruction phase, 80–70 BC (Bernal-Casasola et al. 2021c: DLV-DLVI and CDXCII); (**F**) wall dismantling and rebuilding in the Southern Quarter (Bernal-Casasola et al. 2021c: CDLXXXVIII)

to other areas of Tamuda (Fig. 17). On one hand, the stratigraphic and chronological hiatus between Mauritanian Phases I and II of this study have also been detected in previous excavations, such as those of the Southern Quarter and the "House of the Pilaster" (Fig. 17A-C). A sketch of one of the structures identified by M. Tarradell in 1951 is a very eloquent example of this process (Fig. 17F). This sketch illustrates the dismantling of walls and their rebuilding with different construction techniques. In the first phase, the walls were made of rammed earth with stone foundations and clay-bonded pebbles. However, in a second phase, the walls were systematically dismantled, and a new rammed earth wall using medium-sized clay-bonded masonry was built on top (Fig. 17F). This process and the construction techniques have been identified in Rooms E-18 and E-20 of the Eastern Quarter (Figs. 2 and 7).

Another similarity among the Mauritanian contexts of Tamuda is the identification of stratigraphic facies dated to the early decades of the first century BC, more specifically 80–70 BC (Bernal Casasola et al., 2018, 2019; Bernal-Casasola et al., 2020a, and 2020b). Previous excavations in the Eastern Quarter carried out by M. Tarradell between 1949 and 1951 associated these facies with artisanal occupations of various kinds, including lead metallurgy, pottery making, cereal processing, and food storage, as well as trading activities. Among these, it is interesting to note the common association between rotary mills and complete amphorae, which has already been described. The reinterpretation of the documentation from Tarradell's archive has allowed us to propose a duality of use for these spaces: cereal processing through milling and food storage in amphorae (Bernal-Casasola et al., 2021a). This traumatic destruction horizon is generalized in the 80–70 BC contexts throughout the site, including the "northern midden" and the Southern (Fig. 17E), Western, and Northern (Fig. 17D) Quarters. This suggests a destruction and abandonment event that affected the whole of Tamuda. It corresponds to what M. Tarradell (1960) called "the first destruction of Tamuda," which has recently been placed in a regional political context. This destruction may have had something to do with the dynastic conflicts among the Mauritanian kings and the intervention of the Roman general Quintus Sertorius in favor of one of the contending factions (Bernal Casasola et al., 2018).

When comparing our results to the rest of the stratigraphic contexts of Tamuda (Fig. 17), they show, on the one hand, that the site formation processes identified in our microstratigraphic study in the Eastern Quarter are representative of the town's general urban dynamic. On the other hand, this study clearly shows that the discontinuity of the archaeological sequences is a constant factor in Tamuda, where episodes of occupation and abandonment alternate cyclically, as shown in the stratigraphic sequence of the Eastern Quarter.

Conclusions

For the first time, this study offers a high-resolution geoarchaeological analysis of a diachronic stratigraphic urban sequence for a Mauritanian town. This is the first microstratigraphic analysis of an urban sequence conducted in North Africa. The microfacies analysis of Spaces E18 and E20 in the Eastern Quarter, revealed a complex interaction of deposits and site formation processes resulting from changes in everyday urban life. In this respect, the overlap of different constructions and the alternating active use and abandonment of spaces are very significant. This study examines the functional characterization of the spaces, providing new clues that can only be perceived on the microscale, such as the identification of middening, a combustion feature, and milling by-products associated with fish flour production and other aspects of food processing. These occupations have also been associated with beaten floors and occupation surfaces, the technology and composition of which have also been identified. Furthermore, microfacies analysis shows several subaerial exposition-related features, indicating abandonment periods between short-term occupations. Sometimes these abandonment periods were associated with sudden natural sedimentation processes, like flooding. However, on other occasions, they were long-term processes that culminated in the large-scale restructuring of the urban space. The complex interaction of these natural processes and human activities gives rise to a discontinuous urban biography. This situation is very similar to the current archaeological image of most Mauritanian towns, which are marked by rupture processes and defined by their apparent discontinuous nature. Abandonment facies, natural sedimentation processes, and traumatic destructions have been reported individually at many sites. However, an overview of the chronological and archaeological similarities and differences among these sites is still lacking. What are the intra-site extent and implications of these natural sedimentation processes and traumatic episodes? Regarding their extent, did they affect the whole site, or were they limited to some areas of the urban layout? Are some of these events synchronous between the sites? Some of these traumatic destructions, such as those identified in Banasa (Arharbi, 2010; Arharbi & Lenoir, 2004, 2006, 2011), Kitane or Koudia Talaa (Khayari et al., 2011) were contemporaneous with the destruction event of Mauritanian Phase II at Tamuda.

In conclusion, this article highlights how urban biographies can be reconstructed from studies of urban architecture, material culture, and stratigraphy, particularly when the latter combines geoarchaeological and microstratigraphic analytical techniques, such as micromorphology and μ-XRF, to generate high-resolution stratigraphic data. This concept of urban biography or "biographies of a place" considers the archaeological context as a multidimensional principal unit of analysis. It is a "context-first," interactive, and high-definition approach that uses the archaeological record for reconstructing detailed stratigraphic narratives of urban space (Raja & Sindbæk, 2020). In these narratives, geoarchaeological and microstratigraphic analyses have proven to be very effective (Gutiérrez-Rodríguez, 2018; Gutiérrez-Rodríguez et al., 2019, 2020; Wouters, 2020). Applied to the Mauritanian urbanism, the biographical approach offers a more complex and comprehensive archaeological narrative of individual urban evolutionary trajectories that, in the medium term, will allow a more detailed stratigraphic and chronological comparison between sites. This approach will be key to unraveling the discontinuous stratigraphic nature of the Mauritanian urban reality.

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Data Availability The soil micromorphology datasets analyzed during the current study are available in the GeoDig research platform: Digital technologies applied to the microstratigraphic archaeological record (http://geodig.es).

Declarations

Conflict of Interest The authors declare no competing interests.

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