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**International Master in
QUATERNARY AND PREHISTORY**

Master Thesis

Soil Micromorphology of the Sedimentary Samples from Anta 1 de Vale da Laje, Tomar, Portugal

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ABSTRACT

This master thesis is based on the soil micromorphological study of the sedimentary samples from Anta 1 de Vale da Laje site, located in Tomar, Portugal. The site of Anta 1 de Vale da Laje is one of the sites currently under study within the research framework of the projects Landscape occupation strategies during the Holocene in the Middle Tagus (Es.Ter.Tejo) and Moving tasks across shapes: the agro-pastoralists spread from and into the Alto Ribatejo (MTAS). Asides the stratigraphic problems of the site, it remained unclear the modification successions in time, of the monument and the processes that can be attributed to their sequencing, which were scopes of the abovementioned projects.

Micromorphological study of human impact and natural processes on the environment has been reliant on the interpretation from the study of the undisturbed palaeosols. This study applied the methodological approach of soil micromorphological analyses to understand both the stratigraphic sequence and the evolution of the megalithic tomb of Anta 1 de Vale da Laje site where stratigraphic continuity and discontinuity were observed.

The result of the analyses recognized six (6) periods of activities and three (3) phases of site evolution, as well as identification of human activities relating to agricultural practices, constructions and natural processes such as weathering, leaching, and erosion resulting from impact of rainfall.

Keywords: Micromorphology; Tagus; Megalithic tombs; Stratigraphy; Human activities

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CHAPTER ONE

1. INTRODUCTION

Since the 1980s, numerous archaeological studies have included soil micromorphological studies as one of the several techniques that permit a better understanding of ancient anthropic impacts on soils through agricultural practices (e.g., Romans and Robertson, 1983; Macphail et al., 1990). These investigations reveal that, in addition to macroscopic field evidence, indicators occur that are sometimes only visible under a microscope, thereby giving a complementary and holistic data presentation on the effect of land-use change over a period of time (Nicosia and Stoops, 2017).

Human impact on the environment with particular reference to soils is reflected in agricultural activities such as vegetation clearance performed through uprooting trees, digging out plants or clearance by burning. Other related actions include tillage during cultivation process (Carter and Davidson, 1998) and sometimes construction activities. These activities result in three things, which are soil deterioration as well as enhancement and disturbance of the soil profile thereby affecting the soil's microstructure.

Originally, soil micromorphological analysis was applied to study modern soils, however, two important directions of research on this study have evolved in recent times. The first is the investigation of palaeosols in order to study the development of regional landscapes and climate changes, while the second is the study of Holocene palaeosols focusing on both local and regional interpretations of human influences on pedogenesis (Macphail and Goldberg, 1995), the latter being the focus of this study.

As stated by Sageidet (2000), soil micromorphological analysis is today the most reliable method for identifying and understanding the processes involved in soil formation. Both natural processes and those induced by human impact are included.

Buried soils (palaeosols) can contribute to Quaternary studies through their use as stratigraphic marker horizons and by providing information on Quaternary environments. As to the latter, it is necessary to assume that the pedological features resulting from past pedogenic processes are similar to those produced by the same processes today. It is also necessary to assume that some soil features and processes are uniquely associated with specific environments.

On the basis of these assumptions, certain buried horizons are not only capable of giving indications on climatic, vegetational, topographical and hydrological conditions (Birkeland, 1984) but also the development associated with the soil over time. In general, the buried soil can provide important information about the environment such as the definite and distinct stratigraphic markers, representing a time when a geomorphic surface, now buried, was both stable and subaerial (Ruhe et al., 1971).

Interest in the evolution of the site led to providing more data related to the possible agricultural practices in western Iberia as there are no sufficient data regarding this important aspect of the "Neolithic way of life" and to complement the evidences that exist for the Tagus Valley (López-Dóriga and Simões, 2012; Carvalho et al., 2013; Almeida et al., 2014; Ferreira, 2017). These reasons have allowed proposing the study of the soil micromorphology of the sedimentary samples of Anta 1 de Vale da Laje. This methodological approach is supported by field observation and description based on the earlier excavations of the site (Drewett et al., 1992; Oosterbeek et al., 1992) and recent ones (Almeida and Oosterbeek, 2017, 2018).

Therefore, this master thesis seeks to provide answers to some of the soil Quaternary questions associated with the site of Anta 1 de Vale da Laje, ranging from the difficulty in establishing lower levels of the stratigraphic sequence, to determining the exact nature and spatial extent of human-induced landscape transformations. These transformations can be broadly characterized as direct effects, such as changes in the soil properties resulting from cultivation, or indirect effects related to anthropogenic forcing of past geomorphic functioning (Macphail et al., 1990; Davidson et al., 1992; Courty and Weis, 1997; Gebhardt, 1999).

1.1. AIM AND OBJECTIVES

The aim of this thesis is to understand the stratigraphic settings and the evolution of the megalithic monument of Anta 1 de Vale da Laje (VL1, Tomar, Portugal) using buried soils (palaeosols).

To achieve this aim, the following specific objectives were defined:

1. To identify the stratigraphic phases, and namely to confirm or discard the hypothesis of a layer corresponding to the building phase of the monument, as suggested in the initial stratigraphic interpretation (Oosterbeek et al., 1992) –

This will help to identify and study the stratigraphic continuity and possible discontinuity patterns;

2. To determine the soil forming processes, namely complementing previous sedimentological studies (Botón Garcia, 2000) – This is to understand various factors involved in the development of the soil;
3. To determine the nature of the land use at the site, and namely the presence of a palaeosol rich in phosphates, that has been interpreted as an indicator or important animal pasture in previous studies (Migliavacca, 2000) – This is to understand the activities of human and natural processes that occurred on the site;
4. To understand the construction phases of the megalithic monument, namely its supposed extensive remodelling in the Chalcolithic, as suggested in Oosterbeek (1994) – This will help to build a relative chrono-cultural sequence for the site.

1.2. REGIONAL SETTING

The Alto Ribatejo is a sub-region of Central Portugal defined by Oosterbeek (1997) with a land mass of approximately 2500 km^2, located along the river banks of the Tagus basin. The hydrographic system is controlled by tectonics, so the Tagus River dominates the hydrographical system in this area (Eastwest), followed by the Zêzere River, which flows into the Tagus from the north and east, and the Nabão River, which flows into the Zêzere from the north (Oosterbeek, 1997; Cruz, 1997; Rosina et al., 1998).

The geomorphology of the region is diverse because of the presence of different bedrocks. In fact, in this region there are three main geological units: the detritic formations of the Cenozoic Tagus sedimentary basin which extends mostly along the lower Tagus river valley of central Portugal; the Hesperic (Ancient) Massif composed mainly by schists, quartzite and granitoids; and the carbonated formations of the Estremenho Limestone Massif. Their characteristics are related with the types of substrate, of which we must emphasize the quartzite crests, certain areas with schists and granites, terraces and flood plains in the clay-sand substrate, and karstic phenomena in the areas with limestone outcrops (Teixeira and Gonçalves, 1980). The relief is cut by river courses with accentuated valleys and small alluvial areas (Daveau, 1980).

1.3. GEOGRAPHIC LOCATION AND THE LANDSCAPE

Anta 1 de Vale da Laje site is located in the municipality of Tomar, Santarém district, Portugal. It is situated within the geographic coordinates (GPS WGS84), Latitude N 39º33'22.6" and Longitude W 008º18'08.1". The site is approximately 160 meters above the sea level. It belongs to the hydrographic system of the Zêzere River, with approximately 10 minutes walking distance from the mentioned river (Fig.1).

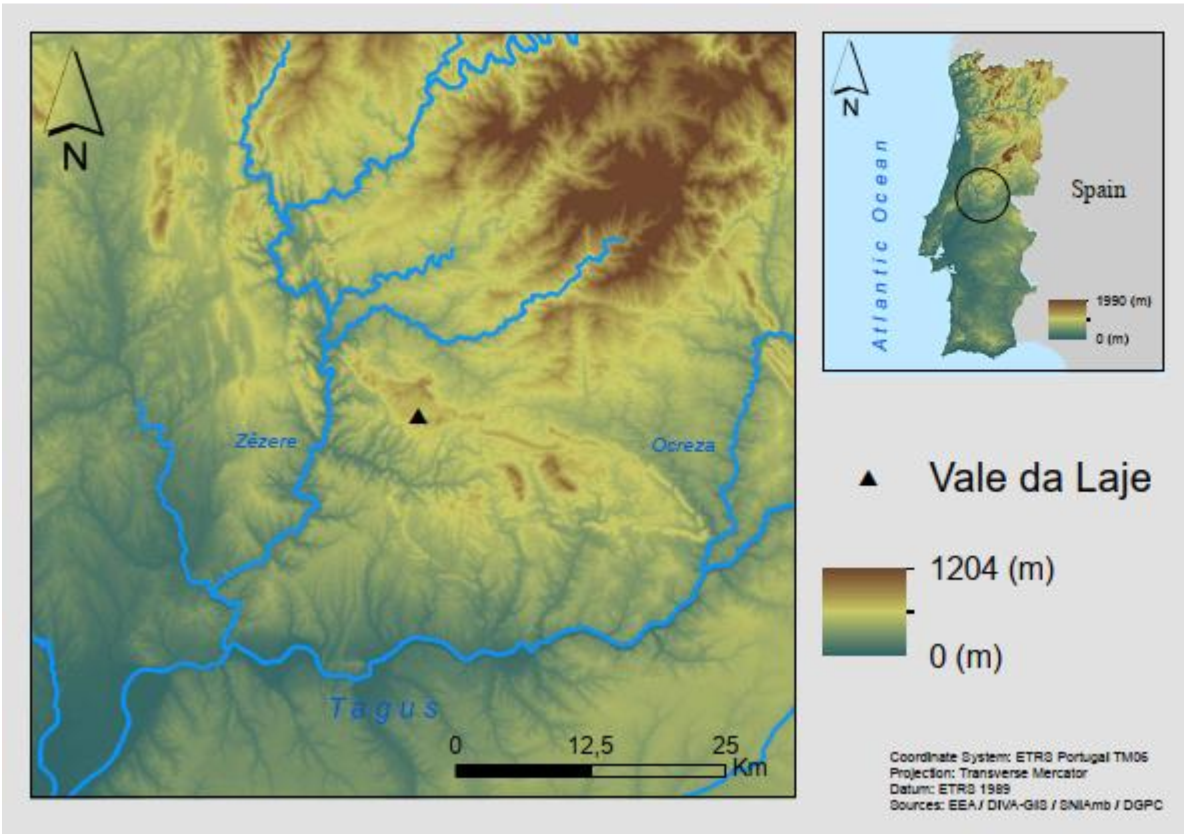

Figure 1: Map showing the location of Anta 1 de Vale da Laje site (Map: Luís Costa).

Anta 1 de Vale da Laje is one of the five (5) Vale da Laje megalithic tombs, previously recorded within this region, of which although geographically defined are currently destroyed (Oosterbeek et al., 1992). The site is positioned in a small elevation that dominates the landscape. It has a total length of about 5.8 meters, with a tumulus of around 9 to 10 metres, and a height of 1.75 metres presenting a small stone cairn (Drewett et al., 1992; Oosterbeek et al., 1992; Cruz 1997; Oosterbeek, 2007). The monument features a pentagonal chamber with a small corridor oriented towards East, formed by two small lateral orthostats on each side and a slab. The capstones are fractured (Fig. 2)

Figure 2: Anta 1 de Vale da Laje Megalithic Tomb (Photo: Nelson J. Almeida, IPT).

1.4. GEOLOGY AND GEOMORPHOLOGY

The bedrock in the site of Anta 1 de Vale da Laje, which is within the Alto Ribatejo region, is composed of gneiss of the Precambrian metamorphic basement, characterized by the abundance of large feldspars, schist, muscovites, micas and biotite crystals (Fig. 3). The alteration of these rocks resulted in their disintegration into single grains components, with the production of medium to fine, weathered sandy materials. As a result of this weathering process, rock outcrops generally have smoothly rounded shapes, resembling those typical of granitic rocks.

The megalithic structure is located on top or nearby the gneiss outcrops. The gneiss used for the construction was close to the site and relatively easy to be quarried because of the sub-parallel schistosity nature of the gneiss. Moreover, the weathering state of the rock facilitates its manipulations for different use.

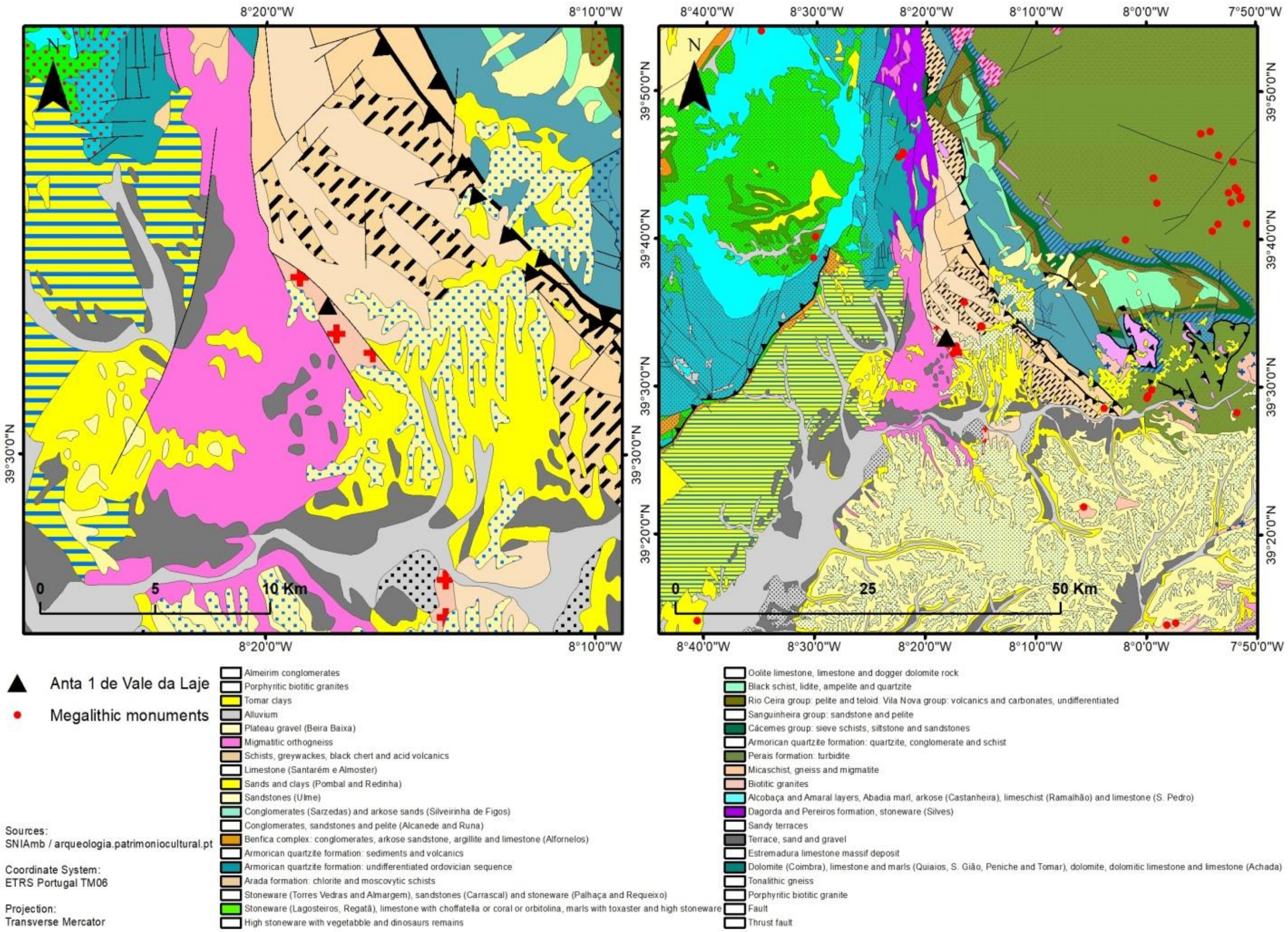

Figure 3: Map showing the regional geology with the location of Anta 1 de Vale da Laje site (Map: Luís Costa).

The lithology of the area which corresponds to the Alto Ribatejo regional setting is composed of limestones and marls (with weak presence of flint) to the West, dendritic deposits filling in the river beds and schist, gneiss and granites to the East (where the monument stands). Schist, greywacke, quartzite and granite are the more abundant rocks near the Anta 1 de Val da Laje (Fig. 4) while clay, silts, sands, and pebbles make up the dendritic drainage basin. The Holocene alluvial sediments, the Pleistocene wide fluvial terraces, the karstic cave fillings (Limestone Massif), and the dendritic coverings represent the regional Quaternary deposits of the region. The Holocene alluvial sediments may arrive at a depth of more than 9 meters in the Tagus sedimentary basin, but erosion tends to render shallow Holocene sequences above 50 metres above the sea level.

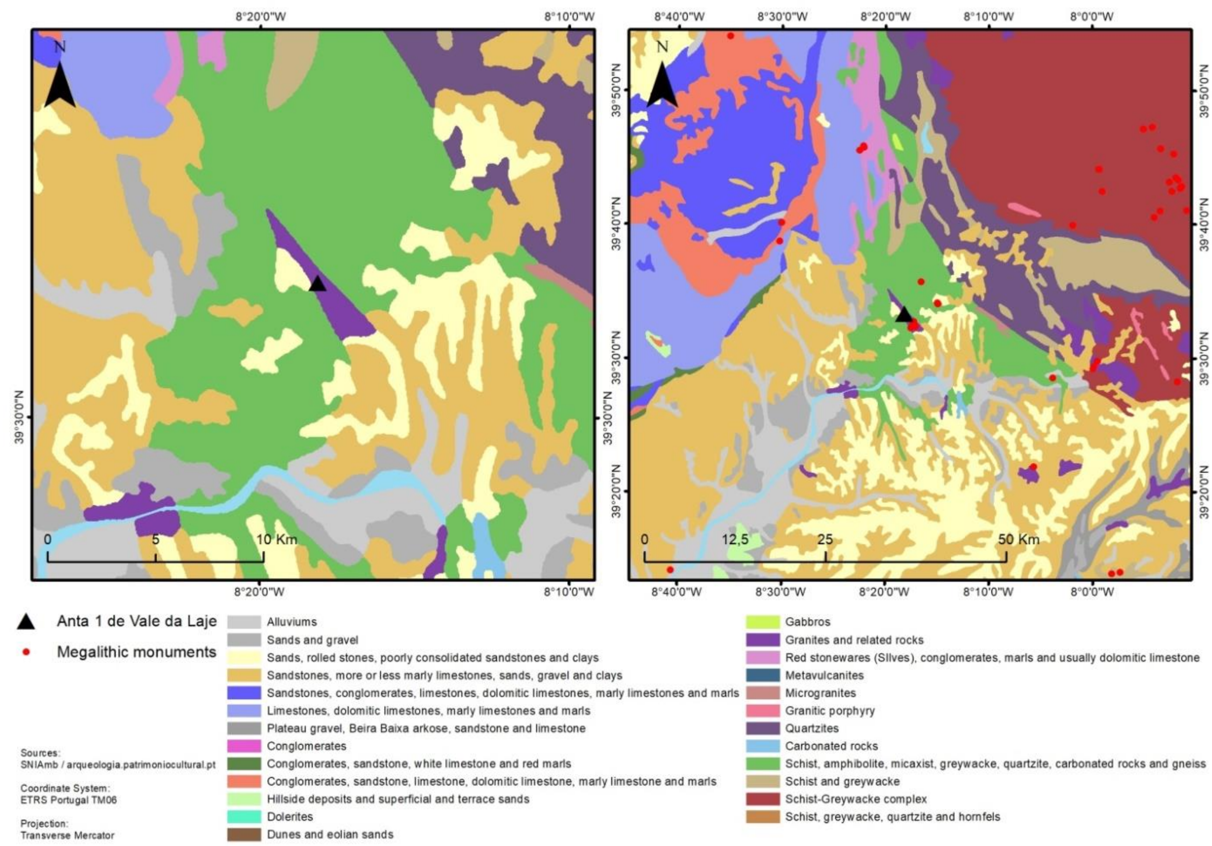

Figure 4: Map showing the regional lithology with the location of Anta 1 de Vale da Laje site (Map: Luís Costa).

CHAPTER TWO

2. STATE OF THE ART

Megalithic monuments are among the earliest and often one of the most visibly prominent and permanent archaeological structures. So many of these structures have been used and reused over the years. Based on their chronological context within the Neolithic (Scarre, et al., 2003), they give a shred of well-rounded evidence for various parts and components of the ancient sedentary agricultural lifestyle (Rodder, 1984; Sheratt, 1990). These unique structures, among other things, have drawn attention from those who are interested in the studies of the early part of humankind to research on this Neolithic phenomenon.

These structures fall within the spread of farming, from the middle Neolithic, a period during which the megalithic phenomenon was believed to have flourished and diffused along the Atlantic façade of Europe, with limited later incursions into the Mediterranean (Gonçalves, 1999; Boaventura, 2009; Scarre and Oosterbeek, 2010; Rocha, 2015; Carvalho, 2016; Paulsson, 2017).

In this study, this literature review will bring out the importance attributed to megalithic monuments and provide a perspective of their status in contemporary scholarship. In particular, the megalithic monument of Anta 1 de Vale da Laje shall be framed in the broader context of European prehistory, and an attempt shall be made to show how its role and significance in prehistoric studies changed through time.

Megalithic monuments are features and symbolic relics of early farming societies of Western Europe and many megalithic monuments have been reused in post-Neolithic times (Cummings, 2009; Scarre et. al., 2011). The use of large stone slabs defines them, sometimes set in upright positions as menhirs or stone rows or rings, and at other times arranged into boxes or chambers to create megalithic tombs (Scarre et al., 2011).

Over the years, the Neolithic period of Western Iberia has been a subject of discussion (Guilaine and Veiga Ferreira, 1970; Arnaud, 1982; Oosterbeek, 1997; Zilhão, 2001; Carvalho, 2008). The subject matter of this dissertation is based on earlier works and interpretations on the Alto Ribatejo sub-region (Oosterbeek, 1994; Cruz, 1997) in inland Central Portugal, till the more recent ones (Carvalho, 2008; Cruz, 2011; Cruz et al., 2014; Almeida, 2017; Almeida et al., 2017; Scarre and Oosterbeek, 2019) that contributed to current knowledge with regard to megalithic monuments.

Portugal, occupying the southwestern region of the Iberian Peninsula, is situated within an area of broader importance for understanding the nature, timing and direction of the Mesolithic-Neolithic transition in Europe (Zilhão, 2011) and its posterior development, and hence, the need for this study.

The Alto Ribatejo sub-region of Portugal, which houses the Anta 1 de Vale da Laje, is distinguishable from other sub-regions by the fact that it represents the contact area of the three major different geomorphological units. The Ancient Massif to the East, the Estremadura Limestone Massif to the West and the Tagus tertiary basin to the South and has been the focus of systematic research for more than two decades till present (Cruz, 1997, 2011; Oosterbeek, 1997, 2001, 2004; Almeida, 2017; Almeida et al., 2017).

Although still a matter of debate, research conducted in this region has led researchers to suggest the presence of two leading cultural traditions during the initial phases of neolithisation. One to the West, expressed in the cave burials (Caldeirão, Cadaval, Ossos, Nossa Senhora das Lapas and Morgado) and another to the East and South, shown in open air habitats (Amoreira, Penhascoso) and later leading to the construction of megalithic tombs (Anta 1 de Vale da Laje, Anta da Lajinha, Anta da Foz do Rio Frio, Anta do Penedo Gordo). Oosterbeek (1994), has suggested that while the former stands for a continuum as a result of the first contact with Mediterranean groups integrated into a “Cardial Ware network”, the latter can be attributed to the interactions with the Mediterranean world arriving at the region from the interior (Oosterbeek, 2004).

Moreover, distinct realities of the Neolithic transition process converge into this territory, which seems clear, in terms of the archaeological record, and a clearer manner, in funerary contexts. In the karstic settings to the West (Nabão valley), there is an extensive use of natural cavities by communities associated with a Cardial tradition, recurrently related to coastal areas such as the Portuguese Estremadura. In parallel, the Tagus valley area is dominated by megalithic tombs, in good accord with the Alentejo and Beira Interior traditions (Oosterbeek, 2003). Nonetheless, the chronological framework of these supposed distinct realities is still a matter of debate among experts (Almeida et al., 2018). Accepted dates for the beginning of the Early Neolithic are far from the earliest megalithic tombs in the region that seem to date back to the Middle Neolithic (Burbidge et al., 2014; Diniz, 2018; Neves and Diniz, 2018).

Archaeologically, the Alto Ribatejo sub-region has produced variants on the paradigms of Neolithization. Prominent among these is a drawing away from focus on coastal spread followed by inland dispersal of people ("Maritime Pioneer Colonization", Zilhão, 1997), towards the possibility of overland spread along river valleys and a balance between the movement of people and that of technology/ideas (integration) (Oosterbeek, 2001). The lengthy Mesolithic-Neolithic co-occupation or transition in the coastal regions of Portugal has led to increasing emphasis on Epipalaeolithic (Early Mesolithic) communities as the precursors for integrative Neolithization (Scarre et al., 2003; Carvalho, 2010), unlike other regions of Atlantic Europe (Scarre, 2007). In fact, besides a few Early Mesolithic contexts discovered in these inland areas, the lack or small expression of Late Mesolithic sites still remains, although recent years have raised several possible explanations that consider problems of research (and not necessarily of historic realities) as having influenced the current dispersion of evidences (Oosterbeek et al., 2006; Almeida, 2017).

Radiocarbon and luminescence dates as early as c. 4000 BC have been ascribed for megaliths in the Tejo valley and various parts of Portugal (Scarre et al., 2003; Cruz, 2007; Scarre and Oosterbeek 2010), but once more, chronology is still an issue with several colleagues indicating the need for absolute dates of culturally-significant and short-lived samples at the detriment of others (e.g., charcoal, sediments, ceramics).

There have been several discussions and debates as to the different angles to view megaliths. Such considerations include the purpose of construction, the methods of construction and its extensive usage which is in nexus with the character of the monument, its symbolism as well as the social and economic context.

Legrand d´Aussy, French antiquarian for example, held the view that the erection of megalithic monuments by the prehistoric communities was to demonstrate their ability to make such construction despite the large size of the stones (Legrand, 1824). About five decades after, Fergusson (1872) opined that the construction of the monument was just for the purpose to impress. Other scholars have even attributed megalithic monument architecture as a criterion for urban civilization (Childe, 1957) and some archaeologists classified monumental structures as an index of development of societal complexities (Scarre, 2002). However, recent approaches to the study of megalithic monuments have focused on the issue of their materiality (Scarre, 2004a), especially the evidence of the unworked nature of the stones.

Concerning the materiality, some of the questions that have previously been raised include the use of this particular method of construction by early sedentary communities especially in the lands bordering the Atlantic, the extensive usage of this methodology and the prominence of the structure.

Previous studies have however shown that the use of unworked stones for the monument construction revealed that there is a close connection between the monument and the stone provenance (Scarre et al., 2011). Some of the critical questions that have been addressed are the preference for particular outcrops with specific shapes, sizes and colours of stones and how the individual arranged the megalithic blocks in the building of these monuments (Kalb, 1996; Tilley 1996; Jones, 1999; Trevarthen, 2000; Cummings, 2002; Scarre, 2002, 2004b; Bradley and Phillips, 2008; Mens, 2008).

This recent approach has succeeded in demonstrating that the choice of stones was not random and that, for instance, varieties of stone combined were for the construction of the monument. The arrangement of the stones was systematically carried out such that it reflects their nature and provenance. Hence it is clear that the origin of the stones was put into consideration by the communities that built the megalithic tombs (Scarre et al., 2011).

Another critical question, however, is whether these monuments were constructed indeed within "domesticated landscapes". For instance, in most of the areas in Western Europe, it was suggested that the construction of the first megalithic monuments was at the beginning of the Neolithic (in terms of pottery and, probably, sedentary farming) after an interval of a few centuries. For example, the first megalithic monuments in Cantabria are likely to be dated to the late 5th millennium BC, several centuries after the Mesolithic-Neolithic transition (Arias et al., 2006), which is the same pattern mirrored in Britain, and southern Scandinavia. Hence major monuments in many areas can be said to belong to a phase referred to as "consolidation" phase which followed several centuries after the beginning of pottery and domesticates. However, it is not inevitably the case that the landscapes in which they were built had not extensively been cleared of trees, nor that they were intensively cultivated. Of course, the context is particularly not the same in areas of rough or mountainous terrain that may be less attractive to early cereal cultivators and where pastoralism may have formed a significant component in Neolithic subsistence economies (Scarre et al., 2011), as it is being suggested for Central Portugal based on the archaeofaunal record, among others (Almeida, 2017).

The early intervention works carried out on the site of Anta 1 de Vale da Laje (Oosterbeek et al., 1992) led to several conclusions and gave way for new directions for present investigations.

The excavation of the site was first carried out in 1989 by Luiz Oosterbeek and Ana Rosa Cruz, to study the Neolithic in the Valley of Nabão, and the excavation focused only on the tumulus. In 1990, the excavation strategy consisted of establishing an axis through the monument towards the rising sun and later reconstituted. While in 1991, the focus was on a detailed study of specific contexts: waist, palaeosol, buttresses and other structures (Oosterbeek et al., 1992). From the correlation between the stratigraphic units and the artefacts found, four layers were identified, (A, B, C and D):

- Layer D is a silty-clayey palaeosol which was defined under the external access floor to the corridor and at the base of the northern part of the chamber (Oosterbeek et al., 1992). This silty-clayey palaeosol corresponds to the beginning of Megalithism in the Tagus Valley (Oosterbeek, 1994). Some of the artefacts collected in this layer seem to correspond to human occupation in the Holocene of macrolithic facies, but the same materials may belong to layer C, (Oosterbeek et al., 1992);
- Layer C was considered "Neolithic of ancient tradition", contemporary with the individual graves in caves in the Nabão River, a major tributary of the Tagus Basin. This pointing to a different origin in the 5th millennium BC;
- Layer B which is early Chalcolithic, contemporaneous with the collective burials in caves in the second half of the 4th millennium BC and Layer A being late Chalcolithic (Beaker) belonging to the second half of the 3rd millennium BC and with strong correlations with the individual burials (Drewett et al., 1992, Oosterbeek et al., 1992).

The monument excavated in the early ´90s, continues to be the studied as several research works have been done over the last few decades. Such studies include archaeobotanical studies; the data obtained allowed the creation of a generic palaeoecological framework with a chronological period between the 6th and 3rd millennium BC (Moleiro, 2015). The archaeobotanical studies revealed for Anta 1 de Vale da Laje, among others species, the presence of *Erica arborea* (white heather); *Arbutus unedo* (arbutus); *Calluna sp.* (heather-vulgar); *Erica sp.* (heather) and *Cistaceae* (steva); *Rhamnus / Phillyrea* (adern**o**); *Leguminosae sp*. (vegetables); *Ligustrum sp.* (common alfena); *Olea sp*. (Oliveira);

Thymelaeaceae sp. (trovisco); *Cornus sp*. (sanguinho-legítimo) and *Pinus sp.* (Pine) (Allué, 2000).

An archaeopetrographic study has also been carried out on some sites in the Alto Ribatejo, namely Anta 1 de Vale da Laje (Tomar), Anta da Lajinha (Mação), Anta da Foz do Rio Frio (Mação), and Anta do Penedo Gordo (Gavião). This was done to provide relevant palaeoeconomic data on the communities that used them and the territory they exploited, while at the same time provide data to uncover the criteria that led to their choice from the diverse resources available, especially the lithic construction materials (Moleiro, 2015). The result showed that in Anta 1 de Vale da Laje, the source of the raw material location was approximately 100 m from the monument which is within a range of 1 to 2 km, a trend evidenced in other European areas by Thorpe and Williams-Thorpe (1991).

More recent works on the site have focused on continued research based on the earlier studies (for example, Oosterbeek et al., 1992) to obtain information about the archaeological and architectural aspects of the site related to the various moments of the construction of the monument, its use and alteration (Almeida and Oosterbeek, 2017, 2018). To allow identifying and understanding the different phases of the monument construction, surrounding vegetation dynamics, as well as the modification that might have occurred with studies of the palaeosols from the site.

At the beginning of the 1960s, interest in Pre-Quaternary palaeosols has been increasing on several fronts, as they were discovered in many non-marine sedimentary sequences (Retallack, 1997a) and even in deep-sea cores (Ford, 1987; Holmes, 1992). The study of fossil soil is essentially compatible with the overall aims of sedimentology to reconstruct ancient environments and geological processes. Palaeosols now often appear in accounts of sedimentary geology (Esteban and Klappa, 1983; Wright, 1986) and weathering process (Martini and Chesworth, 1992; Ollier and Pain, 1996).

Therefore, in this thesis, these theoretical frameworks will be used to achieve the aim of this study because structures just like the megalithic monuments were partly or entirely built of soil materials, and depending on the position within the structure it will undergo alterations, modifications by processes associated with active soils or buried soils.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1.1. SAMPLE COLLECTION

With regards to the ongoing archaeological intervention works at the archaeological site of Anta 1 de Vale da Laje, Tomar, Portugal, a total number of seven (7) samples (Fig. 5) were obtained from already excavated sections of the site. Sampling was performed by removing undisturbed sample blocks by excavating around the desired location and covering them with plasters materials. The sampling was done at different and relevant stratigraphic units from three (3) profiles sections of the site (H, F and G) (Fig. 6, 7 and 8). The samples were from squares G28 (stratigraphic unit 128), H28 west profile (S.U. 115), saprolith, H27 (S.U. 128), H27 WP (S.U. 118), H28 (S.U. 111), F27 (S.U. 131) and F27 (S.U. 122) respectively.

The preparation and the micromorphological analysis of the samples was carried out at the Geoarchaeology laboratory of the Institut de Paleoecología Humana I Evolucío Social (IPHES), Tarragona, Spain. The study of these samples formed the bedrock for this master thesis.

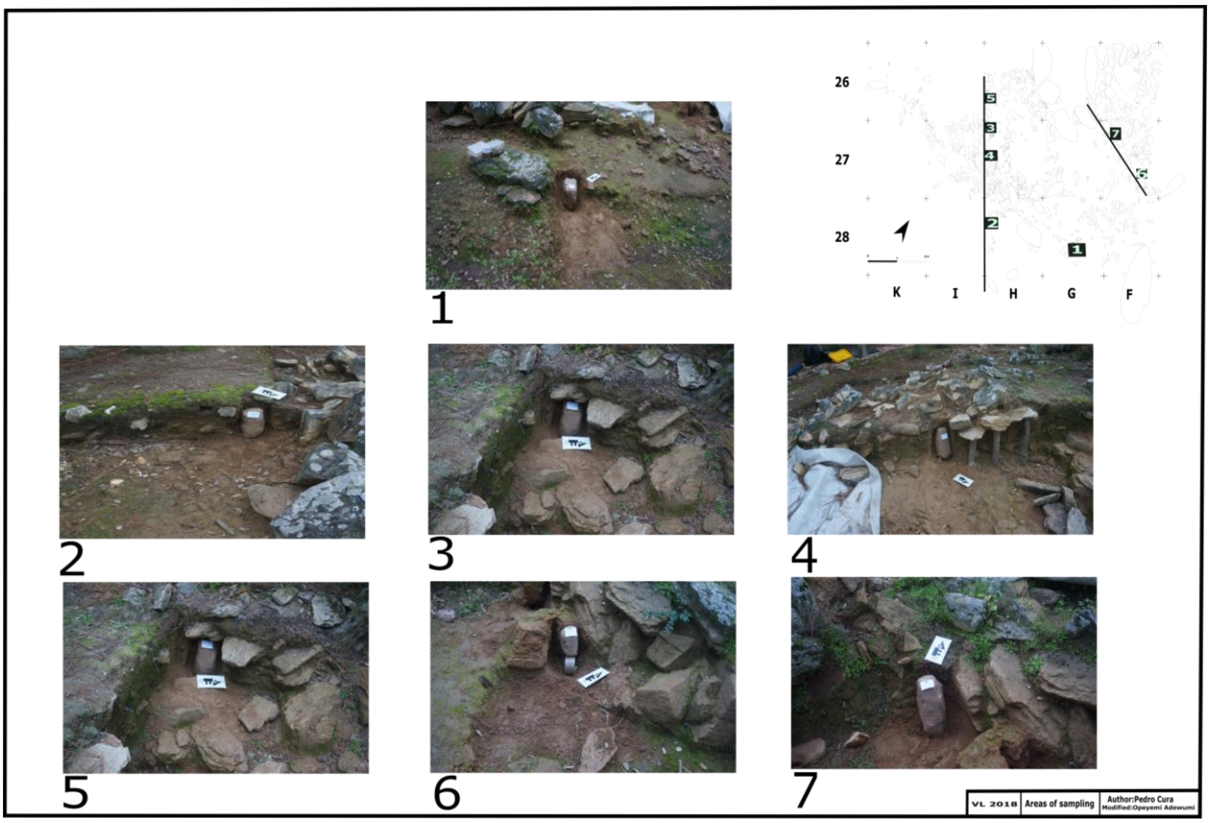

Figure 5: Plan showing the relative position of sampling

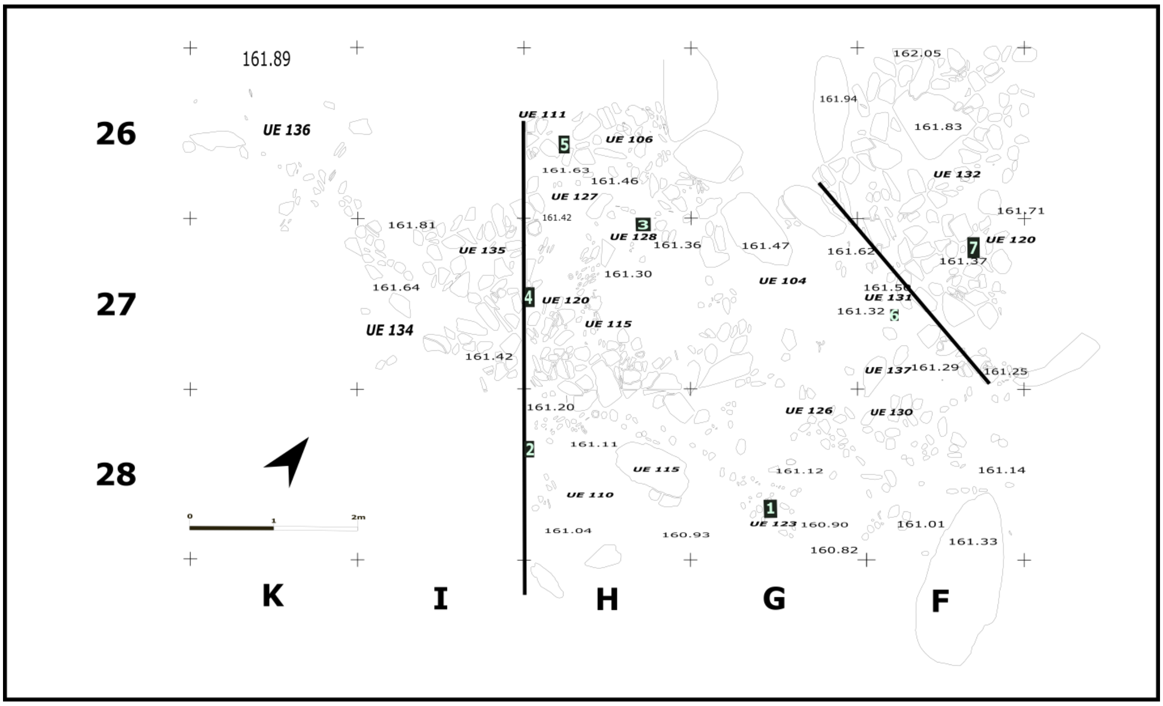

Figure 6: Plan showing section view of the sampled units (Adapted from Pedro Cura drawings in Almeida and Oosterbeek, 2019).

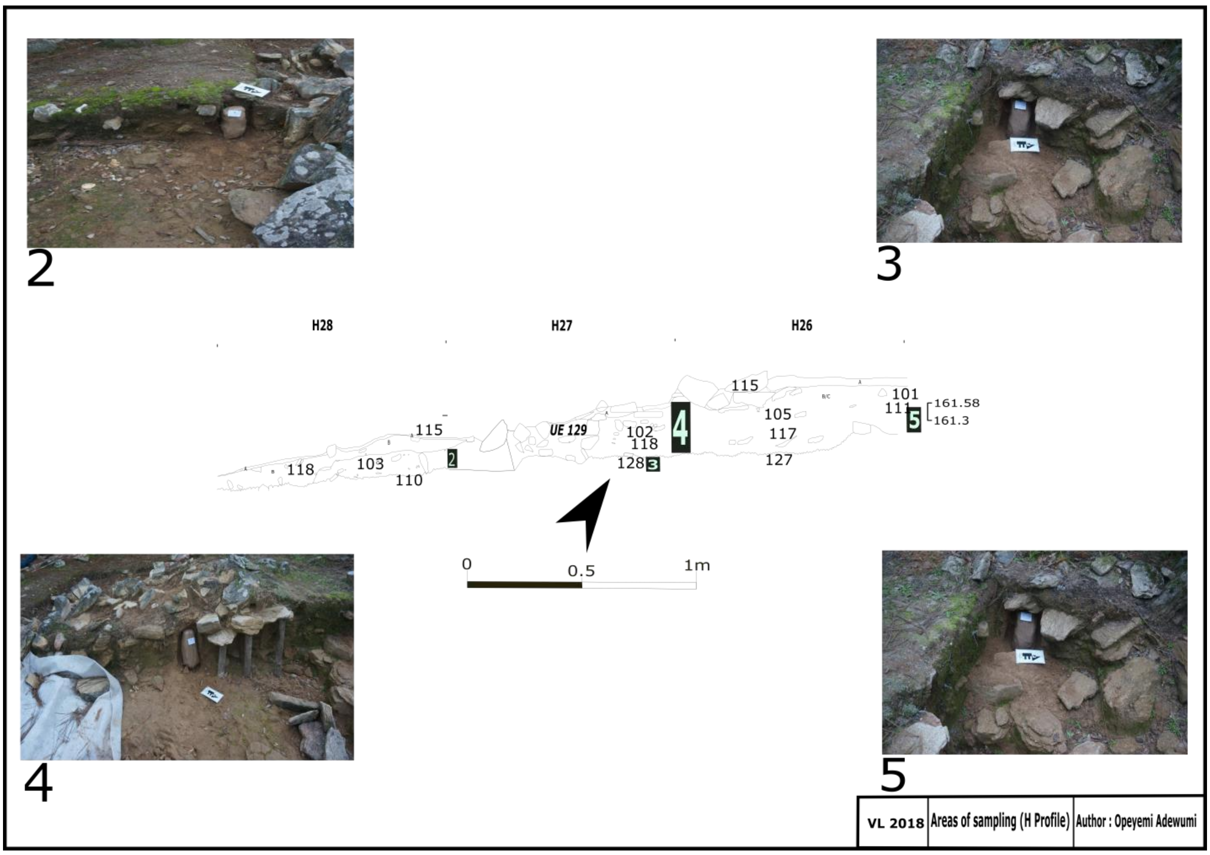

Figure 7: Plan showing the position of sampling in the H profile section (Adapted from Pedro Cura drawings in Almeida and Oosterbeek, 2019).

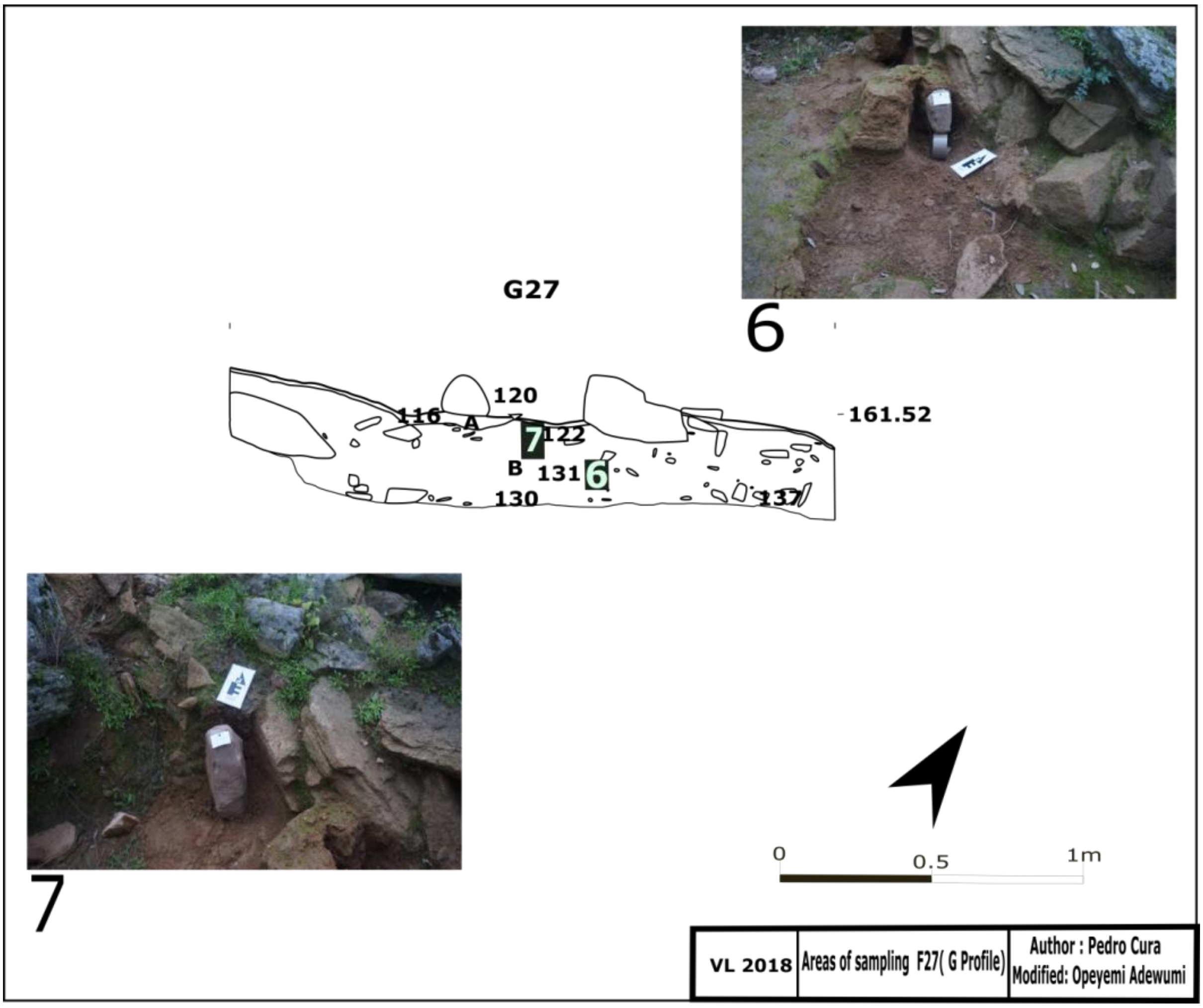

Figure 8: Plan showing the position of sampling in G/F profile section (Adapted from Almeida and Oosterbeek, 2018).

3.1.2. FIELD DESCRIPTION

The description of the samples obtained was done using two (2); H and G out of the three (3) profile sections as mentioned above because the samples obtained at the F27 section are really located at the Western part of the G27 section, therefore allowing a clear presentation of the data as shown in the tables below. Nonetheless, in the general results shown in the annex, each of the samples were described and interpreted independently for holistic understanding. The Munsell soil colour chart was used for the colour description of each sample. The field description was also done taking into cognisance the size of the stones in the sampled stratigraphic units of the site and the material recovered from each unit during the previous excavations.

Stratigraphic Units	Facies Description	Materials
103	Massive sandy clay with pebbles and angular cobbles. Colour 10YR 4/3, (Brown). Approximately 20cm in thickness.	1 flint scrapper, 1 fragment of flint and 1 fragment of pottery.
111	Stratified sandy clay with angular cobbles colour 10YR 6/4 (light Yellowish Brown). Approximately 20cm in thickness.	2 flint flakes, 1 quartz flake and 1 quartzite, 1 flint fragment and 1 pottery fragment.
115	Gravel boulders. Colour 10YR 5/4 (light Yellowish Brown). Approximately 30cm in maximum thickness.	1 pottery fragment, second boulder belt.
117	Stratified sandy clay with angular cobbles. Colour 10YR 4/6 (Dark Yellowish Brown). Approximately 10cm in thickness.	1 flint flake, 1 quartz flake and 1 flint.
118	Massive sandy clay with pebbles. Colour 10YR 6/4 (light Yellowish Brown). Approximately 20cm in thickness. It appeared in H28 and H26	1 retouched bladelet, 5 flint flakes, 5 quartz flakes and 1 flint
110-127-128	This is a saprolith made from packed granitic angular cobbles. It is a stratification surface unit.	2 quartz flakes, 1 in amphibolite, 1 quartz and 1 flint (In Unit 128).

Table 1: Description of the sampled stratification units of Anta 1 de Vale de Laje (H profile Section) and materials according to Almeida and Oosterbeek (2017, 2018).

Stratigraphic Units	Facies Description	Materials
120	Sandy clay with boulders. Approximately 20cm in thickness.	It is in the second belt
122	Stratified sandy clay with angular cobbles. Colour 10YR 4/6 (Dark Yellowish Brown). Approximately 20cm in thickness.	(1 in quartz and 2 in quartzite), scallops (1 in flint, one in quartzite, 5 in quartz), 3 fragments of quartz and 1 of quartzite and 1 arrowhead in flint.
130-137	This is a saprolith made from packed granitic angular cobbles. It is a stratification surface unit.	
131	Massive sandy clay with boulders in vertical positions. Colour 10YR 4/6 (Dark Yellowish Brown). Approximately 20cm in thickness.	Quartz flake.

Table 2: Description of the sampled stratification units of Anta 1 de Vale de Laje (G profile Section) and materials according to Almeida and Oosterbeek (2017, 2018).

3.2. SAMPLE PREPARATION

Upon the arrival of the samples sent by the Museu de Arte Pré-Histórica, Mação, Portugal to the Geoarchaeology laboratory of the Institut de Paleoecología Humana I Evolucío Social (IPHES), Tarragona, Spain, they were placed inside a furnace machine at approximately 60^0C (Fig. 9) for three (3) weeks to dry the samples. After drying, this will ensure that any form of water is extracted from the samples and will allow good resin penetration. (Fig. 10)

Figure 9: Drying Furnace.

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Figure 10: Samples after drying in the furnace.

The polyester resin was prepared and the samples were submerged in it (Impregnation). Afterwards, they were placed inside the Vacuum chamber (Fig. 11) for (2) days.

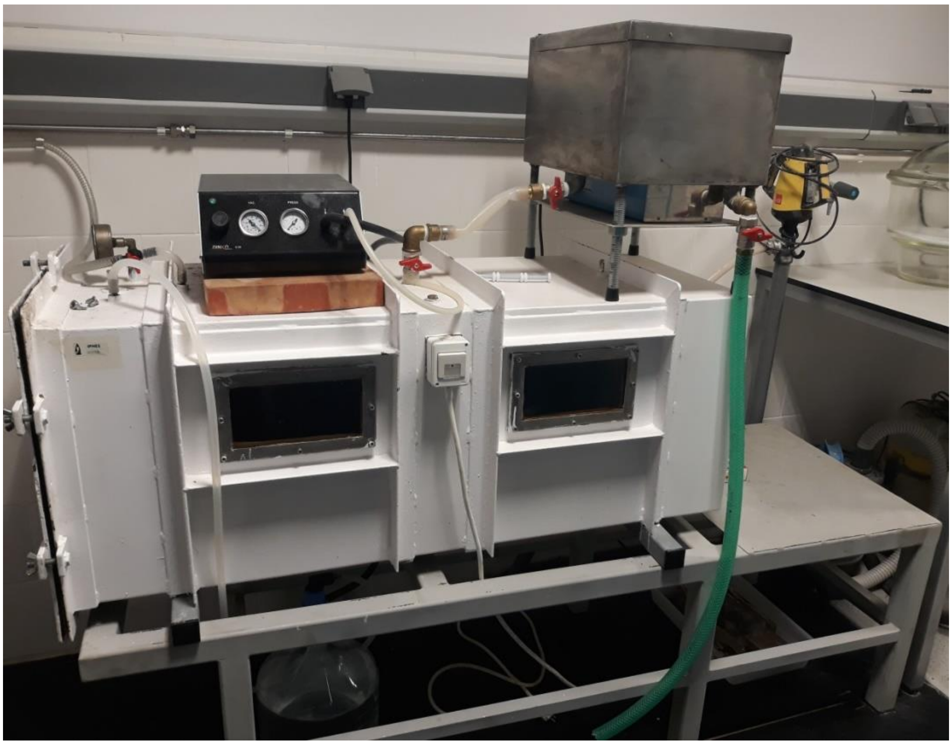

Figure 11: Vacuum Chamber.

3.2.1. RESIN PREPARATION

The polyester resin (Synolite 0328-A-1) was mixed with Acetone (3:1 ratio). This solution was catalysed by Butanox M50 (Methyl peroxide) (0.001%/1l. of polyester resin) and hardened with Cobalt Octate (0.0025% /1l. of polyester resin).

After the addition of the mixtures to the sample, they were placed in the vacuum chamber (Fig. 11) for approximately 67 hours (2 days, 19 hours and 30 minutes). This is to allow the mixture to get the samples hardened and ready for cutting (Fig. 12).

The samples were also placed outside the chamber in an open space for a few days to make it more hardened. After this hardening process, the samples were sliced or cut (Fig. 13) with a diamond cut-off saw to obtain a flat surface with the size of the microscopic preparation that is required.

After cutting, there were a total number of 14 samples to work with (Fig. 14 and 15). These samples were used for the next stages of the thin section fabrication.

Figure 12: Samples polymerized.

Figure 13: Cutting of the samples.

Figure 14: Samples in form of blocks prepared for dying above glass microscopic slide preparations.

Figure 15: Dying the block samples on a glass microscopic slide and labelling.

3.3. THIN SECTION FABRICATION

The following steps were taken as protocols during the thin section fabrication.

STEP 1: CUTTING THE BLOCK

The large blocks were cut into smaller sizes to fit the glass to be used, this was carried out for all the samples and dividing each long block sample to be used for the thin section into two (upper and lower) to have a complete representation of each sample (Fig. 16 and 17).

Figure16: Samples after cutting.

Figure17: Samples cut to fit the glass slide.

STEP 2: PREPARATION OF THE GLASS SLIDE

The glass slides to be glued to the block samples were flat in order for the block sample section to end up with a constant thickness. Several glass sides were prepared (cleaned and polishing the edges as some do not fit on the grinding wheel). Several glasses were prepared because they were needed at certain phases of the thin section preparation. This process of polishing the edges was accomplished using the 240 grit grinding wheel (Fig. 18).

Figure 18: Glass grinding wheel for the glass slide preparation.

STEP 3: GLUEING THE SAMPLES TO THE FIRST SET OF GLASS SLIDES

The first gluing process was carried out with the preparation of the epoxy to be used. The already labelled samples were glued to the prepared glass slides from step two (2) (Fig. 19 and 20).

STEP 4: PREPARATION OF THE DEFINITIVE GLASS

Having prepared enough glass slides in step two (2), some of these slides were picked for this purpose. The edges of the glass slide at this stage was done to make the glass more resistant when it is been attached to the sample holder of the grinding wheel. The surfaces of the glass were marked for polishing and the grinding wheel was left to work for 5 minutes for the purpose of regularising the surface of the glass slide (Fig. 18, 21 and 22).

Figure 19: Applying epoxy to glue the samples.

Figure 20: Glued samples with labels.

Figure 21: Marked definitive glass slide for polishing.

Figure 22: Polishing the glass slide.

STEP 5: CUT THE CHIP (FIRST)

The size of the glued sample was reduced (Step 3, Fig. 20) to slightly smaller size, close to a thin section size (Fig. 23) using the slicing saw. The samples were cut on the slicing saw to a measure of 7mm from the definitive glass slide.

Figure 23: Cutting the first chip off the glued sample.

STEP 6: FIRST POLISHING THE SAMPLES

The samples from step five (5) were subjected to polishing as traces of the slicing saw were noticed on the surface of the sample slide (Fig. 24 and 25). The surfaces of the samples were marked and were polished until the marks disappeared and the grinding wheel was left to work for 5 minutes for the purpose of regularising the surface of the sample.

STEP 7: GLUE THE SAMPLE TO THE POLISHED GLASS (SLIDE)

The already polished samples from step six (6) were cleaned. Some epoxy was added and placed inside a small vacuum chamber set at 0.8 atmospheric conditions to allow the epoxy to flow more easily and allowed it to soak easily. This sample was then glued to the polished and labelled glass slide. Thereafter, they were placed in a big vacuum chamber and left to glue properly (Fig. 26, 27 and 28).

Figure 24: Marked surface of the sample for polishing.

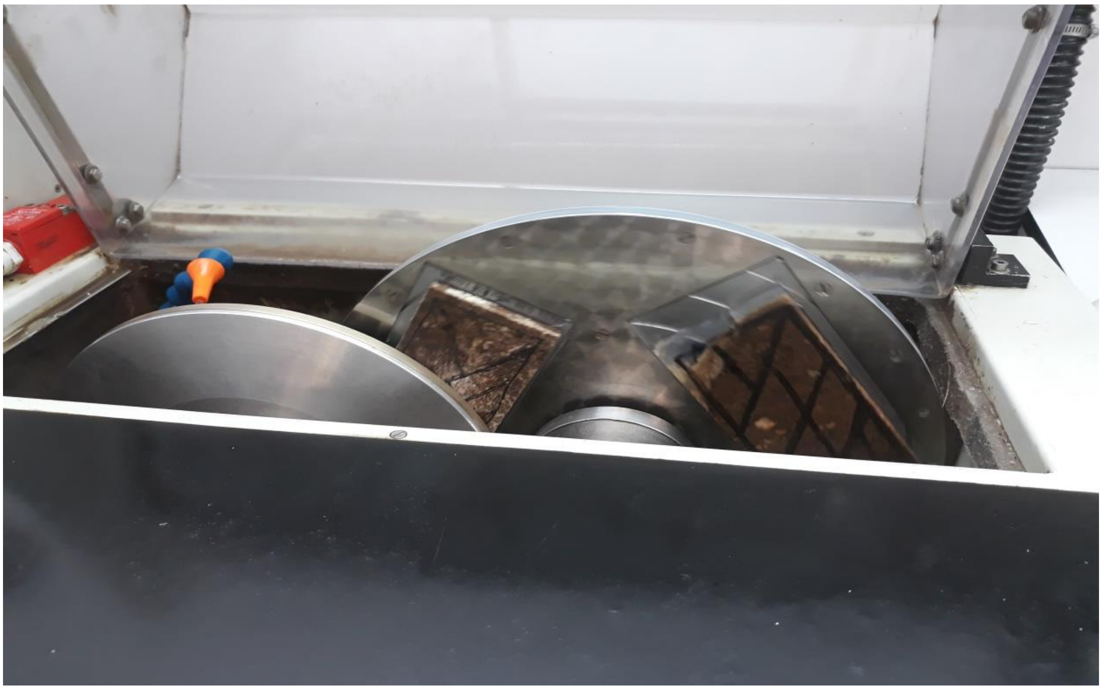

Figure 25: Polishing the sample surface.

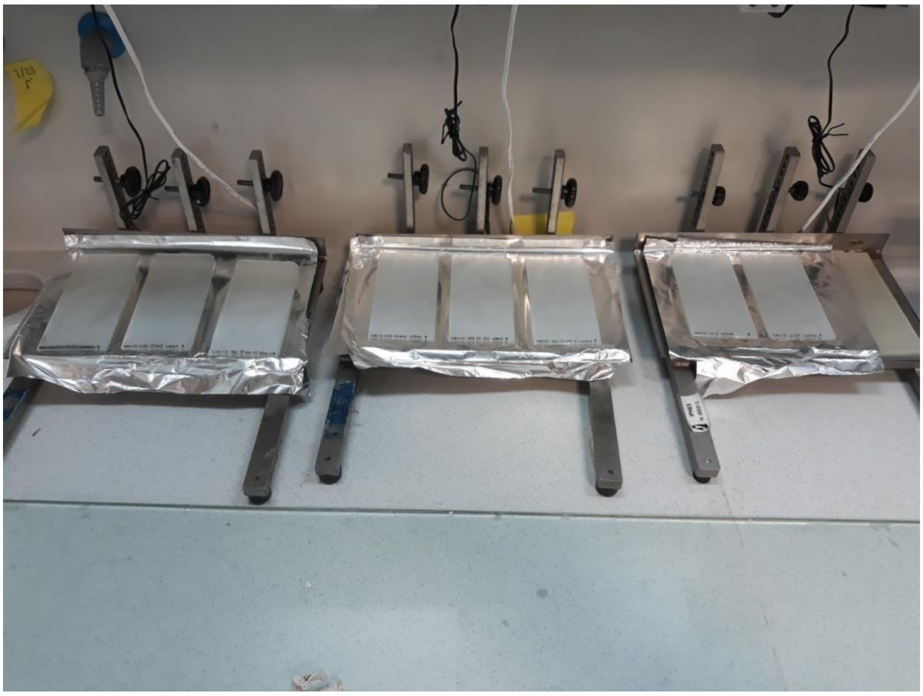

Figure 26: Labelled polished glass slides.

Figure 27: Samples placed in small vacuum.

Figure 28: Glue samples properly to the glass slide.

STEP 8: CUT OFF THE CHIP FROM THE SLIDE (SECOND CUT)

With the samples epoxied to a glass slide from the previous prepared surface (step 7, Fig. 28), some fractions of the chip were cut off, leaving a thin slice attached. The grinding wheel was adjusted to 0.7mm to cut (Fig. 29, 30 and 31).

Figure 29: A second and final cut from the sample.

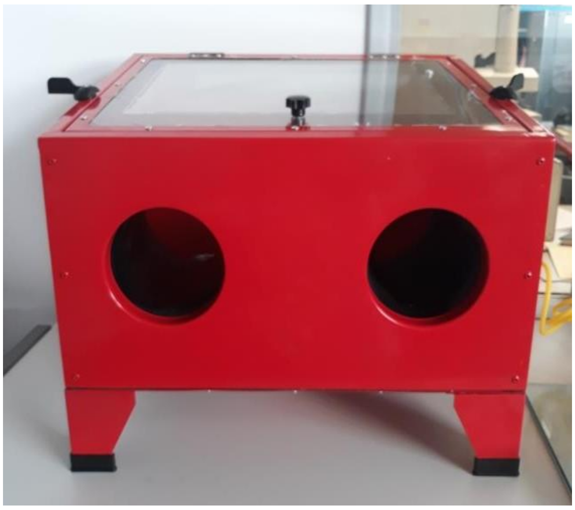

Figure 30: Machine where cleaning process takes place. Figure 31: Process of cleaning after cutting.

STEP 9: GRINDING THE SLIDE TO CORRECT THICKNESS

The sample slides from step 8 were polished using the grinding wheel in a group of three (the maximum that can be fixed to the sample holder) to achieve the finished micron width thin-sections (Fig. 32 and 33)**.** This is the step in which most thin sections go bad. The key here was to go slow, especially as it approached the end. The grinding wheel was left to work until about 60-100 microns of the reference point (polished glasses) and ended at required thickness and surface finish of 30 microns (Stoops, 2003). The thin section slides were removed to check on the petrographic microscope and some minerals (e.g., quartz) were identified thereby achieving the correct maximum interference colour standard (Bullock et al., 1985; Stoops, 2003).The thin section slides were cleaned and ready for analysis.

Figure 32: Polishing the samples to correct thickness.

STEP 10: ADDING A COVER SLIP

For this master thesis, chemical analysis was not carried out on the mineral composition of the thin sections, so the cover slip was added to prevent damages on the thin section and to increase the clarity observed in the microscope (Fig. 33).

Figure 33: Thin section of 30 microns with a cover slip ready for microscopic observation

3.4. MICROSCOPIC TECHNIQUES

The micromorphological analyses of the thin sections (Fig. 33) were performed with the aid of a petrographic microscope (Fig. 34). The observations were done alternatively in polarized light (PPL) and between crossed polarized light (XPL).

Figure 34: Petrographic microscope.

The microscope used has five (5) objectives. The eyepiece (Ocular) on 10x and the revolver of the microscope were with the magnifications (2X: 1000µm, 4X: 500µm, 10X: 250µm, 20X: 100µm, and 40X: 50µm) respectively which were equipped with a micrometre that allowed to set the limit, for instance the coarse and fine at 10 microns, measure the size and to determine the abundance of various objects at each magnification.

3.5. THIN SECTION DESCRIPTION

The thin sections for the Anta 1 de Vale da Laje were described using the principles and concepts from soil micromorphology and sedimentary petrography (Bullock, 1985; Stoops, 2003; Macphail and Goldberg, 2017). The thin sections were interpreted following Courty et al., (1990), Stoops et al., (2010); Macphail and Goldberg, (2017), and Nicosia and stoops, (2017) guidelines. This system aided in the description of the thin section using the following guides as shown in the annex; groundmass, coarse component, fine component, microstructure, porosity and textural pedofeatures.

3.6. STRATIGRAPHIC SEQUENCE

Harris matrix was used for ordering the stratigraphy of Anta 1 de Vale da Laje, in particular, for the profile sections where samples were taken. The primary aim of this was to place the stratigraphic units into their relative succession order without making reference to the artefactual content of the strata. The microfacies (thin section) of each sample as observed on the microscope were further subdivided into sub-microfacies (Fig. 35 and 36) each showing similar and distinct textural pedofeatures.

The microfacies units classified with the sub-microfacies (Fig. 35 and 36) at the microscopic level provided valuable information for refining the criteria visible with the naked eyes (field stratigraphy) aided in developing a new stratigraphic sequence as shown below for the profile sections where sampling took place.

Microfacies analysis, which is similar to the procedure in sedimentary geology employed to study rocks and sediment aimed to unravel the complete complex history of depositional environments based on the classification of sedimentary faces (Carozzi, 1960). This aided in the classification of the observed microfacies that showed general and specific features.

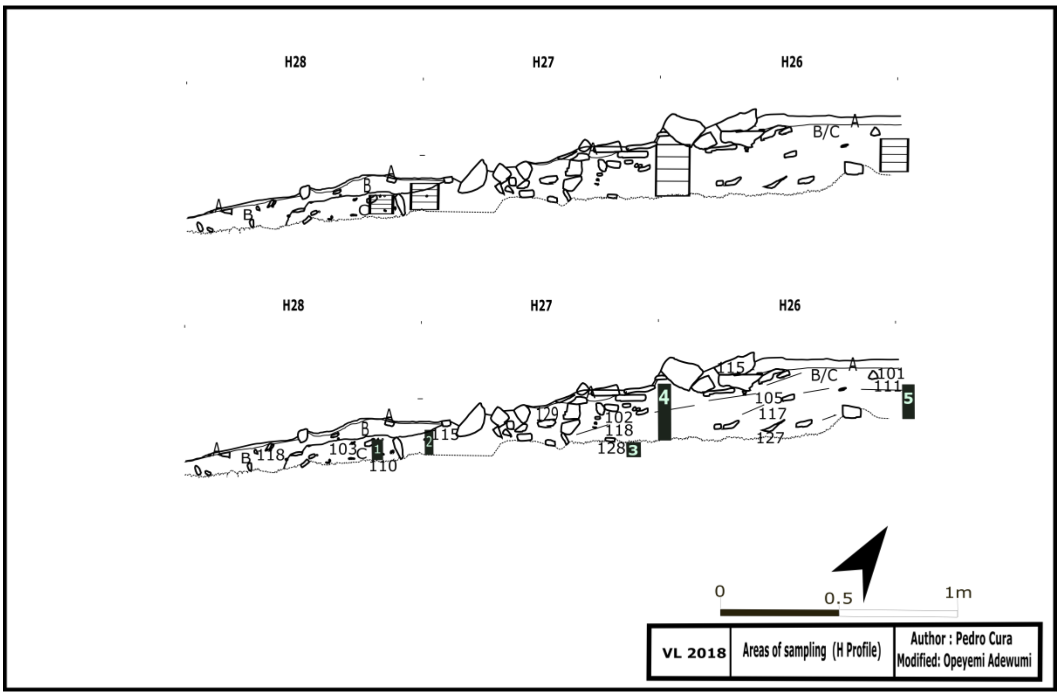

Figure 35: Plan of the sample profile (H section) showing the sub-microfacies from the microscopic analysis (adapted from Almeida and Oosterbeek 2019).

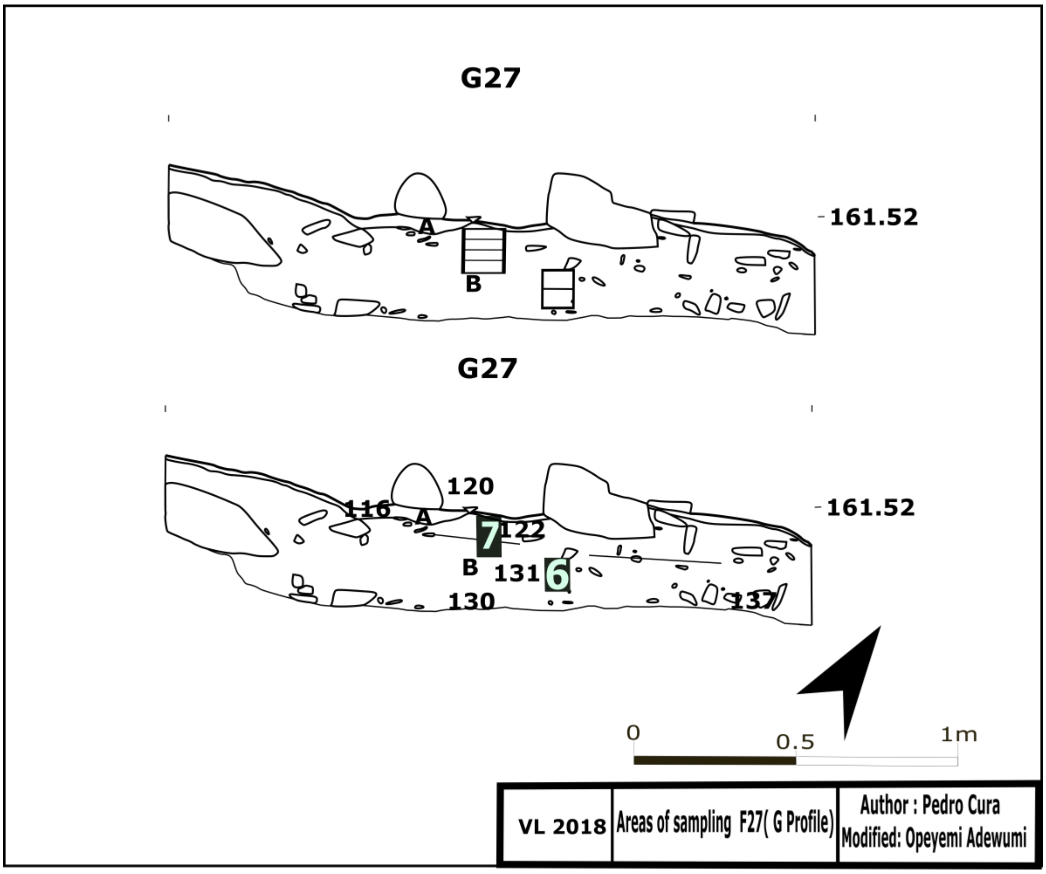

Figure 36: Plan of the sample profile (F/G section) showing the sub-microfacies from the microscopic analysis (adapted from Almeida and Oosterbeek, 2018).

CHAPTER FOUR

4. RESULTS

DESCRIPTION

4.1. GENERAL CHARACTERISTICS OF THE MICROFACIES

In general terms as observed in all the samples, the fabrics of coarse materials are in linear and random distributions with undifferentiated fine materials and variations in the ratio of the coarse and fine materials which are mostly porphiric.

The following general characteristics were observed in relation to the textural pedofeatures in all the samples. They are silty clay coatings around sand grains; loose and incomplete infillings of silty clay of excremental fabric (Fig. 38.1); dusty clay coatings around sand grains; dense and incomplete infillings of chitonic and gefuric dark yellowish brown and punctuated silty clay (Fig. 38.2).

4.2. CLASSIFICATION OF THE MICROFACIES

4.2.1 **Sandy Granular Microstructure** (Fig. 37.1)

The coarse and fine (C/F) limits ratio observed in this microstructure are 6/4, 7/3 and in few cases 4/7, 3/7. The components of the coarse materials are quartz, ferromagnesian, feldspars, charcoal fragments (5-20%), coarse sand (20-30%), phytoliths (less down 2%), burnt materials and sand stone. The fine materials are yellowish brown in colour which are either dotted or speckled and in some cases both. The distinct identified porosity includes channels, chambers, planes, vesicles and vughs.

The observable textural pedofeatures are thin silty clay coatings (Fig. 38.3) around sand grains, rains; dusty clay coatings (Fig. 38.4), thick silty clay coatings around sand grains, and cappings (Fig. 38.5), around sand grains.

<u>Interpretation</u>

The presence of dusty clay coatings associated with charcoals can be attributed to clearance activities and significant site preparation such as digging and levelling (Gebhardt, 2007). It could also be as result of the mobilization by water of the soil components after the soils surface is bare and the bonds of the aggregate are disrupted (Jongerius, 1983). Usually the overland flow as well as raindrop impact on the bare or partly vegetated soil can result in partial soil disintegration (slaking), detachment of soil particles and their translocation into soil voids and into aggregate surfaces (Yarv, 1976, Tarchitzky et al., 1984, Rousseva 1989, Macphail, 1992a).

After slaking process, while the washed out microlayer can be attributed to vertical leaching of the fine materials after dispersion of the aggregates (Mclntyre, 1958; Poesen 1981) or to horizontal transport of coarse grains by raindrop energy (West et al., 1990), a thin layer (silty clay coating) along the surface, called skin seal according to Mclntyre (1958) is assumed to be formed by aggregate break down and compaction by raindrops (Chen et al., 1980; Tarchitzky et al., 1984) or by deposition of fine particles from suspension at the end of the rainfall event (Pagliai et al., 1983b; Onifiok and Singer, 1984; Norton, 1987; Arshad and Mermut, 1988). Such a seal may develop first in small depressions and its occurrence generally expands when precipitation continues (Bresson et al., 2001). The thick silty clay is associated to secondary illuviation (Kühn et al., 2010).

The silty clay of colluvium origin are also formed during heavy rainstorms when rill erosion occurs on a fallow arable land or on arable land partly covered by crops in early stage, which fail to protect soil from rain splash (Mücher, 1974).

Cappings are associated with frost-affected soils (Van Vliet-Lanoë, 1988). The observed cappings along the surface probably results from differential frost heave within a horizon at the microtopographical scale or from lateral displacement of the aggregates by solifluction on a slope (e.g., Harris and Ellis, 1980; Van Vliet-Lanoe, 1982).

4.2.2. Vughy and Massive Microstructure (Fig. 37.2)

Observed C/F limits ratio of 4/6, 3/7 and in few cases 6/4. The components of the coarse materials are quartz, ferromagnesian, feldspars, charcoal fragments (5-20%) and ceramics. The fine materials are yellowish brown in colour which are dotted, speckled or cloudy and the combination of at least two forms in some cases. The distinct identified porosity includes channels, chambers, vesicles and vughs.

The observable textural pedofeatures are crescent shaped silty clay coatings (Fig. 38.6), intercalations and microlaminated silty clay coatings (Fig. 38.7).

Interpretation

Textural crescent shaped coatings (Fig. 38.6) are formed at the horizontal fissures in sandy materials underneath sedimentary crust (Fedoroff and Courty, 1987). Closed vughs, as in this case, and textural intercalations suggests rapid infillings and possibly associated with arable activity, i.e., Colluvial sedimentation (Farres et al., 1992). Microlaminated silty clay is essentially only the product of this episode of physical disturbance. The presence of this closed vughs or polyconcave vughs and associated textural intercalations implies deposition of the sediment as slurry (Macphail, 2007b).

4.2.3. Spongy Microstructure (Fig. 37.3)

For the microstructure, the observed C/F limits ratio of 8/2, 7/3 and 6/4. The components of the coarse materials are quartz, ferromagnesian, feldspars, charcoal fragments (5-20%) and phytoliths (less down 2%). The fine materials are yellowish brown in colour which are either dotted or speckled and in some cases both. The distinct identified porosity includes channels, chambers, vesicles, vughs and planes.

The observable textural pedofeatures are coarse coatings around sand grains, cappings around sand grains, limpid clay coatings (Fig. 38.8), microlaminated limpid clay coatings superimposed by cryptocrystalline amorphous (Fig. 39.9).

Interpretation

Limpid clay coatings is more commonly associated with weathering and clay translocations in “undisturbed” argillic brown earths (Alfisols, Livisols) under broad-leaved woodland (Fedoroff and Goldberg, 1982; Fedoroff et al., 1990; Fedoroff, 1994; Soil survey staff 1999). In other words, it is therefore related to dispersion or flocculation of clay colloids during leaching of soils with more or less continuous vegetation cover (Buurman et al., 1998; Kühn et al., 2010). However, it might also be indirect indicators of a large amount of ash and thus of possible vegetation clearance by burning (Gebhardt and Marguene, 2006). It can also be associated with the final phase of clay illuviation (Van Vliet-Lanoë, 1982; Fedoroff et al., 2010; Kühn et al., 2010; Sedov et al., 2010).

Cappings, mainly consisting of silty material accumulated on top of coarse fragments or peds, were described for buried palaeosols (e.g., Ransom et al., 1987; Fedoroff et al., 1990) and as the result of periglacial processes in fragipan horizons (e.g., Nettleton et al., 1968; Fitzpatrick, 1974; Van Vliet-Lanoë and Langohr, 1981).

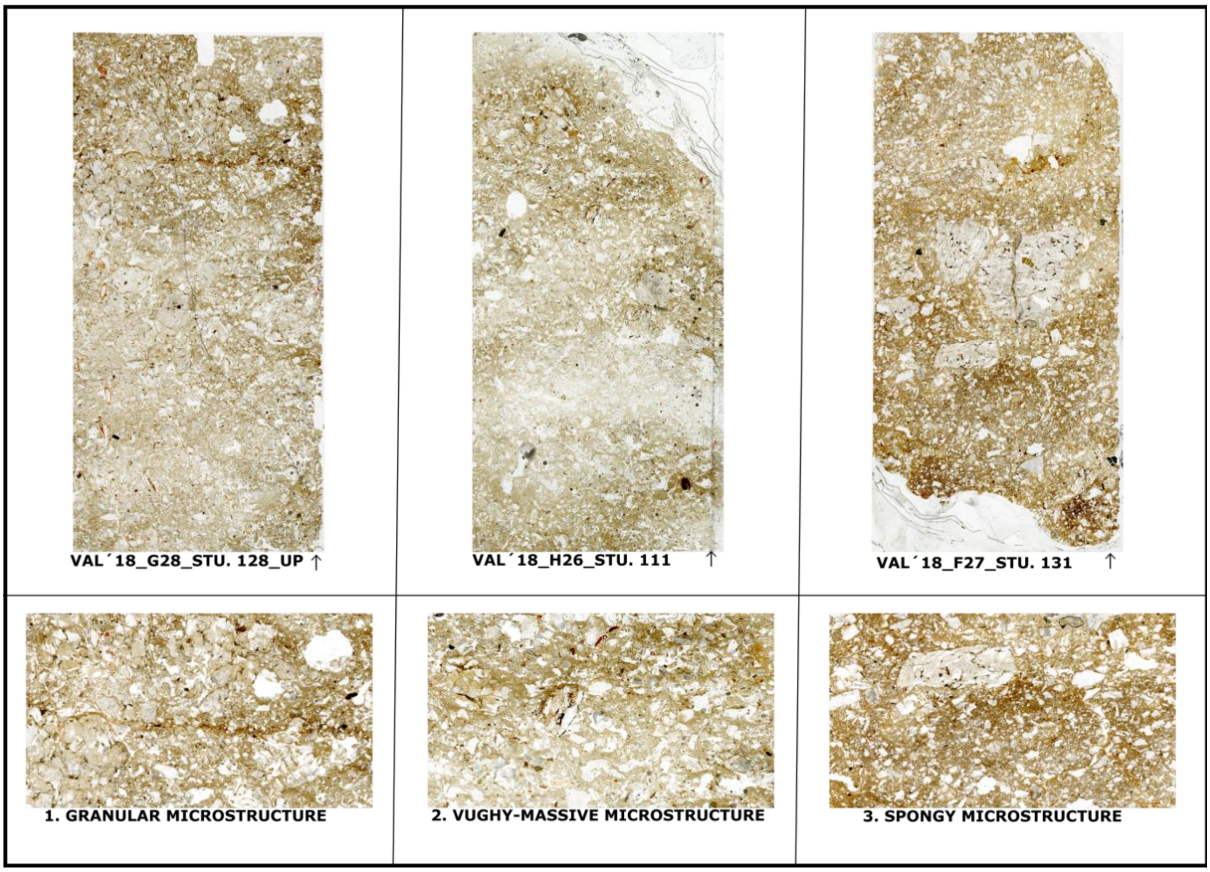

Figure 37: Thin section classification of the microstructures (1). Sandy granular microstructure with chamber and channels from microstratigraphic unit G28 (128.4). (2). Vughy and massive microstructure with vesicles, chambers and channels from microstratigraphic unit H26 (111.3). (3). Spongy microstructure with planes, chambers and channels from microstratigraphic unit F27 (131.2). (5x3 cm dimensions)

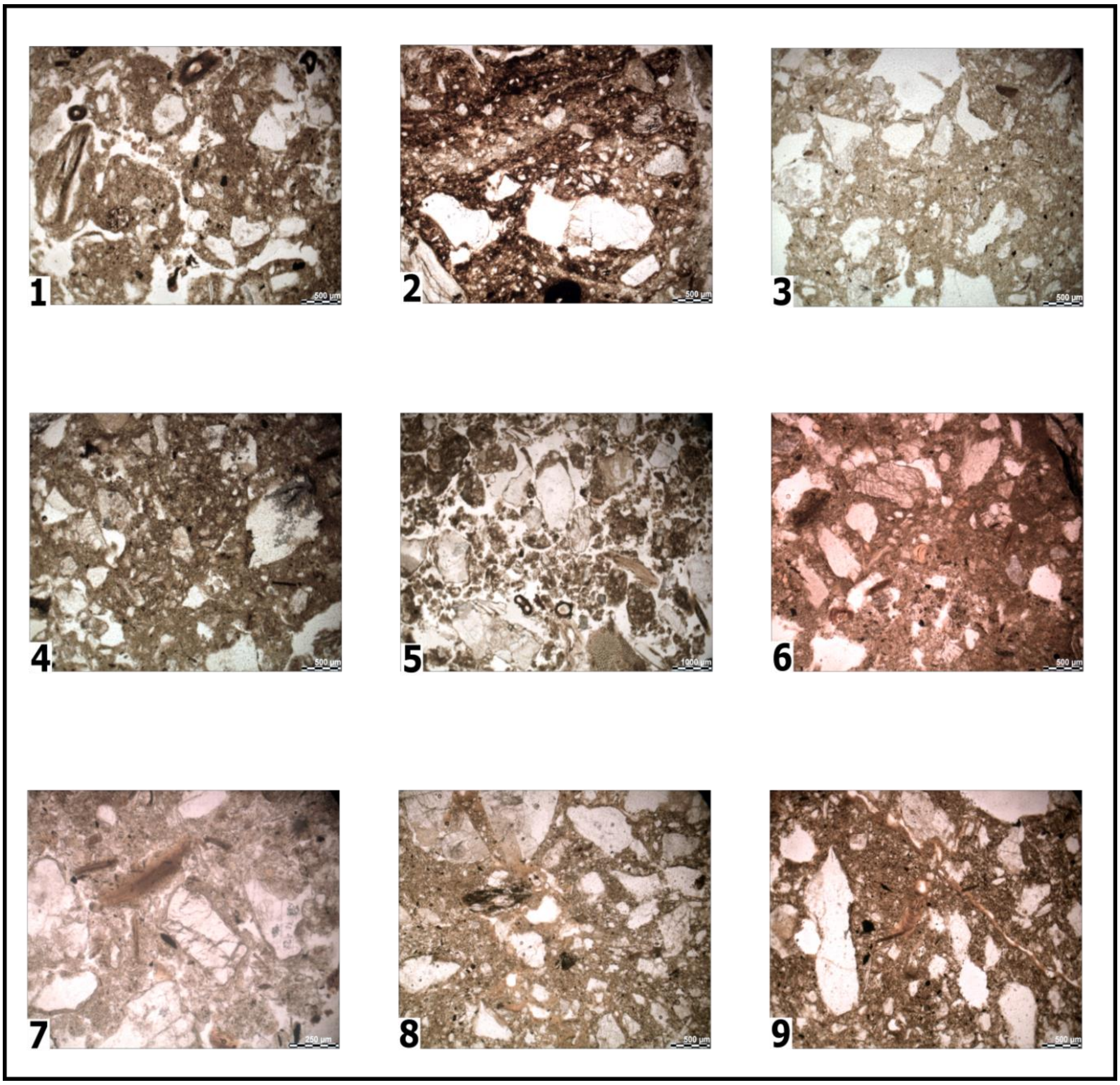

Figure 38: (1). Loose and incomplete infillings of porphiric silty clay of excremental origin from microstratigraphic G28 (128.1) unit (PPL). (2). Dense and complete infillings, dark yellowish brown and punctuated silty clay from microstratigraphic H28 (115.1) unit (PPL). (3). Thin silty clay coatings around sand grains in granular microstructure from microstratigraphic G28 (128.3) unit (PPL). (4). Dusty clay coatings in granular microstructure from microstratigraphic G28 (128.2) unit (PPL). (5). Cappings around sand grains in granular microstructure from microstratigraphic H27 (118.1) unit (PPL). (6). Crescent shaped silty clay coatings in vughy microstructure from microstratigraphic H26 (111.3) unit (PPL). (7). Microlaminated yellowish brown silty clay in vughy microstructure from microstratigraphic H26 (111.3) unit (PPL). (8). Limpid clay coatings in spongy microstructure from microstratigraphic F27 (131.2) unit (PPL). (9). Microlaminated limpid clay coatings superimposed by cryptocrystalline amorphous black materials in spongy microstructure from microstratigraphic F27 (131.1) unit (PPL).

4.3. STRATIGRAPHY

The Harris matrix stratigraphy was applied to re-order and correlate the field stratigraphic units from the sampled profile sections. The features observed from the thin section analysis aided to make correlations and phasing between some of the units of the stratification. This led to the development of new periodization of stratigraphic sequences and stratigraphic phasing.

The periods are A, B, C, D, E, F and G respectively while the stratigraphic phases are I, II, and III respectively (Fig. 39). The period A is composed of microfacies units from G28, B composed of microfacies units from H28 (West Profile), C composed of microfacies units from H27 (West Profile), D composed of microfacies units from H26, E and F composed of microfacies units from F27 and G is the saprolith layer (H27). The periods E and F classified as Phase I, periods C and D as Phase II and periods A and B as Phase III (Fig. 39).

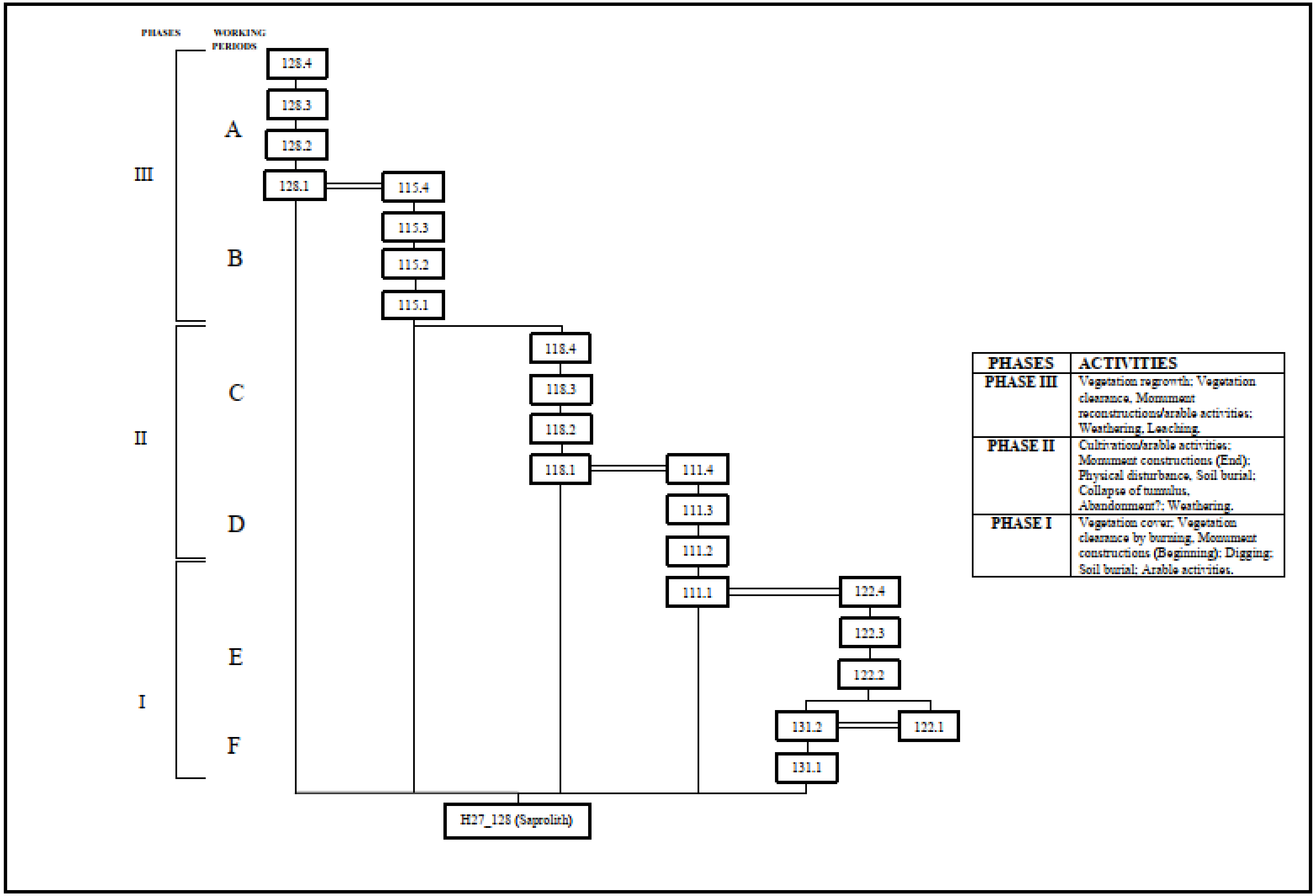

Figure 39: Stratigraphic sequence of the sampled profile section of Anta 1 de Vale de Laje (Harris, 1979).

CHAPTER FIVE

5. DISCUSSION

5.1. STRATIGRAPHY AND MICROFACIES

The result of the micromorphological analysis shows that there were clearly several human activities, as well as sedimentary processes that occurred around the Anta 1 de Vale da Laje site, with indications of various human induced and natural activities that occurred before, during and after the construction of the megalithic monument.

The result obtained from Phase I, in particular the limpid clay coatings has been associated to vegetation clearance by burning (Gebhardt and Marguene, 2006). In other words, during this phase of the site evolution, there exists vegetation cover. Not necessarily a huge and dense forest cover, as it is the mark of the early Holocene or late Pleistocene period (Deák et al., 2017), but in any case a still wooden cover with a mix of shrub vegetation as well (Ferreira, 2017). As noted in the spongy microstructure classification, the limpid clay coatings have been suggested as a result of weathering and translocations under a forested woodland (Fedoroff, 1974; Fedoroff and Goldberg, 1982; Fedoroff et al., 1990; Soil survey staff, 1999).

However, a distinguishable fact at this stage is that microlaminated limpid clay coatings during this phase is also associated with the final phase of clay illuviation (Van Vliet-Lanoë, 1982; Fedoroff et al., 2010; Kuhn et al., 2010; Sedov et al., 2010) as against the secondary phase of clay illuviation noted in Phase II, particularly at period D. Moreover, cappings as observed in this phase has also been suggested and described as the phase of buried palaeosoils (e.g., Ransom et al., 1987; Fedoroff et al., 1990), which converges with the data from phosphate analysis (Migliavacca, 2000).

These textural pedofeatures, particularly silty clay coatings have clearly shown that during this phase, after the clearance of the vegetation cover, there were human induced activities. Such activities include the scratching of a large surface around the monument (since the digging of ditches to erect the large slabs for the monument was not recorded in this site, or in any of the other megalithic monuments in the region so far), and the mobilisation of the slabs, obtained from the gneiss outcrops used was within a close proximity (Moleiro, 2015) as recorded in previous studies on the site. The construction activities began during period F, in the Neolithic, until the interface stage (131.2=122.1) and at period E, the ground surface was simply used for ordinary activities of life particularly, cultivation and these farming activities continued as reflected at the interface (111.1=122.4) which marked the beginning of the second phase.

The textural pedofeatures as noted in the vughy and massive microstructure during the Phase II showed characteristics of continuous cultivation or arable activities as noted at the interface (111.1=122.4) and at the early stage of this phase (Period D, 111.2).

In addition, there were other features associated with the physical disturbance of the site. For instance, as observed in the thin section, crescent shaped textural pedofeatures are usually formed under the sedimentary crust (Fedoroff and Courty, 1987), after the disturbance of the overlying crust, as same reason has been suggested of the textural intercalation relating to colluvial sedimentation (Farres et al., 1992). Also, the microlaminated silty clay as shown in the result is formed during the Holocene and it is essentially a product of a physical disturbance period (e.g., trampling, tillage, digging, etc.), bioturbations evidences of excremental origin and possibly would have resulted from slaking or mass movement.

At this Phase II, after the cultivation as noted above and other related activities, this resulted to physical distances (Crescent shaped silty clay coatings), succeeded by another burial process as evidenced in the features (Cappings) from interface units, which are correlated as parts of a once-whole deposit or feature interface (118.1=111.4). This phase could be regarded as the periods when the construction of the monument was completed and possibly with nearby inhabited places, even if unidentified so far, as there were evidences of continuous agricultural activities and clearances. However, there was a collapse of the tumulus particularly during period C, (H27 west profile, Fig. 35) and subsequent weathering processes as indicated by the limpid clay coatings.

Interestingly, this collapse would have led to the temporary abandonment of the site as there was no supporting evidence from the thin section analysis that says otherwise. The textural pedofeatures from period C and B from the Harris matrix (Fig. 39) showed that units (118.4 and 115.1) have no direct stratigraphic connections (118.4 ≠ 115.1), although the time frame of the abandonment is unknown. However, this collapse may correspond to the late Chalcolithic, which showed no evidence of occupation of the monument (e.g., absence of a Bell Beaker occupation). Beaker layers are also absent from other megalithic monuments in the region, despite the occurrence of their relevant to the west, in the limestone area.

The final Phase III, which is the youngest phase comprising periods B and A revealed also vegetation or forest regrowth, which at this period in time is an indicator of later

Holocene period (Deák et al., 2017). The forest regrowth can be attributed to the abandonment of the site after the collapse of the tumulus. The presence of vegetation cover would necessitate associated human activities such as clearance (Gebhardt, 2007) as evidenced in the later part of period B. This activity of clearance also signalled that the site was re-occupied, as there were cultivation evidence at the interface (128.1=115.4) between periods B and A with silty clay textural pedofeatures, which is associated to arable land that is entirely or partially covered by crops (Mücher, 1977). The individual burials made in the mound, and not inside the monument, during the Bronze Age, would correspond to this phase.

Although, prior to the re-occupation of the site, it has been intermittently exposed to sedimentary actions such as leaching processes as a result of water mobilization (Jongerius, 1983) as observed from the analysis. Weathering and soil erosion also took place due to raindrop effect (Yarv, 1976; Tarchitzky et al., 1984; Rousseva, 1989; Macphai, 1992a).

5.2. COMPARISON WITH OTHER SITES

Under certain environmental conditions, such as in Atlantic Europe or the humid tropics, vegetation regenerates quickly, such that evidence of bare surfaces in the Holocene is often the result of significant human intervention and perhaps maintenance of clearings e.g., cultivation, intensive grazing, routeways or settlement (Deák et al., 2017).

For example, soil studies, including micromorphological investigations of soils covered by and dated through overlying archaeological structures, suggest that the landscape of northwestern Europe has been affected by human clearance and disturbance since at least the Neolithic, and probably earlier (e.g., Macphail, 1990; Gebhardt, 1993; Langohr, 2001; Bork and Lang, 2003; Goldberg and Macphail, 2006; French et al., 2007; Dotterweich and Dreibrodt, 2011; Ertlen et al., 2012; Lespez, 2012; Gebhardt et al., 2014).

As noted on the Neolithic Carn Brea Cornwall (England) and similar sites on granitic substrates in Brittany (France), secondary clearances ahead of constructions took place, probably to maintain grazing land; this led to brown soils becoming podzolised (Macphail, 1990c; Gebhardt, 1993). Also, at Drayton Cursus, Oxfordshire (England) clearance preceded the construction of the Neolithic cursus (Barclay et al., 2003), with the cursus buries soil been affected by in wash of reddish clay containing fine charcoal.

In cases relating to slope environmental setting, significant Holocene erosion and development of colluvial slope and toe-slope deposits, and increased rates of alluviation and lake sedimentation can also be associated with clearance (Van Vliet-Lanoë et al., 1992). In an archaeological record, initial clearance, secondary clearance and maintenance of an open landscape by fire may not always be evident because of natural and anthropogenic post-depositional processes. Recognition of clearance features is usually easier when soils are buried quickly. This can be said to be case at Anta 1 de Vale da Laje as recognised in Phase I and Phase II.

Moreover, the clearance on slopes has many times resulted in increased soil erosion and downslope accumulation of colluvium. However, ploughing may produce fine colluvium (Hillwash), dramatic erosion induced by clearance may form coarse colluvium containing soil clast and fragments of unweathered rock (saprolith), relatively to the stability and erosion capacity of different soil horizons (Grieve, 1980; Burnham and Pitman, 1986; Bell and Boarman, 1992; Brady and Wiel, 2008).

As noted in the result, the presence of charcoal and burnt soil materials, which occurred alongside unweathered rocks (saprolith) subsoil and topsoil material are typical inclusions of clearance colluvial as same case has previously been recorded at the Beaker site of Brean Down, Somerset and the Apennine Chalcolithic Castellaro site of Uscio, Liguria (Allen and Macphail, 1987; Macphail, 1990d; Maggi, 1990; Goldberg and Macphail, 2006b).

The dark colour is mainly caused by finely dispersed organic matter that mostly correspond to the youngest phase of clay illuviation, typically in E- and upper Bt-horizons of loamy material (Kühn, 2003a), below plough layers or in colluvial materials (Kwaad and Mücher, 1977, 1979; Bolt et al., 1980). They are also commonly associated with deforestation (Thompson et al., 1990) or other anthropogenic changes (e.g., Slager and Van de Wetering, 1977; MacPhail, 1986; Kühn, 2003a) and have been used as indicator of early cultivation (e.g., Macphail et al., 1987, 1990; Usai, 2001).

The dusty clay coatings containing quartz and other heavy minerals such as feldspar are frequent in E- and upper Bt-horizons. They do not clearly correspond to a specific phase of the clay illuviation process, and their dusty appearance has been attributed to ageing of former clay coatings (e.g., Bronger, 1969/1970). However, this is questionable, since these dusty coatings have also been found in young soils as well (Kühn, 2003a).

Therefore, the presence or absence of textural coatings such as the dusty clay coatings or coatings darkened by organic matter has been suggested as indicators of tillage activities which reflects successional patterns of deposition and concentrations in soils affected by a change in internal drainage (Usai; 2001, 2005). Also, the presence of the limpid clay coatings as observed in the spongy microstructure are associated with the final phase of clay illuviation (e.g., Rogaar et al., 1993; Miedema et al., 1999; Kühn, 2003a) and suggested to be frequent in Bt- and often in C-horizons (Stephan, 2000).

CHAPTER SIX

6. CONCLUSION

This soil micromorphological study has proven to be useful in the study of undisturbed soils in identifying components of a deposit and the activities that occurred on an archaeological site. Although, it is more likely than not, that no single methodological approach could be sufficient in unravelling the complex arrangement of anthropogenic and natural elements at a site, micromorphological analysis provided complimentary information to that obtained on the field and from the previous research works in Anta 1 de Vale da Laje.

This study shows that micromorphological analysis can be used to characterize changes in soil structure in the samples of a megalithic tomb site. It has allowed examining in detail, the stratigraphic sequence and past activities on the site, resulting in a more comprehensive understanding of the use of space at the site. Moreover, the study confirmed that there were human induced and natural processes related activities at different phases of the site evolution.

The palaeosols record revealed in the thin section observation shows the impact of the Neolithic agriculture on the soil or landscape system from at least the early 4th millennium BC, as well as related activities (e.g., natural processes).

Human impact and natural processes characterize each of the stratigraphic periods until the final phase of the site evolution. Arable cultivation and clearance activities were observed in all the periods from the opening up of the site till the youngest phase, except when the site was abandoned after the collapse of the monument. Although the implements used at every phase of the cultivation and clearances remain unknown, determining this could be important to have a complete history of the nature and type of agricultural activities practised during this phase at the site.

The study confirmed that the monument was constructed in the first two phases (I and II) of the site development until it was abandoned. While the reason for the early construction may directly relate to the spread of pastoralism, the second phase of construction might be part of a wider process of landscape monumentalization.

Concerning the collapse of the tumulus, micromorphological interpretations and previous archaeological knowledge about the site seems to agree. The reoccupation of the monument, in Phase III, relates to mid-Bronze Age individual burials, thus setting the collapse between the end of the third and the beginning of the second millennia.

The evidence of the human related activities, particularly cultivation and presence of anthropogenic material in Phase III indicates human presence at the site after the abandonment period. A single occurrence of this anthropogenic material could have been attributed to chance, but the presence of several fragments of pottery and of the only bone remains (two femoral shafts) suggests that human funerary activities still took place at this phase of the site.

The future perspectives (dating each phase and possibly periods, further micromorphological and stratigraphic analysis) will be aimed at solving these important issues. Presented in this study is the micromorphological study that helped to detail and further describes each stratigraphic sequence and related activities in the identified phases of Anta 1 de Vale da Laje.

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BIBLIOGRAPHIES

A

Allen, M. J., & Macphail, R. I., (1987). Micromorphology and magnetic susceptibility studies: their combined role in interpreting archaeological soils and sediments. In Fedoroff, N., Bresson, L. M., & Courty, M. A., (eds.). *Soil Micromorphology*. Plaisir, Association Française pour l`Étude du sol, pp. 669-676.

Allué, E., (2000). Pollen and Charcoal analysis from archaeological sites from the Alto Ribatejo (Portugal). In Cruz, A. R., Oosterbeek, L., (coord). *Territórios, Mobilidade e Povoamento no Alto Ribatejo Indústrias e Ambientes.* Arkeos 9. Tomar: Ceiphar, pp. 37-57.

Almeida, N. J., (2017). *Zooarqueologia e Tafonomia da transição para a agro-pastorícia no Baixo e Médio Vale do Tejo*. Unpublished PhD Thesis. UTAD,Vila Real.

Almeida, N. J., Ferreira, C., Garcês, S., Cruz, A. R., Rosina, P., & Oosterbeek, L. (2017). The Western network revisited: the transition into agro-pastoralism in the Alto Ribatejo, Portugal. In Besse, M., Guilaine, J. Materials, production, exchange network and their impact on the societies of Neolithic Europe. *Proceedings of the XVII UISPP World Congress* (1-7 September 2014, Burgos, Spain). Volume 13/Session A25a. Oxford: Archaeopress Archaeology, pp. 39-49.

Almeida, N. J., Oosterbeek, L. (2018). *Anta 1 de Vale da Laje*: *relatório dos trabalhos de Outubro de 2017*. Unpublished Technical Report. DGPC, Lisbon.

Almeida, N. J., Oosterbeek, L. (2019). *Anta 1 de Vale da Laje*: *relatório dos trabalhos de Abril de 2018*. Unpublished Technical Report. DGPC, Lisbon.

Almeida, N. J., Oosterbeek, L., Scarre, C., Ferreira, C., Belo, J., & Costa, L. (2018). Dawn of the dead: funerary behaviour in the Middle Tagus Neolithic. In Senna-Martinez, J., Diniz, M., Carvalho, A. F., (eds.). *De Gibraltar aos Pirenéus. Megalitismo, Vida e Morte na Fachada Atlântica Peninsular*. Nelas: Fundação Lapa do Lobo, pp. 233-245.

Almeida, N. J., Ferreira, C., Allué, E., Burjachs, F., Cruz, A. R., Oosterbeek, L., Rosina, P. & Saladié, P. (2014). Acerca do impacte climático e antropozoogénico nos inícios da economia produtora: o registo do Alto Ribatejo (Portugal Central, Oeste Ibérico). In Zocche, J., Campos, J. B., Almeida, N. J., Ricken, orgs., Arqueofauna e Paisagem. Erichim: Habilis Editora, pp. 63-84.

Arias, P., Armendariz, A. & Teira, L. C. (2006). The megalithic complex in Cantabrian Spain. In Rodríguez Casal A. A. (ed.). *The Atlantic Megaliths* Oxford: Archaeopress, pp. 11-29.

Arnaud, J. M. (1982). Néolithique Ancien et processus de Néolithisation dans le Sud du Portugal. In Archéologie en Languedoc, N.º Spécial, Actes du Colloque. *International de Préhistoire*, pp. 29-48.

Arshad, M. A. & Mermut, A. R. (1988). Micromorphological and physico-chemical characteristics of soil crust types in Northwestern Alberta, Canada. *Soil Science Society of America Journal*, 52, 724–729.

B

Barclay, A., Lambrick, G., Moore, J. & Robinson, M. (2003). *Lines in the landscape*. Cursus Monument in the Upper Thames Valley: excavations at the Drayton and Lechlade Cursuses, Oxford, Oxford Archaeological Unit.

Bell, M. & Boardman J. (1992). Past and present soil erosion. Archaeological and geographical perspectives. Oxbow Monograph, 22. Oxbow Books, Oxford.

Birkeland, P. W. (1984). *Soils and geomorphology*. Oxford University Press.

Boaventura, R. (2009). *As antas e o megalitismo da região de Lisboa*. Unpublished PhD thesis. University of Lisbon: Lisboa.

Bolt, A. J. J., Mücher, H. J., Sevink, J. & Verstraten, J. M. (1980). A study on loess-derived colluvia in southern Limbourg (the Netherlands): *Netherlands Journal of Agricultural science*, v.28, pp. 110-126.

Bork, H. R. & Lang, A. (2003). Quantification of past soil erosion and land use / land cover changes in Germany. In Lang, A. & Heinrich-Dikau, K. (eds). Long Term Hillslope and Fluvial System Modelling: *Concepts and Case Studies from the Rhine River Catchment*. Lecture Notes on Earth Sciences 101. Springer-Verlag, Heidelberg, pp. 231–239.

Botón Garcia, F. (2000). Estudios sedimentologicos. In Cruz, A. R., Oosterbeek, L., (coord.), Territórios, Mobilidade e Povoamento no Alto Ribatejo I. Indústrias e ambientes. Arkeos 9. Tomar: Ceiphar, pp. 83-125.

Bradley, R. & Phillips, T. (2008). Display, disclosure and concealment: the organization of raw materials in the chambered tombs of Bohuslän. *Oxford Journal of Archaeology*, 27, 1-13.

Brady, N. C. & Weil, R. R. (2008). *The Nature and Properties of soils*, New Jersey, Prentis Education, p .965.

Bresson, L. M., Koch, C., Le Bissonnais, Y., Barriuso, E. & Lecomte, V. (2001). Soil surface structure stabilization by municipal waste compost application. *Soil Science Society of America Journal*, 65, 1804-1811.

Bronger, A. (1969/70). Zur Mikromorphogenese und zum Tonmineralbestand quartärer Lößböden in Südbaden. Geoderma 3, pp. 281–320.

Bullock, P., Fedorroff, N., Jongerius, A., Stoops, G., Tursina, T. & Babel, U. (1985). *Handbook for soil thin section description*. Waine Research Publications, Wolverhampton, UK.

Burbidge C. I., Trindade M. J., Cardoso, G. J. O., Dias, M. I., Oosterbeek, L., Scarre, C., Rosina, P., Cruz, A., Cura, S., Cura P., Caron L., Prudêncio M. I., Gouveia A., Franco D., Marques R., Gomes H. (2014). Luminescence dating and associated analyses in transition landscapes of the Alto Ribatejo, Central Portugal. *Quaternary Geochronology*, Vol. 20, pp.65-77.

Burnham, C. P. & Pitman, J. I. (1986). Soil erosion. *The Journal of the South East soils Discussion Group*, Volume 3: Ashford, South East Soils Discussion Group, p. 105.

Buurman, P., Jongmans, A. G. & PiPujol, M. D. (1998). Clay illuviation and mechanical clay infiltration – is there a difference? *Quaternary International*, 51, pp. 66–69.

C

Carozzi, A. V. (1960). *Microscopic Sedimentary Petrology*. Wiley, New York.

Carter, S. P. & Davidson, D. A. (1998). An evaluation of the contribution of soil micromorphology to the study of ancient arable agriculture. *Geoarchaeology*, 13, pp. 535 – 547.

Carvalho, A. F. (2008). *A Neolitização do Portugal Meridional*. Os exemplos dos Maciço Calcário Estremenho e do Algarve Ocidental. Promontoria Monográfica 12. Faro: Universidade do Algarve, p. 428.

Carvalho, A. F. (2010). Chronology and geography of the Mesolithic-Neolithic transition in Portugal. In Armbruester, T., Hegewisch, M. (Eds.), On Pre- and Earlier History of Iberia and Central Europe. *Studies in Honour of Philine Kalb. HabeltVerlag*, Bonn, pp. 15-61.

Carvalho, A. F., Gibaja, J. F. & Cardoso, J. L. (2013). Insights into the earliest agriculture of Central Portugal: sickle implements from the Early Neolithic site of Cortiçóis (Santarém). *Comptes Rendus Palevol*. 12(1), pp. 31-43.

Chen, Y., Tarchitzky, J., Brouwer, J., Morin, J. & Banin, A. (1980). Scanning electron microscope observation on soil crusts and their formation. *Soil Science*. 130, pp. 49–55.

Childe, V. G. (1957). *The Dawn of European Civilisation*, 6th (Edn). Routledge and Kegan Paul, London.

Courty, M. A. & Weiss, H. **(**1997). The scenario of environmental degradation in the Tell Leilan region, NE Syria, during the late third millennium abrupt climate change. In *NATO ASI Series, Vol. 149, Third Millennium BC Climate Change and Old World Collapse* (*Eds H.N. Dalfes, G. Kukla and H. Weiss*), pp. 107–047. Springer-Verlag, Heidelberg.

Courty, M. A., Goldberg, P. & Macphail, R. (1990). *Soils and micromorphogy in archaeology*. Cambridge University Press, Cambridge, UK.

Cruz, A. R. (1997). Vale do Nabão: do Neolítico à Idade do Bronze. Arkeos 3. Tomar: Ceiphar. P. 361.

Cruz, A. R. (2011). *A Pré-história recente no Vale do Baixo Zêzere: um olhar diacrónico*. Unpublished PhD thesis. UTAD, Vila Real.

Cruz, A. R., Graça, A. & Oosterbeek, L. (2014). Caves, megalithism and tumuli – three diachronic realities in funerary archaeography from Alto Ribatejo. In Cruz, A. R.; Cerrillo-

Cuenca, E.; Bueno Ramírez, P., Caninas, J. C., Batata, C. (2014, eds). *Rendering death: ideological and Archaeological narratives from recente Prehistory (Iberia).* Oxford: Archaeopress, BAR, IS., pp. 61-75.

Cruz, A. (2007). A Pedra da Encavalada. *In Angulo, Serie I, pp. 1e16 (2006/07).* Retrieved fromhttp://www.cph.ipt.pt/angulo/index.php?option=com_jotloader&section=files&task=download&cid=64_6ce8c2c286d5fa98cd7e28e8d040ad9e&Itemid=14.

Cummings, V. (2009). *A view from the west: the Neolithic of the Irish Sea zone, Oxford, Oxbow,* p. 219.

Cummings, V. (2002). Experiencing texture and transformation in the British Neolithic. *Oxford Journal of Archaeology,* 21, pp. 249-61.

D

Daveau, S. (1980). *Espaço e Tempo. Evolução do ambiente geográfico de Portugal ao longo dos tempos pré-históricos.* Clio: Revista do Centro de História da Universidade de Lisboa 2.

Davidson, D. A., Carter, S. P. & Quine, T. A. (1992). An evaluation of micromorphology as an aid to archaeological interpretation. *Geoarchaeology*, 7(1), 55-65.

Deák, J., Gebhardt, A. & Lewis, H. (2017). Soils disturbed by vegetation clearance and tillage. In Nicosia, C. & Stoops, G. (eds). *Archaeological Soil and Sediment Micromorphology*. John Wiley & Sons, Ltd, Chichester, pp. 233–264.

Diniz, M. (2018). The origins of megalithism in Western Iberia: resilient signs of a symbolic revolution? In Senna-Martinez, J., Diniz, M., Carvalho, A. F., (eds.). *De Gibraltar aos Pirenéus. Megalitismo, Vida e Morte na Fachada Atlântica Peninsular*. Nelas: Fundação Lapa do Lobo, pp. 303-320.

Dotterweich, M., & Dreibrodt, S. (2011) Past land use and soil erosion processes in central Europe. In Dearing, J., Dotterweich, M., Foster, Z. (eds). *Integrative Palaeoscience for Sustainable Management*. Pages news pp. 49–51.

Drewett, P., Oosterbeek, L., Cruz, A. R. & P. Felix (1992). The excavation of a passage grave at Tomar, Portugal. *Bulletin of the Institute of Archaeology*, 29, 133-148.

E

Ertlen, D., Gebhardt, A. & Schneider, N. (2012). Anthropisation et érosion agraire dans un paysage loessique (Bas-Rhin,France). In Bertoncello, F. & Berger, J. F. (eds) Variabilités Environnementales, Mutations Sociales: Nature, Intensités, Échelles et Temporalités des Changements. Actes des XXXII[e] Rencontres Internationales d'Archéologie et d'Histoire d'Antibes, 20–22 October 2011. Éditions APDCA, Antibes, pp. 1–8.

Esteban, M. & Klappa, C. F. (1983). Subaerial exposure environment. In Scholle, P. A., Bebout, P. G. & Moore, C. H. (eds). Carbonate Depositional Environments Memoirs. *American Association of Petroleum Geologists*, 33, l-72.

F

Farres, P. J., Wood, S. J. & Seeliger, S. (1992). A conceptual model of soil deposition and its implication for environmental reconstruction. In Bell, M., and Boardman, J., (eds). *Past and Present Soil Erosi*on. Monograph 22: Oxford, Oxbow, pp. 217-226.

Fedoroff, N. & Courty, M. A. (1987). Morphology and distribution of textural features in arid and semiarid regions. In Fedoroff, N., Bresson, L. M. & Courty, M. A. (eds.). *Micromorphologie des Sols, Soil Micromorphology*. AFES, Paris, pp. 213–219.

Fedoroff, N. & Goldberg, P. (1982). *Comparative micromorphology of two late Pleistocene palaeosols (in the Paris basin).* Catena, v. 9, pp. 227-251.

Fedoroff, N. (1974). Classification of accumulations of translocated particles. In Rutherford, G. K., (ed.). *Soil Microscopy*. Kingston, Ontario. The Limestone Press, pp. 695-714.

Fedoroff, N., Courty, M . A. & Zhengtang Guo (2010). Palaeosols and relict soils. In Stoops, G., Marcelino, V. & Mees, F. (eds.). *Interpretation of Micromorphological Features of Soils and Regoliths*. Elsevier, Amsterdam, pp. 623–662.

Fedoroff, N., Courty, M. A. & Thompson, M. L. (1990). Micromorphological evidence of paleoenvironmental change in Pleistocene and Holocene palaeosols. In Douglas, L.A. (ed.). *Soil Micromorphology: A Basic and Applied Science*. *Developments in Soil Science*, Volume 19. Elsevier, Amsterdam, pp. 653–665.

Fergusson, J. (1872). *Rude Stone Monuments in All Countries; their Ages and Uses.* London: John Murray.

Ferreira, C. (2017) Dinâmicas ambientais e humanas durante o Holocénicono Vale do Tejo. Unpublished PhD thesis. UTAD, Vila Real.

FitzPatrick, E. A. (1974). Cryons and isons. *Proceedings of the North of England Soils Discussion Group*, 11, pp. 31–41.

Ford, A. B. (1987). Chemical characteristics of greywacke and palaeosol of early Oligocene or older sedimentary breccia, Ross Sea, DSDP site 270. In Thomson, M. R. A., Crame, L. A. & Thomson, J. W. (eds). *Geological Evolution of Antarctica.* Cambridge University Press, Cambridge. pp. 293-297.

French, C., Lewis, H., & Allen, M. J. (2007). *Prehistoric Landscape Development and Human Impact in the Upper Allen Valley, Cranborne Chase, Dorset.* McDonald Institute for Archaeological Research Monograph, Cambridge.

G

Gebhardt, A. & Marguerie, D. (2006). Les sols, leur couvert végétale et leur utilisation au Néolithique. In Le Roux, CH. T. (ed.) Monuments Mégalithiques à Locmariaquer. Le Long Tumulus d'Er Grah dans son Environnement. *Gallia Préhistoire sup. XXXVIII, CNRS Editions*, pp. 14–23.

Gebhardt, A. (1993). *Micromorphological evidence of soil deterioration since the mid-Holocene in Brittany, France*. The Holocene 3, pp. 333–341.

Gebhardt, A. (1999). Micromorphological analysis of soil structural modification caused by different cultivation implements. In Anderson, P. (ed.). *Prehistory of Agriculture, New Experimental and Ethnographic Approaches.* Monograph 40. Institute of Archaeology, University of California, Los Angeles, pp. 260–266.

Gebhardt, A. (2007). Impact of charcoal production activities on soil profiles:The micromorphological point of view. *ArchéoSciences.* Revue d'Archéométrie 31, pp. 127–137.

Gebhardt, A., Occhietti, S., & Fechner, K. (2014). Grandes phases de pédogenèse, d'érosion et d'anthropisation des sols au cours de la seconde moitié de l'Holocène en Lorraine (France). *ArchéoSciences,* revue d'archéometrie 38, pp. 7–29.

Goldberg, P. & Macphail, R. I. (2006b). *Practical and Theoretical Geoarchaeology*. Blackwell Publishing, Oxford.

Gonçalves, V. S. (1999). Reguengos de Monsaraz: Territórios megalíticos, Câmara Municipal de Reguengos de Monsaraz, Lisboa.

Grieve, I. C. (1980). Some contrasts in soil development between grassland and deciduous woodland sites: *Journal of soil science,* v.31, pp. 137-145.

Guilaine, J., Veiga F. O. (1970). Le Néolithique ancien au Portugal. Bulletin de la Société préhistorique française. Tome 67, N.º 1, pp. 304-322.

H

Harris, C. & Ellis, S. (1980). *Micromorphology of soils in soliflucted materials*. Okstindan, Northern Norway. Geoderma, 23, 11–29.

Harris, Edward C. (1979). *Principles of Archaeological Stratigraphy*. Academic Press, London.

Holmes, M. A. (1992). Cretaceous subtropical weathering followed by cooling at 60"s latitude: the mineral composition of southern Kerguelen Plateau sediment, Leg 120. *Proceedings of the Ocean Drilling Program, Scientijc Results,* 120, pp. 99-111.

J

Jones, A. (1999). Local colour: megalithic architecture and colour symbolism in Neolithic Britain. *Oxford Journal of Archaeology,* 18, pp. 339-50.

Jongerius, A. (1983). The role of micromorphology in agricultural research. In Bullock, P. & Murphy, C. P. (eds). *Soil Micromorphology,* Volume 1: Techniques and Application. AB Academic Publishers, Berkhamsted, pp. 111–138.

K

Kalb, P. (1996). Megalith-building, stone transport and territorial markers: evidence from the Vale de Rodrigo, Évora, south Portugal. *Antiquity* 70, 685-695.

Kühn, P. (2003a). Spätglaziale und holozäne Lessivégenese auf jungweichselzeitlichen Sedimenten Deutschlands. Greifswalder Geographische Arbeiten 28, Greifswald, 167 p.

Kühn, P., Aguilar, J. & Miedema, R. (2010). Textural pedofeatures and related horizons. In Stoops, G., Marcelino, V. & Mees, F. (eds). *Interpretation of Micromorphological Features of Soils and Regoliths*. Elsevier, Amsterdam, pp. 217–250.

Kwaad, F. J. P. M. & Mücher, H. J. (1977). *The evolution of soils and slope deposits in the Luxembourg*, Ardennes near Wiltz. Geoderma 17, 1–37.

Kwaad, F. J. P. M. & Mücher, H. J. (1979). *The formation and evolution of colluvium on arable land in northern Luxembourg*. Geoderma 22, pp. 173–192.

L

Langohr, R. (2001). L'anthropisation du paysage pédologique agricole de la Belgique depuis le Néolithique ancien – apports de l'archéo-pédologie. Etude et Gestion des Sols 8, 103–118.

Legrand D'aussy, P. (1824). *Des Sépultures Nationales, et particulièrement celles des Rois de France.* Paris: Esnaux.

Lespez, L. (2012). Le temps des paysages, de l'environnement et des plaines littorales bas-normandes. In: Lespez, L. (ed.) Paysages et Gestion de l'Eau. Bibliothèque du Pôle Rural 3. MRSH-Caen, Presses Universitaires de Caen, pp. 199 –234.

Lopez-Doriga, I. & Simões, T. (2012). Early Neolithic agriculture in Portugal: the evidence from plant macro-remains. *Poster presented in the Environmental Archaeologies of Neolithisation*, 10-12 November 2012, University of Reading.

M

Macphail, I. R. (1990c). Soil report on Carn Brea, Redruth, Cornwall, with some references to similar sites in Brittany, France: English Heritage, Ancient Monuments Laboratory Report 55/90.

Macphail, R. (1986). Palaeosols in archaeology: their role in understanding Flandrian pedogenesis. In Wright, V.P. (ed.), *Palaeosols: Their Recognition and Interpretation*. Princeton University Press, Princeton, New Jersey, pp. 263–290.

Macphail, R. I. & Goldberg, P. (2017). *Applied Soils and Micromorphology in Archaeology*. Cambridge University Press: Cambridge, UK.

Macphail, R. I. (1987). The soil micromorphology of tree upsoil hollows. Circaea 5, 14–17.

Macphail, R. I. (1990). Soil micromorphological evidence of the impact of ancient agriculture. 14th International Congress of Soil Science Transactions 7. *International Society of Soil Science*, Kyoto, pp. 264–269.

Macphail, R. I. (1990d). Soil history and micromorphology, in Bell, M., (ed.). *Brean Down Excavations* 1983-1987, Archaeological report No. 15: London, English Heritage, pp. 187-196.

Macphail, R. I. (1992a). Soil micromorphological evidence of ancient soil erosion. In: Bell, M. G. & Boardman, J. (eds) Past and Present Soil Erosion. *Archaeological and Geographical Perspectives*. Oxbow Monograph 22. Oxbow Books, Oxford, pp. 197–215.

Macphail, R. I. (2007b). Soil micromorphology in Prehistoric and Medieval environment in old Town, Eastbourne: studies of the hillwash in the Bourne Valley star Brewery site, by M. Allen: Sussex Archaeological collections, V. 145, P.40.

Macphail, R. I., Courty, M. A. & Gebhardt, A. (1990). Soil micromorphological evidence of early agriculture in north-west Europe. *World Archaeology*, 22, pp. 53–69.

Macphail, R. I. & Goldberg, P. (1995). Recent advances in micromorphological interpretations of soils and sediments from archaeological sites. In Barham, A. J. & Macphail, R.I. (eds.). *Archaeological sediments and soils: Analysis, Interpretation and Management*. University College, London

Maggi, R. (1990). Archeologia Dell`Appennino Ligure. Gli scavi del castellaro di Uscio: un insediamento di cranale occupato dal Neolitico alla conquista Romana, Istituto Internazionale Di Studi Liguri, *Collezionoe Monographie Preistoriche ed Archaeologiche, volume VIII*; Chiavari Bordighera.

Martini, I. J. & Chesworth, W. (1992). Weathering, soils and palaeosols. *Elsevier*, Amsterdam.

McIntyre, D. S. (1958). Soil splash and the formation of surface crusts by raindrop impact. *Soil Science*, 85, pp. 261–266.

Mens, E. (2008). Refitting megaliths in western France. *Antiquity* 82, pp. 25-36.

Miedema, R., Koulechova, I. N. & Gerasimova, M. I. (1999). Soil formation in Greyzems in Moscow district: micromorphology, chemistry, clay mineralogy and particle size distribution. *Catena* 34, pp. 315 – 347.

Migliavacca, M. (2000). Val da Laje, Jogada, Pinheiros. In Cruz, A. R., Oosterbeek, L., (coord.), *Territórios, Mobilidade e Povoamento no Alto Ribatejo I*. Indústrias e ambientes. Arkeos 9. Tomar: Ceiphar, pp. 143-180.

Moleiro, V. (2015). *Antropização da paisagem e gestão das matérias-primas: estudo arqueopetrográfico de monumentos megalíticos do Alto Ribatejo, Portugal*. Dissertação de Mestrado policopiada. Instituto Politécnico de Tomar/Universidade de Trás-osMontes e Alto Douro.

Mücher, H. J. (1974). Micromorphology of slope deposits: The necessity of a classification. In Rutherford, G. (ed.). *Soil Microscopy*. Limestone Press, Kingston, pp. 553–556.

N

Nettleton, W. D., McCracken, R. J. & Daniels, R. B. (1968). Two North Carolina coastal plain catenas: II Micromorphology, composition and fragipan genesis. *Soil Science Society of America Proceedings*, 32, pp. 582–587.

Nevs, C., Diniz, M. (2018). À procura da terra dos vivos: os lugares de povoamento nas primeiras fases do megalitismo funerário no Centro e Sul de Portugal. In Senna-Martinez, J., Diniz, M., Carvalho, A. F., (eds.). *De Gibraltar aos Pirenéus. Megalitismo, Vida e Morte na Fachada Atlântica Peninsular*. Nelas: Fundação Lapa do Lobo, pp. 321-340.

Nicosia, C. & Stoops, G. (2017). *Archaeological Soil and Sediment Micromorphology*. John Wiley and Sons: Hoboken, NJ, USA.

Norton, L. D. (1987). *Micromorphological study of surface seals developed under simulated rainfall*. Geoderma 40, pp. 127–140.

O

Ollier, C. & Pain, C. (1996). *Regolith, Soils and Landforms*. Wiley, Chichester.

Onifiok, O. & Singer, M. J. (1984). Scanning electron microscope studies of surface crusts formed by simulated rainfall. *Soil Science Society of America Journal*, 48, pp.1137–1143.

Oosterbeek, L. (1994). *Echoes from the East: the western network. An insight to unequal and combined development, 7000-2000 BC*. PhD Thesis. University of London (England).

Oosterbeek, L. (1997). *Echoes from the East: late Prehistory of the North Ribatejo*. Arkeos 2. Tomar: CEIPHAR.

Oosterbeek, L. (2001). Re-thinking the Mesolithic-Neolithic transitions in the Iberian Peninsula: a view from the West. *Docmenta Praehistorica, XXVIII*, pp. 75-84.

Oosterbeek, L. (2003). Megaliths in Portugal: the western network revisited. In Burenhult, G., (ed.). Stones and Bones. Formal disposal of the dead in Atlantic Europe during the Mesolithic-Neolithic interface 6000-3000 BC. *BAR-International Series 1201*. Oxford: Archaeopress, pp. 27-37.

Oosterbeek, L. (2004). Archaeographic and Conceptual advances in Interpreting Iberian Neolithisation. *Docmenta Praehistorica, XXXI*, pp. 83-87.

Oosterbeek, L. (2007). Lithos: Circuito Arqueológico do Vale do Tejo. Mação: Museu de Arte Pré-Histórica e no Sagrado do Vale do Tejo.

Oosterbeek, L. M. (1994). Megalitismo e necropolização no Alto Ribatejo. O III milénio. Actas do Seminário "O Megalitismo no Centro de Portugal: novos dados, problemática e relações com outras áreas peninsulares" (Mangualde, Novembro de 1992). Viseu: Centro de Estudos Pré Históricos da Beira Alta, série Estudos Pré-Históricos, pp.137-149.

Oosterbeek, L., Cruz, A. R. & Félix, P. J. (1992). Anta 1 de Val da Laje: notícia de 3 anos de escavação 1989-91. Boletim Cultural. Tomar: Câmara Municipal de Tomar. N.º16, 31-49.

Oosterbeek, Luiz; Cura Sara; Gilson Simon; Antunes Luís Filipe; Bakara Martha; Zorko Mónica; Tomázia Tânia & Fuying Pen. (2006). Os Sítios Arqueológicos da Ribeira das Boas Eiras e Olival das Eiras (Mação). Industrias macrolíticas, megalitismo e arte Rupestre. *Zahara,* 8: 70-80.

P

Pagliai, M., La Marca, M. & Lucamante, G. (1983b). Micromorphometric and micromorphological investigations of a clay loam soil in viticulture under zero and conventional tillage. *Journal of Soil Science*, 34, pp. 391–403.

Paulsson, B. (2017). *Time and Stone: The Emergence and Development of Megaliths and Megalithic Societies in Europe*. London: Archaeopress Publishing.

Poesen, J. (1981). Rainwash experiments on the erodibility of loose sediments. *Earth Surface Processes and Landforms,* 6, pp. 258–307.

R

Ransom, M. D., Smeck, N. E. & Bigham, J. M. (1987). *Micromorphology of seasonally wet soils on the Illinoian till plain, U.S.A*. Geoderma 40, pp. 83–99.

Retallack, G. J. (1997A). *A colour Guide to Palaeosols*. Wiley. Chichester.

Rocha, L. (2005). *Estudo do megalitismo funerário no Alentejo Central: a contribuição de Manuel Heleno*. Dissertação de Doutoramento apresentada à Faculdade de Letras da Universidade de Lisboa, policopiado

Rodder, I. (1984). 'Burials, houses, women and men in the European Neolithic'. In Miller, C. & Tilley, C. (eds.). *Ideology, Power and Prehistory,* Cambridge University Press.

Rogaar, H., Lothammer, H., Van der Plas, L., Jongmans, A. G. & Bor, J. (1993). Phaeozem and Luvisol development in relation to relief and climate in Southwestern Rheinhessen, *Germany. Mainzer Geowissenschaftliche Mitteilungen* 22, pp. 227–246.

Romans, J. C. C. & Robertson, L. (1983). The general effects of early agriculture on the soil profile. In Maxwell, G. S. (ed.). *The impact of Aerial Reconnaissance on Archaeology*. Council for British Archaeology Research Report No. 49. CBA, London, pp. 136–141.

Rousseva, S. (1989). A laboratory index for soil erodibility assessment. *Soil Technology* 2, pp. 287-299.

Ruhe, R. V., Miller, G. A. & Vreeken, W. J. (1971). Palaeosols, loess sedimentation and soil stratigraphy. In Yaalon D. H. (Editor). *Palaeopedology: Origin, Nature, and Dating of Palaesols*. Israel University Press, Jerusalem, pp. 41-46.

S

Sageidet, B. M. (2000). *Soil Micromorphology and its contribution to the interpretation of archaeological sites.* Stavanger, AmS-Varia 37, pp. 21-25.

Scarre C. (2011). *Landscapes of Neolithic Brittany*, Oxford, Oxford University Press, 2011, p. 326.

Scarre, C. & Oosterbeek, L. (2010). The megalithic tombs of the middle Tagus basin and agro-pastoral origins in Western Iberia. IN: Tanya Armbruester, Morten Hegewisch (eds.). *On Pre- and Earlier History of Iberia and Central Europe. Studies in honour of Philine Kalb*, Bonn, Habelt Verlag, pp .97-110.

Scarre, C. & Oosterbeek, L. (2019–forthcoming). *Megalithic tombs in Western Iberia. Excavations at the Anta da Lajinha*. Oxford: Oxbow books.

Scarre, C. (2002). A place of special meaning: interpreting prehistoric monuments through landscape. In David, B. & Wilson, M. (eds.). *Inscribed Landscapes: marking and making place*, Honolulu, University of Hawaii Press, pp. 154-75.

Scarre, C. (2002). *Monuments and Landscape in Atlantic Europe: Perception and Society during the Neolithic and Early Bronze Age*, Routledge, New York.

Scarre, C. (2004a). Displaying the stones: the materiality of 'megalithic' monuments. In DeMarrais, E., Gosden, C. & Renfrew, C. (eds.) *Rethinking materiality. The engagement of mind with the material world*, Cambridge, McDonald Institute for Archaeological Research, pp. 141-52.

Scarre, C. (2004b). Choosing stones, remembering places: geology and intention in the megalithic monuments of Western Europe. In Boivin, N. & Owoc, M. A. (eds.). *Soils, Stones and Symbols. Cultural perceptions of the mineral world*. London: UCL Press, pp. 187-202.

Scarre, C. (2007). Changing places: Monuments and the Neolithic transition in western France. *Proceedings of the British Academy,* 144, pp. 243-261.

Scarre, C., Arias, P., Burenhult, G., Fano, M., Oosterbeek, L., Schulting, R., Sheridan, A., & Whittle, A. (2003). Megalithic Chronologies, IN: Göran Burenhult (ed.), *Stones and Bones. Formal disposal of the dead in Atlantic Europe during the Mesolithic-Neolithic interface 6000-3000 BC*, Oxford, BAR-International Series 1201, pp.65-112

Scarre, C., Oosterbeek, L. & French, C. (2011). Tombs, Landscapes and Settlement in the Tagus Hill-Country. In Bueno Ramirez, P., Cerrillo Cuenca, E., & Gonzalez Cordero, A. (eds.). *From the Origins: the Prehistory of the Inner Tagus Region*. BAR International Series 2219. Oxford: Archaeopress, pp. 83-91.

Sedov, S., Stoops, G. & Shoba, S. (2010). Regoliths and soils on volcanic ash. In Stoops, G., Marcelino, V. & Mees, F. (eds.). *Interpretation of Micromorphological Features of Soils and Regoliths*. Elsevier, Amsterdam, pp. 275–303.

Sherratt, A. (1990). The Genesis of Megaliths: Monumentality, Ethnicity and Social Complexity in Neolithic North-West Europe, *World Archaeology*, Vol. 22, No. 2, Monuments and the Monumental pp. 147- 167.

Slager, S. & Van de Wetering, H. T .J. (1977). Soil formation in archaeological pits and adjacent soils in southern Germany. *Journal of Archaeological Science,* 4, pp. 259–267.

Soil Survey Staff (1999). *Soil Taxonomy, a Basic System of Soil Classification for Making and Interpreting Soil Surveys*, 2nd Edition. Agricultural Handbook 436. Natural Resources Conservation Service, USDA, Washington DC.

Stephan, S., (2000). Bt-Horizonte als Interglazial-Zeiger in den humiden Mittelbreiten: Bildung, Mikromorphologie, Kriterien. Eiszeitalter und Gegenwart 50, pp. 95–106.

Stoops, G., Marcelino, V. & Mees, F. (2010). Interpretation of Micromorphological Features of Soils and Regoliths. *Elsevier*: Amsterdam, the Netherlands, 2010; ISBN 978-0-08-093230-9.

T

Tarchitzky, J., Banin, A. & Morin, J. (1984). Nature, formation and effects of soil crust formed by water drop impact. *Geoderma 33*, pp. 135–155.

Teixeira, C., Gonçalves, F. (1980). Introdução à Geologia de Portugal. Lisboa: Instituto Nacional de Investigação Científica

Thompson, M. L., Fedoroff, N. & Fournier, B. (1990). Morphological features related to agriculture and faunal activity in three loess-derived soils in France. *Geoderma 46*, pp. 329–349.

Thorpe, R. S. & Williams-Thorpe, O. (1991). The Myth of Long-Distance Megalith Transport. In *Antiquity*. ISSN: 0003-598X. Cambridge. 65:246, p.64-73.

Tilley, C. (1996.) *An Ethnography of the Neolithic. Early prehistoric societies in southern Scandinavia.* Cambridge: Cambridge University Press.

Trevarthen, D. (2000). Illuminating the monuments: observation and speculation on the structure and function of the cairns at Balnuaran of Clava. *Cambridge Archaeological Journal* 10, pp. 295-315.

U

Usai, M. R. (2001). Textural pedofeatures and pre-Hadrian's Wall ploughed paleosols at Stanwix, Carlisle, Cumbria, UK. *Journal of Archaeological Science* 28, pp. 541–553.

Usai, M. R. (2005). Textural pedofeatures as tools to diagnose past cultivation - a controlled experiment. In Smith, D. N., Brickley, M. B. & Smith, W. (eds.). *Fertile Ground*. Papers in Honour of Susan Limbrey. Oxbow Books, Oxford, pp. 162–164.

V

Valentin, C. & Bresson, L. M. (1992). Morphology, genesis and classification of surface crusts in loamy and sandy soils. *Geoderma 55*, pp. 225–245.

Van Vliet-Lanoë, B. & Langohr, R. (1981). Correlation between fragipans and permafrost with special reference to silty Weichselian deposits in Belgium and Northern France. *Catena* 8, pp. 137-154.

Van Vliet-Lanoë, B. (1982). Structures et microstructures associé es a`la formation de glace de ségrégation. Leurs conséquences. In French, H.M. (ed.), *Proceedings of the 4th Canadian Permafrost Conference*, Calgary. NRC, Ottawa, pp. 116–122.

Van Vliet-Lanoë, B. (1988). *Le rôle de la glace de ségrégation dans les formations superficielles de l'Europe de l' Ouest. Processus et héritages*. Thèse de Doctorat d'Etat, Université de Paris I, p. 854.

W

West L. T., Bradford, J. M, & Norton L. O. (1990). Crust morphology and infiltrability in surface soils from the Southeast and Midwest U.S. In Douglas, L. A. (ed.), Soil Micromorphology: A Basic and Applied Science. Developments in Soil Science, Volume 19. *Elsevier,* Amsterdam, pp. 107–114.

Wright, V. P., ed. (1986a). *Paleosols: their Recognition and interpretation*. Blackwell Scientific Publications, Oxford.

Y

Yariv, S. (1976). Comments on the mechanism of soil detachment by rainfall. *Geoderma 15*, pp. 393–399.

Z

Zilhão, J. (1997). Maritime Pioneer colonisation in the early Neolithic of west Mediterranean. Testing the model against evidence. *Poročilo o raziskovanju paleolitika, neolitika in eneolitika v Sloveniji*, 24, pp. 19-24.

Zilhão, J. (2001). Radiocarbon evidence for maritime pioneer colonization at the origins of farming in west Mediterranean Europe. *Proceedings of the National Academy of Sciences*, USA. 24(98), pp. 14180-14185.

Zilhão, J. (2011). Time is on my side . . . , In Hadjikoumis, A., Robinson, E. & Viner, S. (ed.). *The dynamics of Neolithisation in Europe:* studies in honour of Andrew Sherratt. Oxford, Oxbow, pp. 46–65.

ANNEX I

Microfaces	Groundmass	Coarse Component	Fine Component	Microstructure	Porosity	Textural Pedofeatures
G28 128. 1	Fabric of coarse materials in random distribution and fine materials undifferentiated. Porphiric. C/F limit: 10um C/F ratio is 6/4	Quartz Ferromagnesian Feldspars Charcoal fragments (5-10%) Coarse sand (20-30%) Sandstone	Yellowish brown dotted and speckled	Granular	Chambers Channels Planes	Silty clay coatings around sand grains Loose and incomplete infillings of silty clay of excremental fabric
.2	Fabric of coarse material in linear distribution and fine materials undifferentiated. Porphiric C/F limit: 10um C/F ratio is 6/4.	Quartz Ferromagnesian Feldspars Charcoal fragments (5-10%)	Yellowish brown dotted and speckled	Granular	Chambers Channels Vesicles Vughs Planes	Dusty clay coatings around sand grains Limpid clay coatings Dense and incomplete infillings of chitonic and gefuric silty clay, dark yellowish brown and punctuated
.3	Fabric of coarse material in random distribution and fine materials undifferentiated. Porphiric C/F limit: 10um C/F ratio is 6/4, 7/3.	Quartz Ferromagnesian Feldspars Charcoal fragments (5-10%) Coarse sand (20-30%) Phytoliths (<2%) Sandstone	Yellowish brown speckled and dotted	Granular	Chambers Channels Vughs	Thin silty clay coatings around sand grains. Limpid clay coatings Loose and incomplete infillings of coarse sand with enauloc, chitonic, and gefuric C/F related distribution Coarse coatings around sand grains
.4	Fabric of coarse material in random distribution and fine materials undifferentiated Porphiric C/F limit: 10um C/F ratio is 6/4, 7/3.	Quartz Ferromagnesian Feldspars Charcoal fragments (5-10%) Coarse sand (20-30%) Sandstone	Yellowish brown speckled, cloudy to speckle.	Granular moderately developed	Channels Vesicles Chambers	Limpid clay coatings Micro-laminated coarse sand superimposed with dusty clay coatings Dense and incomplete infillings of chitonic and gefuric silty clay, dark yellowish brown and punctuated.

Sample 1: Abundance estimate for the coarse component of the section (Bullock et al., 1985)

1= Single occurrence (1%) 2=Rare (<2%) 3=Occasional (2-5%) 4=Many (5-10%) 5=Abundant (10-20%) 6=Very abundant (>20%)

The micromorphological analysis result of sample 1, G28 (S.U. 128).

Microfaces	Groundmass	Coarse Component	Fine Component	Microstructure	Porosity	Textural Pedofeatures
H28 WP 115.1	Fabric of coarse materials in random distribution and fine materials undifferentiated Porphiric, enaulic and chitonic C/F related distributions. C/F limit: 10um C/F ratio is 4/6, 3/7	Quartz Ferromagnesian Feldspars Charcoal fragments (10-20%) Phytoliths (<2%)	Yellowish brown dotted	Granular	Channels Chambers	Thin silty clay coatings around sand grain. Loose and incomplete infillings of silty clay of excremental fabric Dense and complete infillings of silty clay, dark yellowish-brown and punctuated.
.2	Fabric of coarse materials in linear and random distribution and fine materials undifferentiated Porphiric, enaulic , chitonic and gefuric C/F related distributions C/F limit :10um C/F ratio is 3/7 , 4/6	Quartz Ferromagnesian Feldspars Charcoal fragments (10-20%)	Yellowish brown dotted and cloudy	Granular moderately developed	Channels Chambers Vughs Planes	Thick silty clay coatings around sand grain. Loose and incomplete infillings of silty clay of excremental fabric Dense and complete layered infillings of silty clay, dark yellowish-brown and punctuated
.3	Fabric of coarse materials in random distribution and fine materials undifferentiated Porphiric C/F limit:10um C/F ratio is 4/6, 3/7	Quartz Ferromagnesian Feldspars Charcoal fragments (10-20%)	Yellowish brown dotted and speckled	Granular	Vughs Vesicles Channels Chambers	Loss and incomplete infillings of monic and enaulic silty clay Silty clay coatings around sand grains Dense and complete infillings of silty clay, dark yellowish-brown and punctuated.
.4	Fabric of coarse materials in random and distribution and fine materials undifferentiated Porphiric , enaulic and chitonic C/F related distributions C/F limit :10um C/F ratio is 4/6, 3/7	Quartz Ferromagnesian Feldspars Charcoal fragments (10-20%) Ceramics	Yellowish brown dotted and speckled	Granular	Chambers Channels Vughs	Silty clay coatings around sand grains Dusty clay coating around sand grains Dense and complete infillings of silty clay, dark yellowish-brown and punctuated

Sample 2: Abundance estimate for the coarse component of the section (Bullock et al., 1985)
1= Single occurrence (1%) 2=Rare (<2%) 3=Occasional (2-5%) 4=Many (5-10%) 5=Abundant (10-20%) 6=Very abundant (>20%)

The micromorphological analysis result of sample 2, H28 WP (S.U. 115)

Microfaces	Groundmass	Coarse Component	Fine Component	Microstructure	Porosity	Textural Pedofeatures
H27 WP 118.1	Fabric of coarse materials in random distribution and fine materials undifferentiated. Porphiric, enaulic and chitonic C/F related distributions C/F limit : 10um C/F ratio is 6/4, 7/3	Quartz Ferromagnesian Feldspars Charcoal fragments (5-10%)	Yellowish brown dotted and speckled	Vughy	Chambers Channels Planes	Dense and incomplete infillings of silty clay, dark yellowish brown and punctuated Cappings around sand grains Limpid clay coatings Loose and incomplete infillings of excremental fabric.
.2	Fabric of coarse materials in random distribution and fine materials undifferentiated. Porphiric, gefuric and chitonic C/F related distributions. C/F limit : 10um C/F ratio is 6/4	Quartz Ferromagnesian Feldspars Charcoal fragments (5-10%)	Yellowish brown dotted and speckled	Vughy	Chambers Channels	Dusty clay coatings around sand grains. Loose and incomplete infillings of excremental fabric.
.3	Fabric of coarse materials in random distribution and fine materials undifferentiated Porphiric C/F limit : 10um C/F ratio is 6/4, 7/3	Quartz Ferromagnesian Feldspars Charcoal fragments (5-10%)	Yellowish brown dotted	Vughy and massive	Chambers Channels	Silty clay coatings around sand grains. Limpid clay coatings Laminated silty clay, dark yellowish brown and punctuated Loose and incomplete infillings of porphiric and enaulic silty clay
.4	Fabric of coarse materials in random distribution and fine materials undifferentiated. Porphiric, enaulic and chitonic C/F related distributions. C/F limit : 10um C/F ratio is 6/4, 7/3	Quartz Ferromagnesian Feldspars Charcoal fragments (5-10%)	Yellowish brown dotted	Vughy	Chambers Channels	Silty clay coatings around sand grains Dense and incomplete infillings of excremental fabric.

Sample 4: Abundance estimate for the coarse component of the section (Bullock et al., 1985)

1= Single occurrence (1%) 2=Rare (<2%) 3=Occasional (2-5%) 4=Many (5-10%) 5=Abundant (10-20%) 6=Very abundant (>20%)

The micromorphological analysis result of sample 4, H27 WP (S.U. 118)

Microfaces	Groundmass	Coarse Component	Fine Component	Microstructure	Porosity	Textural Pedofeatures
H26 111 .1	Fabric of coarse materials in linear and random distribution and fine materials undifferentiated. Porphiric. C/F limit : 10um C/F ratio is 7/3	Quartz Ferromagnesian Feldspars Charcoal fragments (5-10%)	Yellowish brown dotted and speckled	Vughy	Chambers Channels Vughs	Dusty clay coatings Dense and incomplete infillings of porphiric and enaulic silty clay, dark brown and punctuated Loose and incomplete infillings of silty clay of excremental fabric
.2	Fabric of coarse materials in linear and random distribution and fine materials undifferentiated. Porphiric C/F limit : 10um C/F ratio is 8/2	Quartz Ferromagnesian Feldspars Charcoal fragments (5-10%)	Yellowish brown dotted	Vughy	Chamber Channels Vughs	Layered dusty clay coatings Silty clay coatings around sand grains Dense and incomplete infillings of porphiric and enaulic silty clay, dark brown and punctuated
.3	Fabric of coarse materials in random and linear distribution and fine materials undifferentiated. Porphiric C/F limit : 10um C/F ratio is 6/4	Quartz Ferromagnesian Feldspars Charcoal fragments (5-10%)	Yellowish brown dotted and cloudy	Vughy	Chambers Channels Vesicles	Crescent shaped silty clay coatings Dense and incomplete infillings of porphiric and enaulic silty clay, dark brown and punctuated Microlaminated silty clay coatings
.4	Fabric of coarse materials in random and linear distribution and fine material undifferentiated. Porphiric, enaulic, chitonic and gefuric C/F related distributions C/F limit :10um C/F ratio is 6/4	Quartz Ferromagnesian Feldspars Charcoal fragments (10-20%)	Yellowish brown dotted	Vughy	Chambers Channels	Cappings around sand grains. Limpid clay coatings Dense and incomplete infillings of porphiric and enaulic silty clay, dark brown and punctuated Layered dusty clay coatings, dark brown and punctuated.

Sample 5: Abundance estimate for the coarse component of the section (Bullock et al., 1985)

1= Single occurrence (1%) 2=Rare (<2%) 3=Occasional (2-5%) 4=Many (5-10%) 5=Abundant (10-20%) 6=Very abundant (>20%)

The micromorphological analysis result of sample 5, H26 WP (S.U. 111)

Microfaces	Groundmass	Coarse Component	Fine Component	Microstructure	Porosity	Textural Pedofeatures
F27 131.1	Fabric of coarse materials in random distribution and fine materials undifferentiated. Porphiric C/F limit : 10um C/F ratio is 7/3, 6/4	Quartz Ferromagnesian Feldspars Charcoal fragments (10-20%) Phytolith (<2%)	Yellowish brown dotted and speckled	Spongy	Chambers Channels Vughs	Dusty clay coatings around sand grains Loose and incomplete infillings of silty clay of excremental fabric. Limpid clay coatings Dense and incomplete infillings of porphiric, enaulic and gefuric silty clay, dark brown and punctuated
.2	Fabric of coarse materials in linear and random distribution with fine materials undifferentiated. Porphiric C/F limit : 10um C/F ratio is 7/3, 6/4	Quartz Ferromagnesian Feldspars Charcoal fragments (10-20%)	Yellowish brown dotted and speckled	Spongy	Chambers Channels Vughs Planes Vesicles	Limpid clay coatings Dusty clay coatings Dense and incomplete infillings of porphiric, enaulic and gefuric silty clay, dark brown and punctuated Microlaminated limpid clay coatings, superimposed by cryptocrystalline amorphous black materials

Sample 6: Abundance estimate for the coarse component of the section (Bullock et al., 1985)

1= Single occurrence (1%) 2=Rare (<2%) 3=Occasional (2-5%) 4=Many (5-10%) 5=Abundant (10-20%) 6=Very abundant (>20%)

The micromorphological analysis result of sample 6, F27 (S.U. 131)

Microfaces	Groundmass	Coarse Component	Fine Component	Microstructure	Porosity	Textural Pedofeatures
F27 122 .1	Fabric of coarse materials in striated distribution and fine materials undifferentiated. Porphiric C/F limit: 10um C/F ratio:7/3	Quartz Ferromagnesian Feldspars Charcoal fragments (10-20%) Fragment of sediment Burnt materials	Yellowish brown speckled	Spongy	Chambers Channels	Thick silty clay coatings around sand grains. Dusty clay coatings around sand grains. Limpid clay coatings Dense and incomplete infillings of porphiric, enaulic and gefuric silty clay, dark yellowish brown and punctuated
.2	Fabric of coarse materials in linear and random distribution and fine materials undifferentiated. Porphiric, enaulic, chitonic and gefuric C/F related distribution. C/F limit: 10um C/F ratio: 7/3, 6/4	Quartz Ferromagnesian Feldspars Charcoal fragments (10-20%)	Yellowish brown dotted and cloudy	Spongy	Chambers Channels Vesicles	Silty clay coatings around sand grain. Dusty clay coatings around sand grains. Loose and incomplete infillings of silty clay of excremental fabric Limpid clay coatings
.3	Fabric of coarse materials in random distribution and fine materials undifferentiated. Porphiric, enaulic, chitonic and gefuric C/F related distribution. C/F limit: 10um C/F ratio:7/3	Quartz Ferromagnesian Feldspars Charcoal fragments (10-20%)	Reddish brown speckled, dotted and cloudy	Spongy	Chambers Channels	Thick silt clay coatings around sand grains. Dusty clay coatings around sand grains. Layered coatings of silty clay, porphiric sand, dusty juxtaposed with layered fine silt. Dense and complete infillings of dusty clay
.4	Fabric of coarse materials linear distribution and fine materials undifferentiated. Porphiric, enaulic and chitonic C/F related distribution. C/F limit: 10um C/F ratio:7/3	Quartz Ferromagnesian Feldspars Charcoal fragments (5-10%)	Reddish brown speckled, dotted and cloudy	Spongy	Chambers Channels Vughs	Loose and incomplete infillings of silty clay of excremental fabric Silt monic coatings around sand grains Dusty clay coatings Dense and incomplete infillings of silty clay, dark yellowish brown and punctuated

Sample 7: Abundance estimate for the coarse component of the section (Bullock et al., 1985)
1= Single occurrence (1%) 2=Rare (<2%) 3=Occasional (2-5%) 4=Many (5-10%) 5=Abundant (10-20%) 6=Very abundant (>20%)

The micromorphological analysis result of sample 7, F27 (S.U. 122)

ANNEX II

THIN SECTION PROCEEDURES

STEP 1: CUTTING THE BLOCK

1. The block samples were cut after impregnation to fit on the glass slide (14x5cm as maximum dimensions)
2. Each sample was cut in half. By this to save a part of the sample for future works or unexpected errors.
3. The samples (all of them, even the saved ones) were labelled for proper and easy identification
4. A small notch mark was made at the top of each block sample slice to indicate the upper position of the sample.

STEP 2: PREPARATION OF THE GLASS SLIDE

1. The grinding wheel was turned
2. Some volume of water was sprayed on the wheel for lubrication purpose.
3. Sprinkled some abrasive on the wheel.
4. The edge the glass slide was carefully placed on the moving grinding wheel to polish the edge.
5. The edge of the glass and the entire glass was cleaned.
6. This process was repeated for all the glass slide to be used

STEP 3: GLUEING THE SAMPLES TO THE FIRST SET OF GLASS SLIDES

1. The glasses were checked to know if they fit in the grinding wheel holders. In case they do not fit, we would have rightly corrected them.
2. The glasses were prepared with the labels of each sample.
3. Each block sample was glued to its corresponding labelled glass using the prepared epoxy resin
4. The epoxy was left to work and it took at least eight (8) hours for the samples to be properly glued. The process of gluing was done on a foil paper to avoid laboratory accidents.

STEP 4: PREPARATION OF THE DEFINITIVE GLASS

1. Each glass was marked using a pen marker.
2. A notch was made on the right upper part of the glass to control the surfaces and the position.
3. The marked glass slides were attached to the grinding wheel machine for polishing until the marks disappeared. Then, the machine was left to work for 5 minutes for the purpose of regularising the surface of the glass slide.
4. Where the polishing machine had stopped was noted as this helped for subsequent glass slides
5. The glasses were taken out and cleaned.
6. The glasses were labelled to correspond to the samples.
7. The polished and cleaned glasses were kept in a chamber to avoid particles on top of them.

STEP 5: CUT THE CHIP (FIRST)

1. The surface and the edges of the glass from step 3 were cleaned (remains of epoxy).
2. The glued sample was placed on the slicing saw and turned on vacuum to hold it. The edges of slide were lodged against pins in holder.
3. The samples were cut on the slicing saw to a measure of 7mm from the first glass.
4. The slicing saw motor was turned on
5. The water to the slicing saw was turned on for lubrication.
6. The handle of the slicing saw was used to move the blade into the sample in a manner very slowly to avoid breaking the samples.
7. The chip was cut off the sample slide, it was retrieved it from the water tray. It was kept in case it is needed to repeat the process due to error or for future references.
8. The vacuum and slicing saw motor was turned off.
9. The cut samples and the chip for keeping were cleaned

STEP 6: FIRST POLISHING THE SAMPLES

1. The samples from which the thin section would be made were properly cleaned.
2. The surface of the samples from which the thin section would be made were marked
3. They were polished until the mark disappeared and the machine was left to work for at least 5minutes for surface smoothening.

STEP 7: GLUE THE SAMPLE TO THE POLISHED GLASS (SLIDE)

1. The polished glass slides were labelled corresponding to that of each of the samples.
2. The epoxy was prepared, which was well mixed and spread few drops across the top (polished side) of the samples from step six (6)
3. The samples were placed in a small vacuum chamber at 0.8 atmospheric conditions. This allowed the epoxy to flow more easily and allowed it to soak easily.
4. The samples were placed on the polished glass slides.
5. Each sample was placed in the big vacuum chamber and allowed to properly get glued. They were checked periodically for the first 5-10 minutes to be sure that the glass slide has not slide off the sample.

STEP 8: CUT OFF THE CHIP FROM THE SLIDE (SECOND CUT)

1. The surface of the glass was cleaned to avoid errors.
2. The sample was placed on the cut-off saw (note direction of ground corner) and turned on vacuum to hold it. The edges of sample slides were lodged against pins in holder.
3. Turned on saw motor.
4. Turned on the water to the cut-off saw.
5. The handle of the slicing machine was used to move the blade into the sample in a manner very slowly to avoid breaking the samples.
6. Once the chip was cut off the slide, it was retrieved from the water tray and kept in case it is needed to repeat the process or for future references.
7. Turned off the vacuum and saw motor.
8. Cleaned the slide (sample) to remove any particles and the chip

STEP 9: GRINDING THE SLIDE TO CORRECT THICKNESS

1. The plates of the grinding/ polishing machine were clean.
2. Turned the control (counter-clockwise direction) in a full rotation to zero.
3. The slide holder and the slide were clean and free of any grit or particles.
4. Placed the slide on the grinder (maintaining the same orientation using the corner we notched).
5. Turned on the water to the grinder.
6. Turned on the vacuum and grinder motor.
7. Moved the slide back and forth with the handle, gradually advance the control until the slide contacts the grinding wheel.
8. The grinding wheel machine was left to work until about 60-100 microns of the reference point (polished glasses) and ended at 30 microns
9. The slide was removed after turning off the grinding wheel machine to see on the microscope if any minerals can be identified.

STEP 10: ADDING A COVER SLIP

1. The section to be covered was clean and free of grit or dirt.
2. Mixed up a small portion of epoxy and hardener.
3. Placed a small drop of epoxy on the section.
4. Placed it on the hot plate to avoid bubbles
5. Dropped the cover slip on the section.
6. Moved it around to expel bubbles and fully coat the section.
7. It was left to properly glue
8. After it has glued, some extra epoxy were observed on the top, side and bottom of the section. They were removed very carefully, with razor blade-like equipment.