A PHYTOLITH STUDY FROM KİNET HÖYÜK, HATAY

A Master's Thesis

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Ankara
December 2019

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To my parents and my dogs, rest in peace Efe

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The Graduate School of Economics and Social Sciences
of
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by
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I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Archaeology.

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ABSTRACT

A PHYTOLITH STUDY FROM KİNET HÖYÜK, HATAY

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December 2019

Phytolith studies are now an established subbranch of archaeobotanical studies. However, there is a very limited number of phytolith studies focused on Anatolia. Kinet Höyük is one of the eligible sites since extensive archaeobotanical studies were conducted and studies are ongoing. From Kinet, 23 samples are studied for phytolith analysis. 13 of them are extractions from soil samples and 10 of them are samples which are suspected to contain phytolith fibers. The contexts vary between room floor sediments to storage pits. For this study, the focus is on the multicellular phytoliths, since they can be used for a higher resolution of identification (Rosen, 1992). This study aims to observe the chronological changes in storage pit use, if there are any, and the variation between contexts. Another focus will be the use of reed in these contexts and the possible

reasons for their use. For this thesis, quantifiable data was obtained and they were subject to statistical analysis. The results suggest that there are no contextual difference in the phytolith assemblage of Kinet; however, chronological changes were observed.

Keywords: Anatolia, Archaeobotany, Archaeology, Kinet, Phytoliths

ÖZET

KİNET HÖYÜK, HATAY'DAN BİR FİTOLİT ÇALIŞMASI

Köseoğlu, Tuğçe

Yüksek Lisans, Arkeoloji Bölümü

Tez Danışmanı: Doç. Dr. Marie-Henriette Gates

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Günümüzde fitolit çalışmaları arkeobotaniğin önemli bir dalı olarak kabul edilir. Ancak, Anadolu'ya odaklanan çok az sayıda fitolit çalışması vardır. Kinet Höyük, hali hazırda arkeobotanik araştırmaları yapıldığı ve çalışmalar devam ettiği için bir fitolit çalışması için oldukça iyi bir adaydır. Kinet'ten 23 adet örnek bu tezde incelenmiştir. Bu 23 örneklerden 13'ü toprak, 10 tanesi fitolit barındırdığı düşünülen fiber örneğidir. Bağlamlar oda dolgusu ve depo çukurları olarak sınırlanmıştır. Bu çalışmanın amaçlarından biri çok hücreli fitolitleri gözlemlemektir, çünkü bu çeşit fitolitler tanımlama konusunda oldukça yardımcıdır (Rosen, 1992). Çalışmanın ana sorularından bir diğeri, bu

bağlamlarda sazlıkların nasıl ve niçin kullanıldığıdır. Bu tez için ölçülebilir veriler toplanmış ve bu veriler istatistik analizlere tabi tutulmuşlardır. Sonuçlar, fitolit grubunun bağlamsal olarak değişim göstermediğini, ancak kronolojik olarak değişimler gösterdiğini vurgulamıştır.

Anahtar Kelimeler: Anadolu, Arkeobotani, Arkeoloji, Fitolit, Kinet

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I managed to finish this thesis not only thanks to many academics who guided me, my friends were great support during this process. My friends who I shared an office with Eda Doğa Aras, Dilara Uçar Sarıyıldız, Duygu Özmen, Defne Dedeoğlu and Seren Mendeş always lended an ear whenever I needed somebody. In addition, Umut Dulun was a great project partner and colleague in my time at the department. Roslyn Sorensen and Hatibe Karaçuban were always there for a nice cup of tea.

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CHAPTER 1

INTRODUCTION

Phytoliths are plant microfossils of silica origin. Increasingly since the 1970s, they have been an interest of archaeobotanists and archaeologists. Archaeobotany is a specialization of environmental archaeology. It is mainly concerned with plant remains such as seeds, woods, charcoals, and microfossils. Phytolith research is a complementary proxy of archaeobotany and it is an established branch in its own right. This thesis will be concerned with phytolith assemblages recovered from Kinet Höyük excavations that took place between 1991-2007.

The first chapter of the thesis will give an overview of phytolith research. In this chapter the many aspects of phytolith research will be discussed, such as its history, the development of phytoliths in higher plants, their structure, and, last of all, the analytical steps in phytolith research. To begin with, phytoliths, a term derived from Greek words "phyto" meaning plant and "lith" stone, are the result of plants retaining groundwater and storing the silica between their intracellular or extracellular matrix. As agreed by many scientists in the field, this term only refers to siliceous or opal crystals. The history of research can be

traced back to the first samples Charles Darwin collected in his famous voyage with HMS Beagle (Piperno, 2006). Unfortunately, phytolith research has been underdeveloped in Anatolia for archaeology. The development of phytoliths in a plant is dependent on many factors such as the environment of the plant, the age of the plant, versatile aspects of the soil the plant grew in, and most importantly the taxonomic classification that the plant in question belongs to. Two mechanisms have been proposed for the uptake of phytoliths: active transportation and passive transportation (Piperno, 2006). Through these mechanisms, simply, plants acquire the silica dissolved in the water and they transport and deposit the silica into different types of tissues. The deposited silica is polymerized, therefore a solid structure is formed. After the death of the plant, the organic parts of it decompose and the silica in the form of phytoliths is left in the soil where the plant was the last present.

My introductory discussion will conclude with the phytolith assemblage analysis. Phytolith analysis is a meticulous job. The process begins with phytolith extraction from soil samples. For this thesis, Madella et al.'s protocol (1998) will be the basis of the extraction procedure. The protocol entails many steps towards "cleaning" the other components of soil and retaining the silica at the end. Phytolith analysis begins once the extraction is completed. The phytoliths are mounted on a microscope slide and they are examined under it with different lenses. A phytolith study requires phytoliths to be counted according to the most abundant morphotypes. For this thesis, only the Poaceae (grass family) and Cyperaceae (sedge family) related morphotypes will be considered. After

counting, necessary statistical analyses such as Principal Component Analysis and two-way independent t-test will be performed according to the research problem (RStudio Team, 2018).

Phytolith research has been used in archaeology for many reasons. The first and foremost is preservation: phytoliths are essentially inorganic, because they mostly consist of silica, therefore they are more durable than organic remains. Phytoliths do not need anoxic or extremely dry environments for their preservation like organic remains. Also, unlike archaeobotanical examined seeds, they do not need to be carbonized to survive in the soil. Phytolith studies have shown that phytolith patterns are widespread among higher plants and they are faithfully reproduced among the members of the same taxa. The downside of this research, however, and the main reason why it is not as widespread as it should be in archaeology, is that it requires specialization or interest in the natural sciences. The extraction and analysis processes require biology and chemistry knowledge, therefore the numbers of phytolith experts in archaeology are still low. Nevertheless, phytolith research has been beneficial for archaeological questions and environmental reconstructions.

The second chapter will focus on Kinet Höyük phytolith research. First, Kinet Höyük will be introduced in detail and the samples, along with sampling strategies, will be explained thoroughly. Following this information, the questions concerning why archaeologists need phytolith research and why Kinet Höyük was a good candidate for phytolith research will be answered.

The materials for this thesis were collected during excavations at the site of

Kinet Höyük, Hatay. Kinet Höyük, also known as ancient Issos, is located 30 km away from İskenderun, close to Dörtyol, Hatay. It is in the region known as the Late Bronze Age Kizzuwatna and Classical East Cilicia (Gates, 2015). This region has been geographically important for a very long period and Kinet Höyük is the reflection of this. The main economic source of this city was the ancient harbor. The location of Kinet made it one of the important ancient harbor sites among other Mediterranean cities. The settlement has a long period of continuous habitation starting from the Late Neolithic until Hellenistic periods (5000 BC – 80BC) and followed by a Medieval phase, when it was reused by Crusaders (Novák et al., 2017).

It should be noted that Kinet Höyük is exceptional in excavation methods since soil samples for phytolith analysis have been collected since 1993, which is a rare practice in Turkish excavations. The samples form a representative set both contextually and in quantity. One of the contexts selected from samples is the storage pits. The storage pits have yielded much information for archaeobotany and zooarchaeology, and they are appropriate candidates for a phytolith research. The storage pits have been used in most of the lifespan of Kinet, therefore they have the potential to show chronology of the changes in food culture. Storage pits have been used in other similar phytolith research projects and they have yielded significant results (Madella, 2001). The second candidate for a contextual analysis is the room floor deposits. Plant remains can be observed from the debris as a result of a number of activities carried out with plants including cooking and weaving. The floor deposit samples also reflect the chronology of Kinet Höyük with precision. In total, there are ca. 20 samples selected from

the list of phytolith samples collected and stored that represent both of the contexts.

Kinet Höyük is an excellent candidate for phytolith research for many reasons. The first is that Kinet Höyük remains represent domestic life very well. Domestic life has been closely tied with food culture, therefore, it has been a great context for archaeobotanists to explore. The second reason is that Kinet Höyük's archaeobotanical research has been carried out and overseen for many years by the experts in the field with great care. Any phytolith evidence is supported and completed by the archaeobotanical data accurately. The third and most practical reason is that Kinet Höyük's excavation team has been visionary enough to collect enough material during the excavations so that research can be conducted with an effective quantity of materials. Overall, Kinet Höyük is a promising candidate for conducting a phytolith research project.

My third chapter will focus on the three main questions which the thesis aims to answer. Based on all the facts about phytoliths and Kinet Höyük, the thesis will be built upon three main hypotheses. The first hypothesis is that the storage pits and floor deposits will have different phytolith assemblages. For this, an experiment will be devised with control samples and the assemblages will be assessed only qualitatively. The second hypothesis is that the storage pits will show different assemblages through different chronological periods. The use of storage pits is connected closely with food culture and environmental factors, therefore a change in the characteristics of assemblages is expected. The third hypothesis is that phytolith assemblages from room deposits will be closely tied

with the functions of the rooms. Archaeobotanical research and phytolith research are expected to be parallel and give more information about the functions of the rooms. All three questions will give a further understanding of daily life, food culture and environment of Kinet Höyük.

The fourth chapter is about the synthesis of information gained from phytolith assemblages. In this chapter, the results of the experiments and the questions mentioned above will be presented as a synthesis, to shed light on the possible answers to the questions. The results will be categorized accordingly, such as but not limited to morphology, chronology, and context. Because of the unpredictable nature of experimentation, there may be non-fitting data to the existing categorization.

The fifth chapter is about a novel input to the phytolith research. This chapter will focus on artistic three-dimensional reconstructions of some morphotypes identified in Kinet Höyük materials. This need was present due to the fact that no reference collection was available during the research for this thesis. Therefore, to be able to recognize the phytoliths from different angles, and to be more aware of the distinguishing features of the morphotypes, such reconstructions were most helpful. Also, this chapter aims newcomers to the field to be more familiar with the 3-D nature of phytoliths.

Following this, in the sixth chapter, the synthesis of what has been gathered will be discussed in light of the main questions. The information gained through synthesis will pave the way for discussion. This chapter will have sections for each question at hand. In this chapter each sample will be introduced with the

relevant quantitative and qualitative analysis performed on them. This last chapter will present an overall conclusion of the thesis.

CHAPTER 2

A REVIEW OF PHYTOLITHS

Phytolith research is a major part of archaeobotany, however it has been employed in different areas of science as well (Fig. 1). The focus of this thesis encompasses archaeobotanical research of phytoliths mainly.

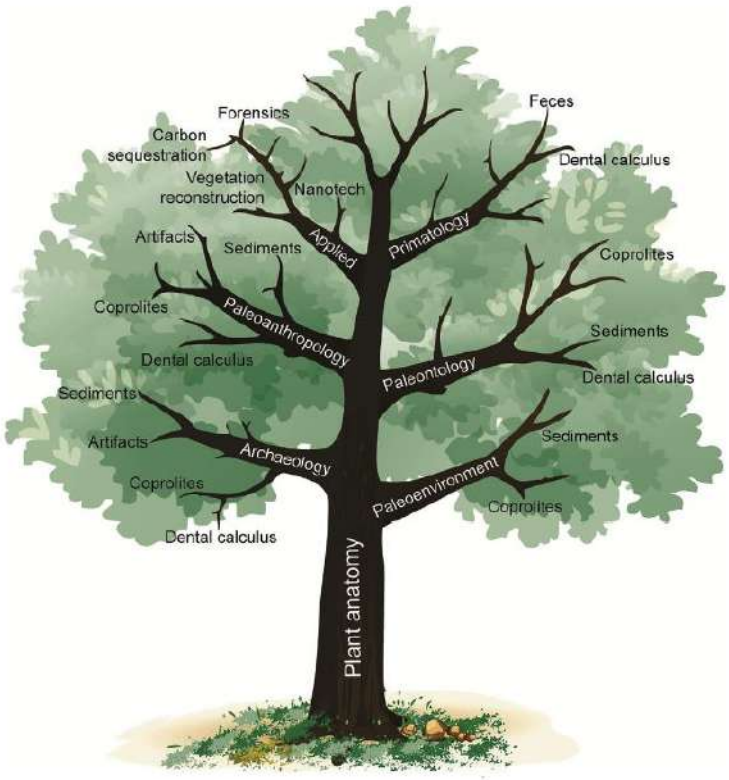


Figure 1: The tree diagram showing different uses of phytoliths (Hart, 2016: 29, Fig. 3)

2.1 Research History

Phytolith research stands between disciplines like biology, anthropology and soil chemistry. Phytolith research was adopted and adapted into archaeology around the 1970s and it has become an established paleoecological discipline. This section will survey briefly the first academic evidence of phytolith research to the current issues and directions in the field, with an addition of studies specifically carried out in Anatolia.

According to Piperno (1988), the chronology of phytolith research can be examined under four categories: i.) the discovery and explanatory stage, from 1835 to ca. 1890; ii.) the botanical phase from the 1900's to 1936; iii.) the ecological research period from 1955 to 1975 and finally iv.) the modern period of phytolith research since the 1970s (Piperno, 1988: 1-2). She uses this type of framework to convey the change in research interests during the history of research.

2.1.1 The Discovery and Explanatory Stage (1835-1890)

This stage was primarily about the observation of phytoliths within living plants and some of the first encounters with phytoliths from environmental contexts (Piperno, 1988: 2). The first studies emerged in Europe because of curiosity about the microscopic world (Powers, 1992: 15-16).

The very first work on phytoliths was by Struve, a German botanist, in 1835 on actual living plants rather than sediments (Piperno, 1988: 3). He submitted a

dissertation about the silica bodies found in plants to Berlin University (Powers, 1992: 18). The first and arguably the most prolific research was done by Christian Gottfried Ehrenberg. Ehrenberg was a medical doctor who had left his practice to join General von Minutoli on "an antiquarian journey to Egypt". He was interested in the flora of that region and then joined many expeditions in Africa and Asia later on to further his knowledge on the subject (Powers, 1992: 16).

According to Ehrenberg, "phytolitharia", a term coined by him to mean plant stones, were like microorganisms Foraminifera, Protozoa and Coelenterata. After his published works in 1841 and 1845, he was approached by Charles Darwin to study dust that was collected from the deck of his expeditionary boat *H.M.S.* Beagle (Powers, 1992: 17). Darwin provided him with a vivid description of the dust while they were anchored at Cape Verde Archipelago:

> "On the 16th January (1833), when the Beagle was ten miles off the N.W. end of St. Jago, some very fine dust was found adhering to the underside of the horizontal wind vane at the mast head, it appeared to have been filtered by the gauze from the air ... (and) the dust probably came from the coast of Africa. The atmosphere was so hazy that the visible horizon was only one mile distant. During our stay of three weeks at St. Jago ... the atmosphere was often hazy, and very fine dust was almost constantly falling, so that the astronomical instruments were roughened and a little injured. The dust collected in the Beagle was excessively fine grained and of reddish brown colour; it does not effervesce with acids ..." (as cited in Powers, 1992: 17).

From these dust samples, Ehrenberg found 67 different types of *infusoria*, simply meaning microscopic animal and plant life, and 34 of them were *phytolitharia*. Later on, Ehrenberg expanded his repertoire of contexts and included mud, gypsum, and clay to study the *phytolitharia* and *infusoria*. In addition to

his work in Europe and Africa he also studied soil samples called "Black Earth" from Central Russia. This particular project paved the way to realize the potential of such plant micro-fossils to be used in paleoenvironmental reconstructions, because his work showed that there was "ancient forest debris" in the soil samples (Powers, 1992: 17).

Ehrenberg also created a parataxonomic system to name specimens and identification. He put the 67 *phytolitaria* under four paragenera. Three of these paragenera were identified as belonging to the Poaceae family, the other to the Equisetaceae family. This signifies that he was able to identify the silica up to family level. His para-taxonomic system acted as a prototype for future researchers, who have adopted a similar approach. Ehrenberg's *Mikrogeologie*, published in 1854, influenced later scientists as well (Piperno, 1992: 3).

2.1.2 The Botanical Phase (1845-1935)

The botanical phase extended from 1895 to 1936. In this phase, especially German scientists contributed to the literature by studying live plants. They systematically tried to gather more knowledge about the derivations of phytoliths on plant tissues and explore the production, taxonomy and variation in the phytoliths produced in different tissues. Mechanisms of silica deposition were also considered for the first time in this period. Scientists reported the occurrence of phytoliths, or *Kieselkörper*, in many plant families. For instance, the German scientist Möbius noted the presence of phytoliths in Chrysobalanaceae, Dilleniaceae, Palmaeceae, Orchidaeceae, Urticaceae and Hymenopyllaceae. Later on,

like Möbius, Netolitzky added Podostemaceae, Burseraceae, Musaceae, Cannacea and Marantaceae to the list of phytolith producing families. In addition to detecting the plant families that produce phytoliths, the morphology of the found phytoliths started to be documented (Piperno, 1988: 4).

During this phase almost exclusively German botanists published new research. As a result, phytoliths went unnoticed in the English-speaking academic spheres. After World War II, the botanical phase nearly came to an end (Piperno, 1988: 5). Only a few publications can be found after 1936 which were written by German botanists (Piperno, 2006: 3).

2.1.3 The Period of Ecological Phytolith Research (1955-1971)

Only after the 1950s did English-speaking academics became interested in phytolith research. In the years between 1955-1975 many scientists such as botanists, soil scientists, agronomers and geologists started to apply phytolith research to their fields. Phytolith analysis became an index of environmental history. Hence, this period can be called the ecological phytolith research period (Piperno, 1988: 5).

During the second half of the 1950's, scientists from Britain, the United States and Japan documented the occurrence of phytoliths in their native soils. In this period, the annual phytolith productions of plants were examined. They were able to identify attenuating factors in production. For example, both biotic and abiotic factors such as annual and multi-annual climatic variation, soil pH, and concentrations of iron and aluminum were examined for their effect on phytolith

production or the amount of silica in an individual plant. The other complication was that the roots of grass family members may contribute silica as much as the above-ground parts. The lifespan of different plants also was determined to play a role (Piperno, 1988: 5).

During this period, phytoliths were employed in understanding many different ecological issues. Phytoliths were found in geological formations millions of years old. Studies about the relationship of phytoliths and pedogenesis flourished. Especially, the grass family was examined more closely. Studies about the grass family phytoliths such as Twiss, Suess, and Smith (1969), are still relevant today. At that time, the identification of subfamilies of grasses was considered problematic by the researchers, yet today the recent morphological research shows promise on the subject (Piperno: 1988: 6).

2.1.4 The Modern Period of Archaeological Phytolith Research (1971-2001)

The chapter heading gives the impression that the use of phytolith analysis came into partnership with archaeological research only after 1971, however the first examples of such work were already done in the first half of 20th century (Piperno, 1988: 9). Netolitzky (1914), Schellenberg (1908), Edman and Söderberg (1929) and others combined archaeology and phytolith research (as cited in Piperno, 1988: 9).

Most of the early works from Netolitzky and Schellenberg[1] were concerned with

[1]Schellenberg's work is noted incorrectly in this edition of Piperno (1988). The archaeological site Anau is in Turkmenistan, not Turkey. Rosen (1992) confirms this.

the Near East. They paid attention to the shape of silicified bodies from the epidermal and short cells found in glumes. Their criteria paved the way for future research done 50 years later (Piperno, 1988: 9). Helbaek also worked in the Near East and his focus was on agricultural origins and their dispersal. His main sources were ash heaps and pottery. He noticed differences in the silicified epidermis cells from husks of wheat, rice, millet and barley (as cited in Piperno, 1988: 9).

Phytoliths couldn not draw much attention in early archaeological research. However, later on, their contribution was recognized in areas like Eastern North, America and for the tropics where preservation of archaeobotanical remains was poor. Problems related to issues like the origins and dispersal of seed and root cropping in antiquity couldn't be explored efficiently with current materials like pollen or macrobotanical remains. Pearsall (1978) and Piperno (1984) have contributed to the research by focusing on tropics (Piperno, 1988: 10).

2.1.5 The Period of Expanding Applications (2001-Present)

This period witnesses some key changes and a new phase in phytolith research. Namely the first characteristic is a sharp increase in the number of new publications including phytolith analysis. The second characteristic marks more diverse areas of application. The third is a reassessment of using C-14 dating. The fourth characteristic is the inclusion and application of digital tools for refining and sharing phytolith identification [2]. The fifth is the development of the field

[2]The table given in Hart (2016) contains a number of online digital collections gathered by various researchers. Out of three links two of them are currently still online. On the same page, he gives another table about actively online and offline databases.

of applied phytolith research. The last one, and probably the most crucial, is the collective efforts toward standardization of phytolith research (Hart, 2016: 25)

Hart (2016) notes a significant increase in the number of phytolith publishings. He searched for the English language databases of five major international publishing companies and determined that the annual number of publications from 1971 to 1996 was 1.03 (std ±1.61), and has risen to 13.58 (std ±8.71) in 1997 to 2015 (Fig. 2) (Hart, 2016: 25)[3].

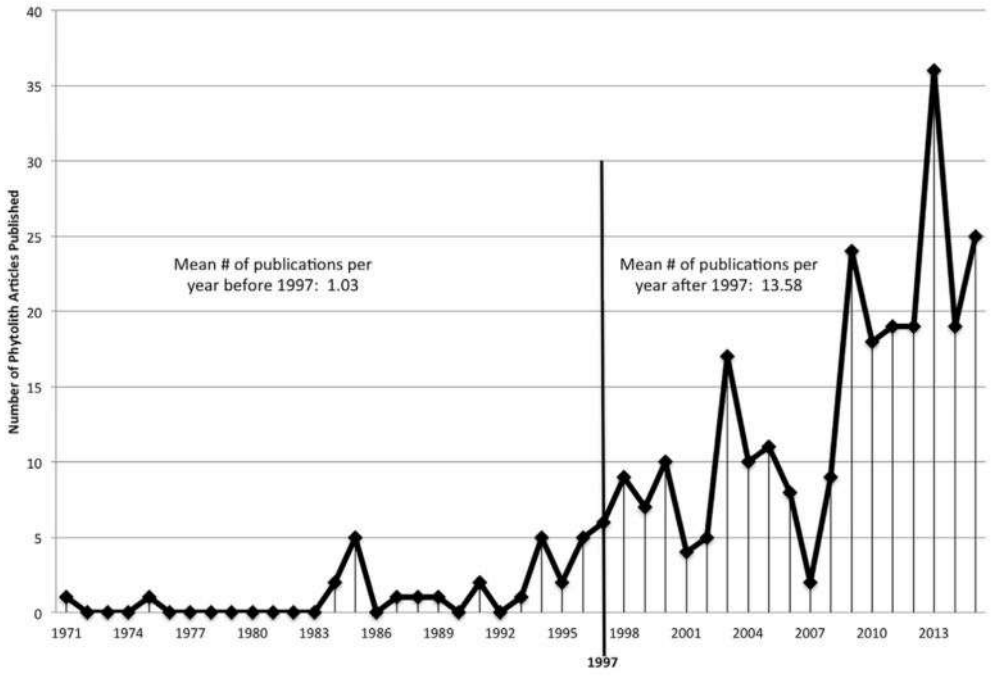


Figure 2: Number of phytolith publications from 1997 to 2015 (Hart, 2016: 25, Fig. 1)

As Hart (2016) also notes, the greatest contribution to the literature in this period is the collective effort towards standardization of phytolith research. One

[3]This rise can be due to the fact that phytolith research was becoming more established after those years and becoming more widespread.

of the great achievements is the establishment of an International Code for Phytolith Nomenclature (ICPN). As the authors explain, this nomenclature is developed to rectify the inconsistencies regarding phytolith nomenclature which impede the communication between various researchers (Madella, Alexandre, & Ball, 2005: 253). Also, new works aim towards standardization in laboratory techniques such as assessing the minimum phytolith sum for archaeological studies (Zurro, García-Granero, Lancelotti, & Madella, 2016; Zurro, 2017).

2.1.6 Phytolith Research in Anatolia

Unfortunately, Anatolia has been underrepresented in phytolith literature. Nevertheless, there are a handful of publications concerning Anatolian excavations.

The greatest contribution to Anatolian research comes from Çatalhöyük. Throughout the years many publications about the site have been gathered (Ryan & Rosen, 2016; Shillito, 2017). Annula Çatalhöyük Archive Reports from 2004 onwards include information about the phytolith research done on the site. Specialists like Arlene Rosen, Philippa Ryan, Lisa-Marie Shillito and Emma Jenkins have carried out research related to Çatalhöyük material. They have worked on the site at various periods (Rosen, 2005; Ryan, 2013; Shillito & Ryan, 2013) .

The rest of the publications referring to Anatolia are also mostly on the Neolithic period. For instance, a recent publication focuses on the phytoliths found in three neighbouring sites: Boncuklu, Pınarbaşı and Çatalhöyük (García-Suárez, Portillo, & Matthews, 2018).

An exception to this trend concerns the Iron Age occupational phase at Kilise Tepe in the Göksu Valley (Madella, 2001). In his work, Madella (2001) gathered several samples from pits, (secondarily) and assessed them to be storage pits later used for rubbish.

Currently there are two available articles in Turkish language which can be found on the Internet concerning phytoliths (Ağcabay-Kırnak, 2013; Rapp Jr & Mulholland, 1993). One of them, Rapp Jr and Mulholland (1993), is a direct translation from the original English written by other scholars. They only give a general literature review. There are also a few internet articles giving information about the subject and some recent research [4]. There are no current theses with keyword "phytolith" in the YÖKSİS (Turkish Council of Higher Education) database.

2.2 Production and Deposition of Phytoliths

The term "phytolith" is a combination of the two Greek words,"phyto" meaning plants and "lith" meaning stone. Phytoliths are the natural result of a biological process by which higher plants deposit the silica excess in their intracellular or extracellular matrix of tissues after the absorbtion of silica in soluble form from groundwater. They are inorganic, therefore they can last in the soil more than most of the plant remains. Hence, they can be called the "most durable plant fossils known to science" (Piperno, 2006: 5). This term only encompasses opal,

[4]Sheffield University archaeobotany website (https://sites.google.com/sheffield.ac.uk/ archaeobotany/phytoliths?authuser=0) offers a good amount of information about phytoliths overall. There are blogs and articles about case studies involving phytoliths.

or silica based, phytoliths since there are calcium versions of phytoliths as well. Calcium "phytoliths" are proven useful in some cases, however their study is not widespread in archaeology and paleoecology. Phytoliths are also called opal phytoliths, plant opals and opaline silica because their structure is not crystalline, like geological opals found in soil. A more general category like bioliths serves as an umbrella term to cover the silicon found in lower plants and animals like diatoms (Piperno, 2006: 5).

Phytoliths are a form of amorphous (noncrystalline) silica and they are made of silicon dioxide (SiO_2). More technically, they are "made of porous opal-A ($SiO_2 \cdot nH_2O$)" (Madella & Lancelotti, 2012: 77). They contain ca. 4 to 9 percent water in varying amounts. Phytoliths encase the cytoplasmic matter, therefore elements like Al, Fe, Mn, Mg, Cu, P and organic C can be found in their composition (Piperno, 2006: 15). Recent studies have shown that they can encase glycoproteins, however no DNA sample has yet been extracted from phytoliths directly (Elbaum, Melamed-Bessudo, Tuross, Levy, & Weiner, 2009). Nevertheless, the carbon encased in phytoliths can be used for conventional radiocarbon dating methods. Stable isotope ratios like oxygen, hydrogen and carbon can be detected. Stable isotope studies on phytoliths have been proven useful in reconstructing past vegetation and climate (Piperno, 2006: 15).

Optical properties of phytoliths are useful for distinguishing them from pedogenic silica. Biogenic silica from plants is optically isotropic. The refractive index ranges from 1.41 to 1.7. The specific gravity of phytoliths varies between 1.3 to 2.3. They have three dimensional shapes under the microscope. Their color

can be colorless, light brown or opaque under transmitted light, but usually they are transparent. The darkness of phytoliths can be an indicator of either dense organic material encasement or burning of the plant remains [5] Burnt or organic matter carrying phytoliths may have lower densities (Piperno, 2006: 15).

2.2.1 Phytolith Production in Higher Plants

As noted before, the term phytolith only refers to silica bodies originating from plant tissues. However, not all plant species accumulate phytoliths in their tissues (Table 1). As seen from Table 2.1, different plant families have different production rates. As Piperno (2006) notes, many plant families weren't explored with respect to their phytolith production. Research about this issue is ongoing and new publications add to the collective knowledge. For this purpose, Evett has gathered an extensive bibliography about phytolith literature (Evett, 2017).

The journey of phytolith production begins with the uptake of monosilicic acid (H_4SiO_4). The transportation of acid can be either passive or active (with energy expenditure). Especially grasses are known to employ both passive and active transportation (Piperno, 2006: 9). Even though some plants actively transport monosilicic acid, some plants may have rejection mechanisms for it. It is observed in pea seedlings (*Pisum sativa*) that after removal of the root organs the silica deposition was detected in leaves and tendrils (Winslow & Parry, 1977). Parry and Winslow (1977) point out the fact that the plants which do not accumulate phytoliths have their root hairs covered with a thin layer of

[5] More about burned phytoliths can be found in Parr, 2006. Also Weiner, 2012 explains the property changes after burning.

waxy substances resembling cutin and suberin. Such structures may interfere with the uptake of silica from the soil. In correlation to this, phytolith productive plants like maize and barley don't have fatty encapsulations at the tip of their root hairs. This rejection can be one of the possible reasons why some plant families don't produce phytoliths (Piperno, 2006: 9).

The actual mechanism of monosilicic acid to SiO_2 is not exactly known. It is associated with transpiration and water loss at the level of the leaves. Yet regulation of silica deposition is not due to one particular reason. One of the evidences for the regulation of deposition is the rapid loss of the cytoplasm and the nucleus in an early stage of leaf formation. The inclination here is that plants are enabling silica deposition in some selected cells which undergo this formation. This is atypical silicification of grass leaves. Another evidence for regulation is the silicon channels detected in diatoms. The presence of such channels may explain the concentrated silicification of some parts of plants (e.g. the sedge achene pericarp, which has more concentrated phytoliths than the seeds). Another direct evidence comes from maize and *Cucurbita*. Gene loci have been recognized in them that are responsible for the production of lignin. They are also responsible for the phytolith production in those plants (Piperno, 2006: 10). A new study elaborates more on this topic. According to the presence of NIP-III channels, plants can be categorized as accumulators of silica and non-accumulators (Coskun et al., 2018: 4). This is a distinction on a genetics level which can lead to understand the phytolith production in plants.

There are in fact a few reasons why phytolith production is not equal amongst

different plant families, even in the members of the same taxa. These factors can be the different climatic growth environments, nature of the soil plants grow in, the age of the plant, tissue selectivity in plants, and the taxonomic affinity of the plant family for phytolith production (Piperno, 2006: 5).

Probably the most vital factor in phytolith production is the affinity of the plant taxa for production. Table 2.1 demonstrates which families are more inclined to higher phytolith production. It is a collective effort. Highly encountered crop products in Near East like wheat, barley, and millet are members of Poaceae, therefore their presence in the assemblages are not surprising in Near East. Those highly productive plant families will show close rates of production regardless of the type of soil (Piperno, 2006: 6).

Another vital factor is the nature of the soil. Generally this refers to the chemical composition of the soil. The pH levels, available dissolved silica, presence of other compounds like iron oxides and similar factors can play a part in the production of phytoliths. For example, acidic soils can hold more free silica. On the other hand, the presence of iron oxides can bind the free silica and impede silica absorption (Piperno, 2006).

2.2.1.1 Why Plants Make Phytoliths? The Function

One important question regarding phytolith production is why do plants need them in the first place. As noted previously in this chapter, plants can invest energy in silica uptake. This brings the question why plants would invest in phytolith production unless it is advantageous to survival.

A recent study about functions of phytoliths examined them from an evolutionary perspective, and the hypothesis that phytolith production is an adaptation was tested (Strömberg, Di Stilio, & Song, 2016). According to Strömberg et al. (2016) the hypothesis that phytolith production is an adaptation as a cost-effective substitute for lignin production in plants needed to be tested. They were also interested in the co-evolution of grazing animals and phytolith production. They had three foci: first, the wearing of phytoliths on the teeth of grazing animals; second, the silicon accumulation being fit for the evolutionary pattern, third the comparing of paleontological evidence for the hypothetical function of phytoliths as structural support and herbivore defence. Their results show that teeth wear is related to phytoliths, however it is not the sole culprit. Secondly, they note that phytolith production evolved in land plants more than once therefore a direct temporal connection is missing. They conclude that phytoliths are helpful for defense and structural support yet their adaptive origin must be explored further (Strömberg et al., 2016).

In addition to Strömberg et al., Piperno (2006) adds that phytoliths can help against mitigating the damaging effects of aluminum oxides in soil, resistance to pathogenic fungi in various plant species, preventing the collapse of cell walls and other advantages.

On the other hand, a very recent article which discusses the function of silica in plants provides an alternative view (Coskun et al., 2018). According to Coskun et al. (2018), silica is not an essential plant nutrient, however they proved that silica can be useful. Specifically, they stress the semantics of this issue. They

note that Si is not particularly an agent of promotion in plant growth yet it prevents or mitigates the agents of stress, therefore influencing the plant growth in a positive way. They also note in the case of rice gene expression silica supplementation wasn't effective significantly. However, they stress the fact that silica is particularly beneficial for the plants showing signs of stress such as in a fungal infection. They are strongly in favor of the hypothesis that silica has a prophylactic role in plant growth.

2.2.2 Taphonomy

Like other biological remains found in archaeological sites, phytoliths should be considered according to their taphonomy. After phytoliths are formed, they are deposited into soil. This is not a single event, it is a series of processes. These steps are i) necrolysis, the decomposition and dissolution of plant organic materials after death; ii) biostratinomy, which refers to all events after the death of plant but before a phytolith is incorporated into soil; and finally iii) pedogenesis (soil formation) or diagenesis (rock formation), which is the summation of all effects phytoliths undergo in soil that can result with an alteration on the assemblage [6] (Madella & Lancelotti, 2012: 76) (Fig. 3)

Considering pre-deposition, the combination of necrolysis and biostatinomy, phytoliths may undergo important changes. Since plants are always regenerating their cells, the cells may die in different phases of their formation. This results with incomplete phytolith formation and the traces of it can be detected in

[6]The term assemblage here is the sum of all the phytoliths found in a research. It shouldn't be confused with archaeological assemblages although they bear similar traits. For more see Piperno (2006).

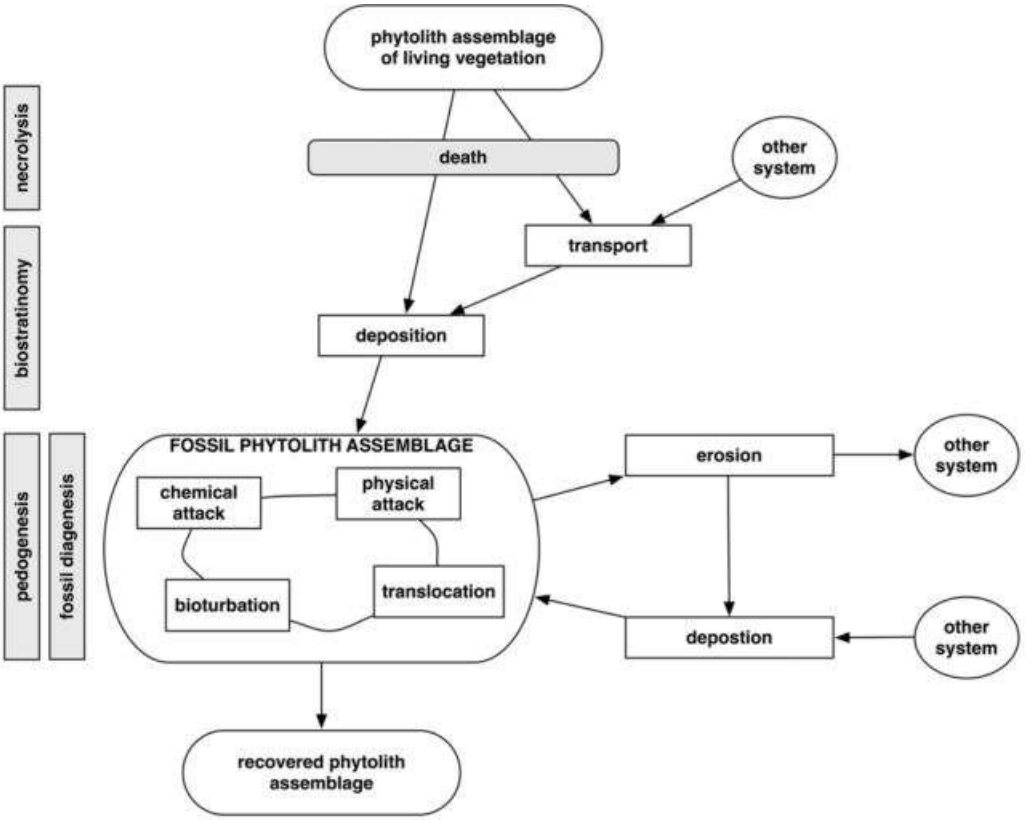
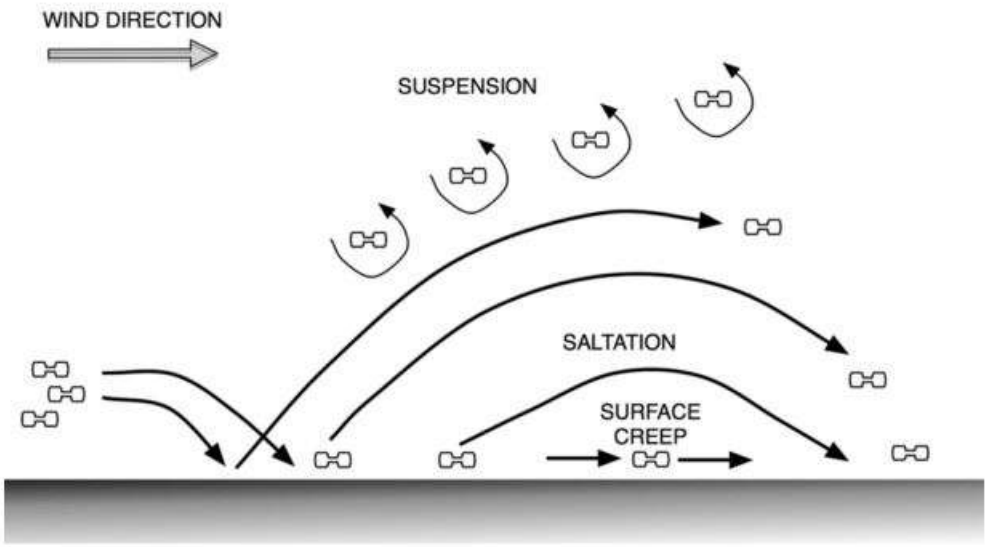


Figure 3: Depositional and post-depositional processes (Madella & Lancelotti, 2012: 77, Fig. 1)

recovered assemblages. After the necrolysis is final, another important issue is the disposition of phytoliths. Although, phytoliths are thought to be immobile, depending on the environmental conditions they can be transported (Fig. 4).

The result of transportation through natural forces can be detected in recovered phytolith assemblages as well, such as with the breakage on delicate phytolith morphotypes or chipping/abrasion on them. Post-depositionally, the assemblages can undergo physical, chemical, biological or anthropogenic processes. For archaeologists, especially the anthropogenic disturbances are vital to understand. Anthropic activities drastically affect the phytolith assemblages. Exploitation of crops, crop processing, animal related activities, architectural activities and many others will have an effect on the assemblage. Such activities yield

Figure 4: Phytolith transportation by wind (Madella & Lancelotti, 2012: 78, Fig. 2)



much more phytolith evidence than solely found in soil. The actions of past humans determine the size of an assemblage found in soil. Hypothetically, an agronomic society will yield a bigger phytolith assemblage than a hunter-gatherer activity area. Bioturbation is also another common problem after deposition. The biological life may alter the initial location of phytoliths. As an example, termites may disturb the soil horizons. Water seepage, change in pH or temperature of soil, the mass of current vegetation (such as thick forests), erosion and similar factors alter the fossil diagenesis (Madella & Lancelotti, 2012: 78-79).

In addition to depositional taphonomy, sampling too can be considered as a part of the whole taphonomical processes. Therefore, sampling strategies play a great role. The wetlab recovery of phytoliths can be significant. Taphonomic stress is a key element of representativeness of a phytolith assemblage, therefore it should be understood correctly. A few methods have been suggested. One method depends on the observation of the degree of pitting in bulliforms and

the degree of abrasions on elongate (long) cells. This may give the researchers a preliminary idea about the status of preservation, however it is subjective and depends on the experience of the researcher. Also, some of the post-depositional markers may be present in the fresh plant material. Two mathematical methods can be also used. The first one can be summarized as calculating the long vs. short cells in the assemblage. If the assemblage yields a high ratio, it indicates good preservation. The other method is based on the number of morphotypes identified and the concentration of phytoliths per gram of AIF (Acid Insoluble Fraction). A high correlation between number of morphotypes and AIF phytolith concentration means that the assemblage richness is preserved (Madella & Lancelotti, 2012: 80-82).

2.3 Classification of Phytoliths

Phytoliths have been used in paleoecological and archaeological reconstructions because of their two most important aspects: multiplicity and redundancy. Multiplicity of phytoliths means that many types of phytoliths can be found in a species or a family. Redundancy means that several shapes of phytoliths can occur in many plant taxa (Twiss, 1992). These qualities enable researchers to study morphotypes (a type of phytolith) and create a classification system for the plant types and phytoliths. To further understand the phytolith morphology, first the living plant and the metabolisms should be examined.

2.3.1 Plant Morphology

To understand phytolith morphology, understanding plant morphology to some extent is essential. Phytoliths can be found in the leaves, the stem (or botanically, culm), inflorescence or, even, in the roots.

To start discussing morphology, some botany terms must be established beforehand. Flowering plants are placed in two classes, commonly called as dicots, short for *Dicotyledonae*, and monocot, short for *Monocotyledonae* (Bidlack & Jansky, 2011: 127). There are several main distinctions between monocots and dicots, here only the distinctions that affect phytolith production directly will be mentioned. The first one is about their leaf veins. Monocots have more or less parallel primary veins whereas dicots have a network of web-like primary veins. The second distinction is about their tissues. Dicots have vascular cambium and cork cambium present; on the other hand, monocots do not possess these tissue types. Another important difference to be mentioned is about the arrangement of vascular bundles of stems. Monocots have scattered vascular bundles, dicots have the vascular bundles in a ring formation (Bidlack & Jansky, 2011: 127) (Fig. 5). The last distinction is about the leaf tissue arrangements. Besides the difference in vein arrangement in monocots, they don't have differentiated palisade and spongy layers in mesophyll. Some monocot leaves, particularly for grasses, have bulliform (also called motor) cells on both sides of the main central vein. The bulliform cells are responsible for leaf blade movement. They help the leaf blade to collapse under dry conditions to reduce transpiration (Bidlack & Jansky, 2011: 109).

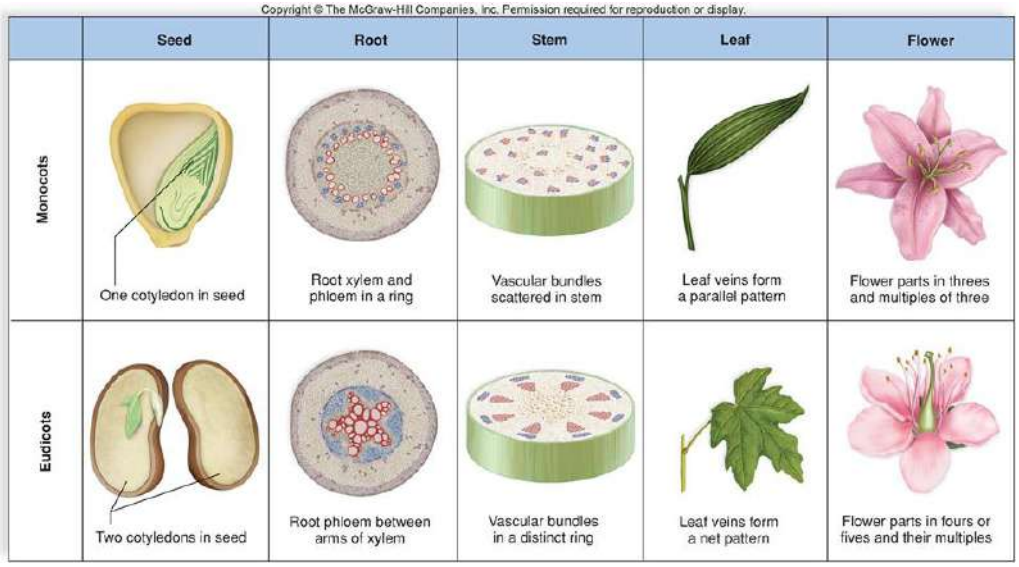


Figure 5: Monocots vs. dicots. Copyright © McGrawHill Companies Inc. (https://saeedmutlu.wordpress.com/2015/09/02/monocots-versus-dicots/)

2.3.1.1 C_3, C_4 and CAM Plants

All plants photosynthesize, but the light-independent reactions of photosynthesis can be different. The plants can be artificially grouped depending on the first product of light-independent reactions.

C_3 plants are named as they are because the first isolated product of light-independent reactions in these plants is a 3-carbon compound called 3PGA. These plants undergo a process called photorespiration, which is an alternative process to the carbon-fixing role of photosynthesis. In hot and dry climates photorespiration is promoted since stomata are closed in these conditions. Important archaeological plants like wheats and barleys are good examples of C_3 plants (Bidlack & Jansky, 2011: 174).

Some tropical plants and grasses, including sugar cane, corn and sorghum, have a different leaf anatomy from C_3 plants. This is called Kranz anatomy. Plants

with Kranz anatomy produce a different product after light-independent reactions which is a 4-carbon molecule, oxaloacetic acid. This modification allows the enzymes to have a greater affinity for carbon dioxide and reduces the photorespiratory loss. Hence, these plants are called C_4 plants (Bidlack & Jansky, 2011: 175-176).

Crassulacean acid metabolism, or shortly CAM, is another type of photosynthesis. CAM plants operate on availability of water. In rainy days, they can operate like C_3 plants and in dry days they can switch to CAM photosynthesis. Their leaf tissues have resembling features both from C_3 and C_4 plants. Plants like cacti, orchids and bromeliads are stressed by changing water resources however they possess this metabolism to compensate for variable conditions (Bidlack & Jansky, 2011: 177).

2.3.2 Phytolith Morphology

In a very basic sense, phytoliths can be divided into two groups: short cells and silica skeletons. Short cells are morphotypes which derive from the single cells of a plant. Saddle cells are good examples of short cells. Silica skeletons, or multicellular phytoliths, are multiple silicified cells derived from one tissue.

2.3.3 Phytolith Nomenclature

Phytolith nomenclature has been a problematic issue in the past. Each phytolith research group had developed their own keys and naming system, therefore a coherence of nomenclature had not been reached. However, there are recent developments to establish a standardized naming system.

To remedy this need, the first introduced solution was the International Code of Phytolith Nomenclature (ICPN) 1.0 which was published in 2005. ICPN 1.0 advocated that a standard protocol should be used for the process of naming, and a glossary of descriptors should be established. In this publication, the working group offered descriptive tools which are based on Latin and Greek. They included naming examples that were different from their old nicknames (Table 2.2). They also introduced the first description procedure. According to ICPN 1.0 the descriptors are shape, texture and/or ornamentation and anatomical origin. Those three components were essential for naming phytoliths. Morphometric data, illustrations and symmetrical features were also suggested as descriptors. They also introduced the nomina conservanda. The glossary provided in the publication was supported with illustrations and additional descriptors (Madella et al., 2005).

As the ICPN 2.0 introduction indicates, Linnaeus had established the binomial nomenclature for naming plants and animals. The same has been implemented for algae, fungi and plants under the supervision of ICN (International Code of Nomenclature). Unlike the case for pollens, phytolith nomenclature cannot be

established based on the parts of the plants because phytoliths have redundancy. In addition, the anatomical origin of phytoliths from the plant tissues is, sometimes, uncertain. Therefore, the ICPT (International Committee for Phytolith Taxonomy) offers the solution to name phytoliths according to their shape, size and texture, simply according to their morphological qualities, and collectively call the distinct shapes as "morphotypes", which is a direct implementation from ICPN 1.0 (Ball, Albert, Vrydaghs, & Cummings, 2019: 1-2). The revised nomenclature includes 19 morphotypes (Table 2.3).

The new ICPT was formed in 2014 and had the following tasks: revision of ICPN 1.0, extending the list of descriptors and development of the PhytCore database for more extended use by the community. ICPN 2.0 introduced a new set of principles for naming phytoliths. Some of these principles are:

1. Each name should be a unique identifier.

2. The naming must follow a certain order, from taxonomic to anatomical to morphological. The grass silica short-cell phytoliths (GSSCP) are an exception for this rule. Since these morphotypes are specific to Poaceae their morphology is more important then their taxonomic classification.

3. When a name is given based on morphology, it should be supplemented with proper descriptors about texture and ornamentation.

4. If a phytolith exibits features of closely related morphotypes both names can be used using a slash between them.

5. Phytolith names should be written in small capitals with the first letter

fully capitalized.

6. Each name should have a code to facilitate data management.

7. An explanation should be given about the naming of phytolith (Ball et al., 2019: 3).

In addition to the newly introduced principles, the group offers a detailed summary of the 19 morphotypes mentioned as a supplement to the article.

2.4 Field and Laboratory Techniques

2.4.1 Field Sampling

Phytolith sampling is one of the crucial aspects of the research. There is a balance between sampling and forming questions. Sampling should be semi-dependent on the research question, whereas routine sampling can be also helpful. Mainly, there are two sampling strategies that can be used for phytolith sampling: selective sampling and systematic sampling. In selective sampling, the samples are taken based on the visual evidence such as a white ashy layer and it is very local. Systematic sampling, on the other hand, requires interval-based sampling based on distance, depth or change of stratigraphy. As Piperno (2006) indicates, phytolith sampling is not limited to soil samples; stone artifacts, dental calculus and coprolites can be sampled for phytolith remains. Essentially, the research foci and sample availability helps to form the questions, whereas the questions can lead to focus on certain sample types.

One of the most common systematic sampling methods is by sediment columns. Column samples can be taken from an exposed stratigraphy wall, showing the changes of sedimentation or by coring. The proper way to get samples is:

1. Scraping the exposed soil, so that the local modern phytolith samples aren't in the assemblage.
2. Cleaning the sample taking tool (e.g a trowel) after each sample is securely bagged so that cross-contamination between samples is eliminated.
3. Placing the samples in a secure plastic bag. If starch analysis will be performed, the bags should be starch-free and starch-free gloves must be used during the sampling process.
4. A general amount of 200 gr will be enough to carry most of the extraction procedures related to microfossils (phytoliths, starch, pollen, diatoms etc.).
5. The preservation of phytoliths is not problematic since the phytoliths are very durable, however to keep the soil integrity for further research the collected samples in plastic bags should be kept in dry and cool places. Although phytoliths are durable, pollens and starches are more degradable.

If the samples are directly from the soil coring, the depth of the sample and the interval of sampling should be noted. Also, a sample from the top soil and control samples should be present (Piperno, 2006: 81-82). A good example of control sampling and how it is helpful to show contrast is evident in Madella 2001.

In addition to column sampling, horizontal sampling is another method of systematic sampling. Horizontal samples come from the same stratigraphy and

enables the researchers to compare contemporaneous but different areas. It is especially important for spatial analysis based on phytolith evidence. Pits (storage, garbage and other use), hearths and ash residues sampled from the same horizon can give comparative results about diet and plant use. Another good example for horizontal sampling is the room fills, where the *in situ* plant residue can be accounted to flooring, roofing, basketry, and textile production. To be able to achieve resolution on the plant use of different purposes horizontal sampling can be performed in addition to column sampling (Piperno, 2006: 83). A good example of how to achieve horizontal sampling resolution was presented in a research about Göytepe, Azerbaijan (Kadowaki et al., 2015).

As mentioned above, artifact remains and other materials can be used for phytolith sampling. For example, the first research about phytoliths were conducted on residues from pottery (Schellenberg, 1908). Lithic artifacts such as grinding stones are good candidates for phytolith work since their porous surfaces capture phytoliths. They are of great importance since they also give ideas about food preparation practices. The key aspect here is that the pottery fragments or stone artifacts which will be used for phytolith analysis should not be washed since the phytoliths can fall off from the pores. It may be problematic to assign which artifacts will be used for phytolith research during the excavation season, therefore the samples must be chosen carefully (Piperno, 2006: 83-84). The chosen artifacts should be first dry sampled with the help of a clean brush and wet sampled with the help of, preferably, deionized water (author, personal notes). A good example of this kind of work was done at Monjuklu Höyük, Turkmenistan (Öğüt, 2016).

For dental calculus, a different kind of extraction procedure must be performed. An example of dental calculus phytolith research in tandem with sediment samples was done on a West African site (Madella, García-Granero, Out, Ryan, & Usai, 2014). Fox, Juan, and Albert (1996) also offers more insight about dental calculus phytolith removal and procedures.

2.4.2 Laboratory Techniques

Phytolithculus extraction is a chemical process. There are numerous protocols relating to this matter (Weiner & Albert, 2001, Madella, Powers-Jones, & Jones, 1998, Piperno, 2006, Pearsall, 2016). For soil sedimentation there are a few established steps that are included in most of the procedures. All the procedures aim for the same result: to remove all the soil components except the silica particles. According to Madella et al. (1998), these steps are:

1. Primary fractionation: This step includes the physical removal of larger particles in the sample. Processes such as sieving is essential to remove bigger stones, charcoals and other materials to be taken away prior to the chemical extraction steps. Rosen (1999) notes that a sieving mesh of 0.250 to 0.500 is useful for capturing the silica skeletons while filtering out the other materials.

2. Secondary fractionation: This step sediments the soil samples into silt, clay and sand. Such fractionation can be achieved by low-speed centrifuging or water column fractionation.[7] Low-speed centrifuging is advised in

[7]Centrifuging is a physical removal method based on centrifugal force. Water columns

Madella et al. (1998) because it is less time consuming than using water columns. However, Piperno (2006) advices that through a series of water columns the smallest fractions of soil can be cleansed better.

3. Deflocculation: Deflocculation essentially means that the clay should be loose and readily dissolved in the mixture. Clay can obscure the view under the microscope. This step prevents mineral fractions from clumping together. This may be a problematic issue depending on the type of the soil.

4. Removal of the carbonates: The soil is a mixture of many materials. The carbonates are generally the remnants of bones or shells. They should be properly washed away for a better resolution. For this step, an acid is used since acids react with carbonates and they are released as CO_2 gas. The most commonly used acid is HCl.

5. Removal of organic matter: The organic material is both present within phytoliths and the soil. The organic matter present in phytoliths obscure their view under the microscope as black residues. The organic material present in soil can react negatively with the heavy liquids, such as sodium polytungstate. The most commonly used chemical for this purpose is H_2O2.[8]

6. Heavy liquid flotation: As Madella et al. (1998) notes, heavy liquid flotation is the main way to remove the phytoliths from the remaining soil

are 1000 mL beakers filled with water and the particles settle in time. For more, information consult Piperno (2006): 91.

[8]In case of organic material presence, sodium polytungstate will be in a mud-like state and the heavy liquid flotation cannot be achieved.

composition. This is based on a simple density difference principle. It is known that phytoliths generally have a density between 2.30-2.35 g/cm^3. The heavy liquids are prepared in a density which is lower than the density of phytoliths, therefore the phytoliths float on the top of the liquid. To facilitate this part, the suspension is generally centrifuged.

In general, most of the protocols are designed to include these steps. The preferred ordering or the chemicals may differ from one protocol to another. The amount of starting soil material can differ between protocols as well. Zhao and Pearsall (1998) offers insights about the various chemicals used in the extraction protocols and gives suggestions about improving the protocols.

Following the chemical extraction process, the phytoliths must be inspected under microscope. The usual type of microscope used for phytolith quantification is the light microscope but scanning electron microscopes (SEM) can also be employed for detecting minute variation in phytolith morphology. To achieve this, the phytoliths can be temporarily or permanently mounted on the appropriate slides. For temporary observation of phytoliths, a mixture of glycerin and water is sufficient. For permanent mounting, special balsams like Canada Balsam or adhesive liquids like Entellan can be used. Single cells are visible from x200 to x600 magnification, whereas it is possible to detect silica skeletons even in x40.

Table 1: Patterns of phytolith production and taxonomic significance in plants (Piperno, 2006: 7, Table 1.1)

Table 1.1. Patterns of Phytolith Production and Taxonomic Significance in Plants

I. Families where **production is usually high**, phytoliths specific to family are common, and subfamily and genus-specific forms occur, sometimes widely in the family
Pteridophytes: Cyatheaceae (tree ferns), Equisetaceae (scouring rushes and horsetails), Hymenophyllaceae (ferns that grow as epiphytes on trees), Selaginellaceae (forest floor ferns)
Basal Angiosperms: Annonaceae (sour sop, custard apple), Magnoliaceae (magnolias)
Monocotyledons: Arecaceae* (palms), Bromeliaceae (pineapple family), Commelinaceae, Costaceae, Cyperaceae* (sedges), Heliconiaceae*† (banana-leaved Neotropical herbs), Marantaceae*† (Neotropical forest herbs—*Maranta*, arrowroot), Musaceae* (bananas), Orchidaceae (orchids), Poaceae* (grasses—*Zea*, maize and *Oryza*, rice), Zingiberaceae* (the ginger family)
Eudicots: Acanthaceae, Aceraceae (sugar maple), Asteraceae* (the sunflower family), Boraginaceae*, Burseraceae* (tropical trees), Chrysobalanaceae* (tropical trees), Cucurbitaceae* (*Cucurbita* [squashes and gourds], *Lagenaria* [bottle and dipper gourds], *Citrullus* [watermelon], *Cucumis* [cantaloupe and honeydew melons and cucumber], and *Sicana* [cassabanana]), Dilleniaceae, Moraceae* (breadfruit and jackfruit, figs, mulberry), Podostemaceae (herbs on rocks in rivers and streams), Ulmaceae* (elms), Urticaceae (stinging nettles)

II. Families where **production may not be high in many species studied but** where family and genus-specific forms or forms diagnostic of specific growth habits (trees and shrubs, marked with #) occur
Pteridophytes: Polypodiaceae (many species of ferns)
Gymnosperms: Cupressaceae (junipers, cedars), Pinaceae (pines, firs, Douglas fir, hemlock), Taxaceae, Taxodiaceae (Sequoias, bald cypresses)
Monocotyledons: Flagellariaceae, Joinvilleaceae, Restionaceae
Eudicots: Capparaceae, Dipterocarpaceae (Southeast Asia tropical trees), Euphorbiaceae* (rubber, castor oil, manioc), Fagaceae (oaks, beech, chestnut), Flacourtiaceae# (subtropical to tropical trees and shrubs)

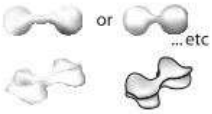
III. Families where **production may be common to abundant in some genera** but where taxonomically significant phytoliths appear to be limited in number
Basal Angiosperms: Aristolochiaceae (twining lianas), Chloranthaceae, Hernandiaceae, Piperaceae
Eudicots: Combretaceae, Loranthaceae (mistletoes), Menispermaceae, Sapotaceae (sapodilla, star apple), Verbenaceae (teaks and verbenas)

IV. Families where **production varies substantially** among different subfamilies and tribes and forms of taxonomic value appear to be limited
Eudicots: Clusiaceae, Fabaceae (legumes), Malvaceae (cotton, mallows, and relatives), Sterculiaceae (chocolate and kola)

V. Families where **phytoliths have not been observed** or where **production is often uncommon to rare** and is usually not of taxonomic significance
Gymnosperms: Araucariaceae, Cycadaceae (cycads), Gnetaceae, Podocarpaceae
Basal Angiosperms: Myristicaceae, Nymphaeaceae (water lilies), Winteraceae
Monocotyledons: Agavaceae (agaves), Alismataceae (water plantains), Amaryllidaceae, Araceae (taro, *yautia*), Burmanniaceae, Cyclanthaceae, Dioscoreaceae (true yams), Eriocaulaceae, Hydrocharitaceae, Iridaceae, Juncaceae** (the rush family), Liliaceae (onions, garlic, asparagus), Pontederiaceae, Potamogetonaceae, Smilacaceae, Trioridaceae
Eudicots: Amaranthaceae (amaranths), Apiaceae (carrots), Apocynaceae, Araliaceae, Asclepiadaceae (milkweeds), Bignoniaceae, Bixaceae, Bombacaeae, Cactaceae (cacti), Campanulaceae, Caricaceae (papaya), Cartonemataceae, Chenopodiaceae (chenopods), Convolvulaceae (sweet potato), Ericaceae (heaths), Guttiferae (mamey, mangosteen), Juglandaceae (walnut, hickory, pecan), Labiatae (mints), Lacistemnaceae, Lauraceae (cinnamon, avocado), Lecythidaceae, Lentibulriaceae, Loganiaceae, Malphigiaceae, Mayacaceae, Melastomataceae, Meliaceae, Myrtaceae, Myrsinaceae, Olacaceae, Oxalidaceae, Pedaliaceae, Polygonaceae, Primulaceae, Proteaceae, Ranunculaceae, Rhamnaceae, Rosaceae, Rubiaceae, Rutaceae, Salicaceae, Sapindaceae, Saxifragaceae, Solanaceae (potatoes, peppers, and tomatoes), Theaceae, Tiliaceae, Typhaceae (cattails), Vitaceae, Violaceae, Xyridaceae, Zygophyllaceae

Note: All information is based on phytolith studies of modern plant communities from the following parts of the world: 1) *general coverage of dicotyledons and monocotyledons* (Ayensu 1972; Metcalfe 1960, 1971; Metcalfe and Chalk 1979; Tomlinson 1961, 1969), 2) *North America* (Blinnikov et al. 2001, 2002; Bozarth 1992, 1993a; Brown 1984; Geis 1973; Hodson et al. 1997; Kerns 2001; Klein and Geis 1978; Lawlor 1995; Mulholland 1989; Mulholland and Rapp 1992b; Norgren 1973; Scott Cummings 1992; Solereder 1908; Strömberg 2004; Wilding and Drees 1968, 1971), 3) *American tropics* (Piperno, 1988, 1989, 1998, 2001a; Pearsall 2000; *www.missouri.edu/~phyto*); 4) *subtropical and temperate southern South America* (Bertoldi de Polmar 1971; Iriarte 2003a, 2003b; Zucol 1998), 5) *The United Kingdom* (Hodson et al. 1997; Powers et al. 1989), 6) *Mediterranean and Alpine Europe* (Bremond et al. 2004; Carnelli et al. 2001, 2004; Delhon et al. 2003), 7) *the Near East* (Albert et al. 1999; Rosen 1993, 1999), 8) *Africa* (Alexandre et al. 1997a, 1997b; Barboni et al. 1999; Runge 1995, 1999, 2001a, 2001b; Runge and Runge 1997; Scott Cummings 1992), 9) *southern China* (Zhao 2004; Zhao and Piperno 2000), 10) *mainland Southeast Asia* (Kealhofer and Piperno 1998), 11) *New Guinea, other parts of Melanesia, and Oceania* (Boyd et al. 1998; Denham et al. 2003; Lentfer 2003; Lentfer et al. 2001; Scott Cummings 1992), 12) *northern and central Australia* (Bowdery 1998; Hart and Wallis 2003; Wallis 2000, 2003), 13) *New Zealand* (Kondo et al. 1994), and 14) *subantarctic regions (Campbell Island)* (Thorn 2004a).
* Reproductive structures (fruits and seeds) also produce high amounts of diagnostic phytoliths.
† Underground organs (roots, corms, rhizomes, and tubers) may contribute high amounts of diagnostic phytoliths.
** Phytolith production is sometimes more common in inflorescences than in leaves.

Table 2: Examples from International Code for Phytolith Nomenclature 1.0 (Madella et al., 2005: 255, Table 1)

Schematic drawings*	ICPN names	Former nicknames
	Bilobate short cell	Dumbbell or bilobate
	Trapeziform short cell	Square or rectangle
	Cylindrical polylobate	Polylobate
	Trapeziform polylobate	Polylobate
	Trapeziform sinuate	
	Elongate echinate long cell	Elongate spiny or elongate sinuous
	Cuneiform bulliform cell	Bulliform or fan-shaped
	Parallepipedal bulliform cell	Bulliform
	Acicular hair cell	Point-shaped
	Unciform hair cell	Point-shaped
	Globular granulate	Spherical rugose
	Globular echinate	Spherical crenate
	Cylindric sulcate tracheid	Tracheid

*Several drawings are made after Fredlund and Tieszen (1994).

Table 3: The 19 morphotypes in ICPN 2.0 (Ball et al., 2019: 2, Table 1)

ICPN 2.0	Code	ICPN 1.0
SPHEROID PSILATE	SPH_PSI	–
SPHEROID ECHINATE	SPH_ECH	Globular echinate
SPHEROID ORNATE	SPH_ORN	Globular granulate
ACUTE BULBOSUS	ACU_BUL	Acicular hair cell/Unciform hair cell
BLOCKY	BLO	Parallelepipedal bulliform cell
BULLIFORM FLABELLATE	BUL_FLA	Cuneiform bulliform cell
ELONGATE ENTIRE	ELO_ENT	–
ELONGATE SINUATE	ELO_SIN	–
ELONGATE DENTATE	ELO_DET	Elongate echinate long cell
ELONGATE DENDRITIC	ELO_DEN	Dendritic/Dentritic
PAPILLATE	PAP	Papillae
TRACHEARY	TRA (with subtypes TRA_ANN, TRA_PIT, TRA_BOR)	Cylindric sulcate tracheid
Grass silica short-cell phytoliths (GSSCP)		
SADDLE	SAD	Saddle
BILOBATE	BIL	Bilobate short cell
POLYLOBATE	POL	Cylindrical polylobate
CROSS	CRO	Cross
CRENATE	CRE	Trapeziform polylobate/Trapeziform sinuate
RONDEL	RON	Rondel
TRAPEZOID	TRZ	Trapeziform short cell

CHAPTER 3

KİNET HÖYÜK AND THE PHYTOLITH SAMPLES

Kinet Höyük is a long lived harbor site on the Mediterranean coast of Anatolia. It was inhabited for at least five millennia without interruption and offers a significant assemblage of finds spanning the Late Neolithic to the Medieval era. It has been an integral part of the research recently conducted in this sector of Anatolia and gives many insights about the ancient populations who inhabited it.

The Kinet Höyük project first started with the Bilkent University Archaeological Survey in August 1991 (M.-H. Gates & Özgen, 1993). This survey encompassed the eastern half of this region known as Cilicia and modern-day northern Hatay. It is noted that Kinet Höyük was already known in the 19^{th} century and is the largest mound in this area. Historically, it has been identified with Issos, where Alexander the Great battled against Persian Darius III in 333 BC, and with a harbor named Sissu associated with Phoenicians (Hellenkemper, 1984). The name Kinet is a modern one and it is of unknown origin. Earlier names of Issos eventually are Zise and Izziya in the Late Bronze Age (C. Gates, 2015).

The Kinet excavations ran annual campaigns from 1992 to 2012. During the excavations, many samples for faunal and botanical analysis were collected. This thesis will focus on the soil samples especially collected for eventual phytolith analysis.

3.1 Geography

Cilicia is at the junction of Anatolia, Syro-Mesopotamia, and Cyprus. This area can be divided into two main regions, Plain Cilicia (gr. *Kilikia Pedias*, lat. *Cilicia Campestris*) and Rough Cilicia (gr. *Kilikia Tracheia*, lat. *Cilicia Aspera*). Kinet is located at the eastern limits of Plain Cilicia which is an alluvial plain of ca. 8000 km^2 (Novák et al., 2017).

Kinet Höyük is a steep, triangular, 26 m high mound covering 3.3 ha. It is located in the southern part of Turkey, 30 km north of İskenderun province in the Erzin Plain. It sits on the north bank of an ancient estuary and points towards the sea (Novák et al., 2017). Kinet is on the seashore of Iskenderun Bay. This enables Kinet to have access to fishing as well as coastal and riverine docking (M.-H. Gates, 2011, M.-H. Gates, 2013) The distance from the mound to the modern shore is only 500 m (Çizer, 2006: 8). To the west of the settlement, there is a volcanic outcrop; on the other side, the Amanus Mountains stand. (Fig. 6). In addition, Kinet Höyük is very close to the fault line below Iskenderun Bay.

About 2.5 km south of the mound is the modern course of the Deliçay River. The riverbed changed twice during the occupation of settlement and the change

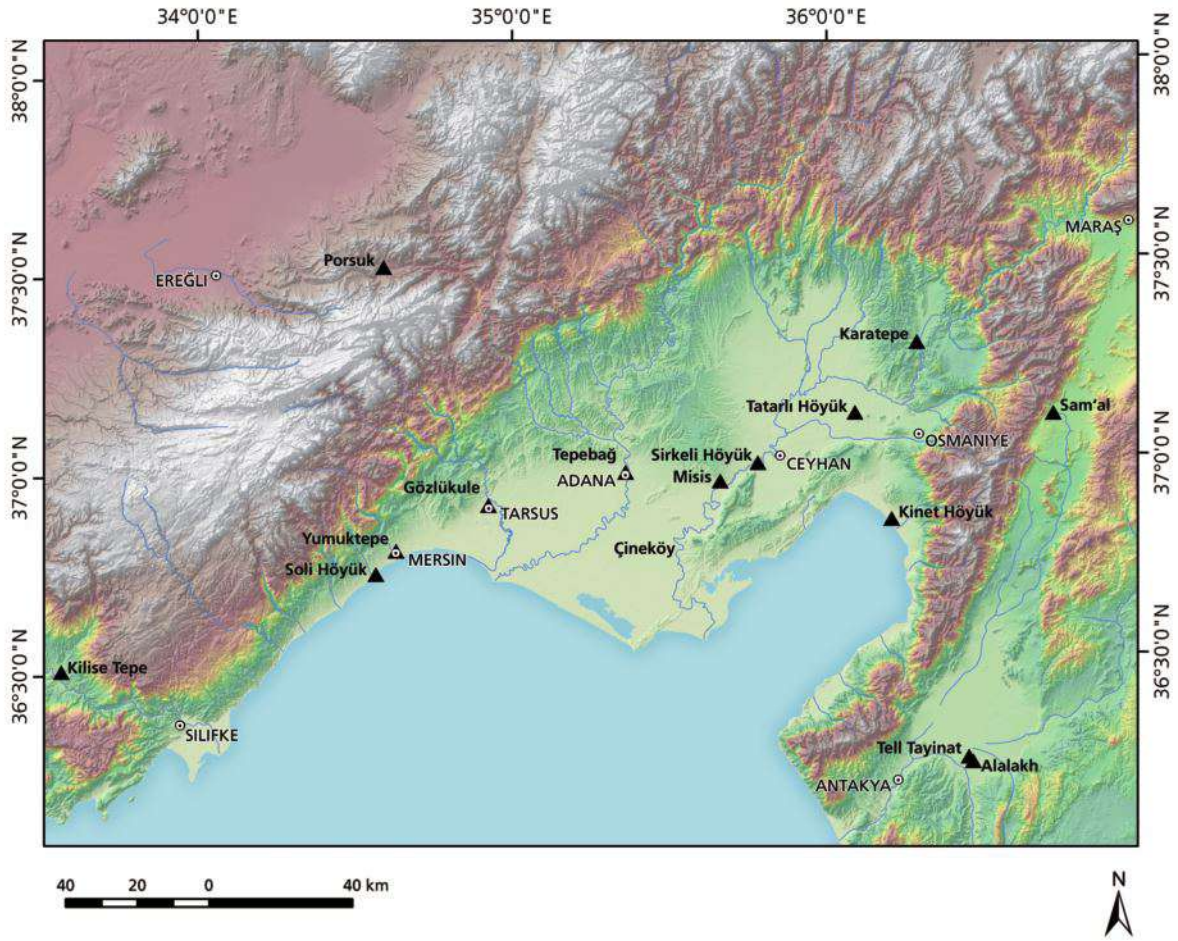


Figure 6: A general map of the region (Novàk et al.: 151, Fig. 1)

can be related to the abandonment the site at the end of the Hellenistic period. Its reoccupation in the Middle Ages must have depended only on the shoreline for a harbor. Currently, the landscape is eroding because of the steel industry present in its vicinity, other urbanization activities and deforestation in the Amanus mountains.

The initiation of geomorphological research was carried out in the early years of the Kinet project (1991-1994) by S. Ozaner (Ozaner, 1994). Later, starting in 1998, T. Beach and his group studied the region around the settlement as the first step of a general survey. According to the study done on the soil samples collected from the shore it is evident that alluvium and erosion had

shaped the landscape, especially in pre-medieval times (M.-H. Gates, 2000). The most recent geomorphological studies show that there are regional trends in soil erosion in the geoarchaeological record. The first is the fluvial migration and coastal/floodplain formation. The second general trend involves aggradation. There is a considerable amount of aggradation from the Hellenistic times to the Medieval era and it is continuing in the present. The third is related to the mound and how it adds to the rates of aggradation. It occurs that the aggradation rates around the mound vary greatly. In addition to this, it should be noted that as the fourth finding, there is deep aggradation of Hellenistic and Roman sediments in the region (Beach & Luzzadder-Beach, 2008).

The soil chemistry of Kinet Höyük was also studied. The soil samples range from middle to late Holocene and have moderate pedogenesis. The results show that they are generally not rich with organic matter, moderately alkaline and are rich in cations. Their texture is generally loam to silt loam. Also, well developed Mediterranean Red Soils were encountered in the immediate region. (Beach & Luzzadder-Beach, 2008).

3.2 Settlement History

The settlement history of Kinet Höyük is extensive. This site was occupied from ca. 5500 BC until the 14^{th} century AD, with a gap in occupation after 75 BC to the 12^{th} century AD (Novák et al., 2017).

The excavation has its own phase system and periods. This system was based on the settlement patterns observed during the excavation. Kinet phases are

based on archaeological eras and Kinet periods are archaeological levels. The Early Bronze Age I and earlier periods like the Late Chalcolithic were not excavated. Phase VI extends from the Early Bronze Age (EB) II to EB III with four sub-phases. This phase encompasses Kinet periods 29 to 19. The Middle Bronze Age I (MBA) to MBA II is called Phase V and has two sub-phases, covering Kinet periods 18 to 16. The Late Bronze I to LBA III is Phase IV and has two sub-phases (IV.2 and IV.1), also one sub-phase is divided into two (IV.1.1 and IV 1.2). This timeline covers Kinet Periods 15 to 13.2. The Early Iron Age (EIA) to the Late Iron Age (LIA) is Phase III and encompasses Kinet period 12 to 3B. Kinet Phase II is entirely Hellenistic and only Period 3A-2 is present. The Medieval era is Phase I and Kinet Period 1 is present with the additional materials from the Tüpraş Field site (see below). The chronological sequence and datings are listed in Table 4. These relative datings from EBA II to EIA were supported with C_{14} dating (Novák et al., 2017).

Some important events affected the sequential history of the settlement. Most of the periods ended with catastrophic events such as earthquakes or destruction (Novák et al., 2017). The stratigraphy suggests that there are at least five major earthquakes and one possible one that resulted in abandonment or destruction of an occupational level. In addition to the earthquakes, the settlement underwent seven destructions not due to natural causes. After Period 19 the settlement was abandoned and there is a gap in occupation. Similarly, in Period 15 the settlement was briefly abandoned and it was followed by erosion. Also, the site was occasionally re-founded with a new architectural layout, for this instance in the mid 2^{th} c. BC in the Hellenistic era (Novák et al., 2017).

This chronological reconstruction was supported by the pottery evidence and observed technological changes. The pottery evidence gives a few insights into the cultural ties of the populations that inhabited the settlement. Kinet Höyük Phase V.1 and V.2 picture closer ties to the neighbors in the vicinity and even suggests ties with Cyprus; in contrast, starting from Phase IV.2 the Syro-Cilician pottery repertoire was replaced completely by Hittite/Central Anatolian wares. The pottery evidence also suggests that there were Late Helladic imports (and maybe people) found in the site in the LBA. Following the Bronze Age during the Phase III in Period 8 the presence of Neo-Assyrian material culture makes a striking change in the established character of the Iron Age site. The Periods 5 to 3B show Persian presence in the settlement. In general, Kinet was inhabited by groups with different cultural ties throughout its history (Novák et al., 2017).

3.3 Vegetation and Climate

Kinet is located in the eastern part of the Eu-Mediterranean climate belt. This region has characteristic mild, rainy winters and hot, rainy summers (November is the only month with low rainfall) (Çizer, 2006). The yearly precipitation varies from 1019 to 1500 mm. The precipitation regime peaks in winter and is the lowest in summer. Snowfall is rare (Türkmen & Düzenli, 1998).

Kinet Höyük has a unique condition. It can be seen as a microclimatic area where topography plays a big role. It is one of the wettest ecozones in the area. Because the Amanus Mountains enclose the area, Kinet tends to be quite rainy

Table 4: Chronology of Kinet Höyük (Novák et al., 2017: 151)

General Periodization

Archaeological Period	Date	Kinet Phase	Kinet Period
EB I and **earlier periods,** including **Late Neolithic/Ḥalaf**	*5500–2900 BC*	[not excavated: finds out of context]	————————
Early Bronze II *not excavated to base of EB II	*2900–2600 BC*	**VI.4**	**29–25**
Early Bronze III	*2600–2420 BC*	**VI.3**	**24**
Early Bronze III	*2420–2250 BC*	**VI.2**	**23–22**
Early Bronze III	*2250–2050 BC*	**VI.1**	**21–19**
Middle Bronze I	*2000/1900–1750 BC*	**V.2**	**18**
Middle Bronze II	*1750–1550*	**V.1**	**17–16**
Late Bronze I (= end of Hittite Old Kingdom)	*1550–1400 BC*	**IV.2**	**15**
Late Bronze II (= Hittite Empire)	*1400–1200 BC*	**IV.1.1**	**14–13.1**
Late Bronze III (Sub-Hittite)	*1200–1150/1130 BC*	**IV.1.2**	**13.2**
Early Iron Age	*1150/1130–900 BC*	**III.3**	**12–(?)11**
Middle Iron Age (Kinet Period 8: **Neo-Assyrian**)	*900–650 BC*	**III.2**	**11 (?)** **10** **9** **8** Neo-Assyrian
Late Iron Age (Kinet Period 5–3B: **Persian**)	*650–330/300 BC*	**III.1**	**7–6** **5** Persian **4** Persian **3B** Persian
Hellenistic	*330/300–90/75 BC*	**II**	**3A–2**
Medieval	*8th/9th c.–14th c. AD*	**I**	**1** + Tüpraş Field site

(pers. comm., M-H. Gates). According to a recent study, Hatay province is not a prolific producer of wheat, whereas it excels at citrus agriculture (Semerci, 2018).

Depending on the altitude, the vegetation varies between macchie vegetation to steppe vegetation. Machhie vegetation is encountered from 50 to 600 m altitudes. Forest vegetation ranges from 350 to 1900 m altitudes. Steppe region is found at altitudes higher than 1900 m. Previous studies yielded different percentages about the distribution of plant taxa according to the phytogeographical region (Türkmen & Düzenli, 1998). According to Türkmen and Düzenli (1998), about 30% of the plant taxa belong to Mediterranean, 10% to Euro-Siberian, 5.8% to Irano-Turanian, 54% to cosmopolitan or unknown origin. 7.5% of the

species are found to be endemic. Some of the most encountered families are Fabaceae, Compositae, Poaceae, Labiatae, Cruciferae, Liliaceae, Rosaceae.

The reconstruction of natural vegetation was based on the present vegetation and the known conditions of early Holocene. Palynological data is scarce for this area and lacks the coastal zone. For Kinet Höyük, there is no direct palynological evidence. The most relevant pollen evidence comes from Söğüt Lake, Köyceğiz and Ova Lakes from the south-western part of Turkey. This pollen evidence shows that humidity reached the modern levels less than 3000 years ago. *Pinus*, *Pistacia*, *Olea* and *Quercus calliprinos* pollens were encountered. The pollen cores suggest that the climatic and environmental conditions of Kinet Höyük in the past were similar to the conditions in the present (Çizer, 2006). Hynd (1997) also notes that the conditions were generally consistent regarding the region.

3.4 Previous Archaeobotanical Studies of Kinet

Kinet Höyük is one of the sites in Anatolia where extensive environmental archaeology studies were done. In addition to the zooarchaeological studies, archaeobotanical samples were collected almost every year. This data was discussed in the research for one published and one unpublished Master's theses, and a third Honours degree thesis was recently finished. Archaeobotanical results for the Medieval period have also been published.

The first thesis concerning archaeobotany and macrobotanical samples was submitted by Alison Hynd in 1997. She studied the cereals, legumes, oilseeds, tubers and vegetables, and wild species from the 1995 season Kinet macrobotanical samples. The samples were dated from the Middle Bronze to the Medieval and were recovered from Op. K and Op. M on the east and west sides of the mound. According to her study, the major cultivars included einkorn and emmer wheat, lentil, grape and flax. Her general assessment is that the Kinet assemblage doesn't show great variation in 3000 years and shows continuity with the exceptions of variation in its details.

She also introduces models of agricultural development for Kinet and the region. First, she summarizes the findings from different regions of Anatolia regarding the changing patterns of wheat cultivation; then, she comes to a general conclusion about the presence of glume wheats, an unexpected component of the sample. According to Hynd, at the beginning of the Bronze Age, glume wheats were disappearing from the cultivation crops in southeastern Turkey, a trend that was continued in the western part of Anatolia as well. About the glume wheats in the Kinet assemblage, she assesses the adaptive nature of the crops and notes that they represent "... an effective response to the local [wet] environmental and technological conditions" (Hynd, 1997). She suggests that crop rotation was possible as fallow-wheat-barley, which Kinet crops would respond well to. In her thesis, she also notes that despite the fact that intercultural contact is evident in the archaeological samples, it is not the case for archaeobotanical remains.

One of the most striking results of Hynd's thesis is that she reported no signs

of local wheat production. It is noted that the by-products of the earliest stages of crop processing, like chaffs or glumes, were not commonly encountered in the Kinet assemblage. However, she also acknowledges other possibilities. One possibility is that the relevant waste were not sampled at all. Another one is that the early processing stages were carried away from the site. In addition, she notes differential charring rates and, simply, the possibility of the lack of fire to preserve the crop byproducts. Nevertheless, there is a lack of evidence for local production of wheat in Kinet Höyük. According to Hynd, the most possible scenario is export. She points out that if wheat was not produced locally despite the fact that soil is very arable, it is logical that export (by boat) was an option (Hynd, 1997: 69). Nevertheless, the sample size for this thesis was limited since the 1995 archaeobotanical samples were the first group to be ever collected from the site (pers. comm. M-H Gates, 2019).

The second thesis concerning Kinet archaeobotanical remains was written by Çizer in 2006. In her thesis, she compared Kinet remains to Tell Atchana remains and focused on the Late Bronze Age particularly. In her conclusion, she notes for Kinet that cereals dominated the subsistence economy. Following the faunal remains, Kinet had a stable subsistence economy. From the evidence about wild weed taxa, she infers that in the Late Bronze Age intensive large-scale agriculture supplied the site. She warns that the absence of einkorn and the rare occurrence of emmer in Kinet does not necessarily mean direct connections to the LBA Aegean sites, where a similar pattern was also observed. As a summary, she notes that the free-threshing wheat and hulled barley may be reflective of the agricultural character of the eastern Mediterranean and the ties to

the Hittite Kingdom (Çizer, 2006).

One of the latest archeobotanical studies of Kinet Höyük botanical materials are concerned with the EBA samples. In contrast to Hynd (1997), Fairbairn (2013) notes that the lack of crop processing and the lack of crop by-products used as fuel or found in dung at the site can be indicative of Kinet being a specialist settlement. According to him, most likely grain or foods were imported to the site from the producers. He also emphasizes that the sample composition is similar to the ones found in Classical urban contexts because the samples are mostly originating from food preparation and consumption debris (Murphy, Thompson, & Fuller, 2013). Following this, he underlines that in comparison to the archaeobotanical data recovered from other contemporaneous sites such as Kaman-Kalehöyük and Kültepe, Kinet is strikingly different since those other sites show crop processing or use of crop processing by-products (Fairbairn, 2002; Fairbairn, 2003; Fairbairn, 2014). In this preliminary report, he underlines some other important aspects of the archaeobotanical assemblage such as the presence of *Adonis sp.* and *Lolium sp.*. The seeds of these wild grasses can be mistakenly collected as grains since they have large seeds similar in size. In addition, he mentions the use of reed as fuel. According to him, some of the members of sedge family (*Cyperaceae*) could be growing in the streets and the premises around the settlement (Fairbairn, 2013).

As the sole published article about archaeobotany of this region, Ramsay and Eger studied the Medieval archaeobotanical remains from the Tüpraş Field Project, which is a part of Kinet Höyük excavations. The Tüpraş Field site is

1 km northwest of Kinet, also on the coast and was inhabited in a time period (8^{th} to 11^{th} century AD) when Kinet was not occupied. Their study shows that in addition to date palms, cereals and cotton were also predominant. Cereal agriculture was supported by the data, also a boom of cotton production was revealed. They also raise questions about the presence of *Chenopodium album* in the storage facilities; they are suspicious that this species was not just a wild weed but a contributor to the diet. Through archaeobotanical evidence, they show that the subsistence economy in the Medieval period was more complicated than previously thought (Ramsay & Eger, 2015).

3.5 Samples

During the Kinet Höyük excavations in various years, many soil samples were collected. These samples were collected during excavations in the expectation that they contained plant remains suitable for a phytolith study.

For this thesis, initially 19 soil samples were selected. During the first extraction process, two of them were considered to be poor in condition, and after the second extraction procedure, four more were discarded. Only 13 samples were left at the end of the second extraction procedure. The samples were from a long range of periods, starting from the EBII to the Medieval.

In addition to the soil samples, fiber samples were selected for further analysis. The selection of fiber samples was based on visible white residues. Their Kinet numbers are KT 1224, 5637, 19320, 19610, 19826, 19869, 22760, 23175, 24654, 24791, 25166. For one sample (16018), both soil and fiber samples are present.

Table 5: The 13 samples analyzed in this thesis with the relevant information and Munsell color assignments.

Kinet No	OP	Lot	Locus	Type	Period	Context	Munsell Color
8506	97 A II	199	321	phytolith	LFe/7	pit fill	10 YR 7/1 - Light gray
12678	99 D	175	444	ash	MFe/8	trash deposits, late in Period 8	10 YR 6/2 - Light brownish gray
13105	99 D	183	472	ash	MFe/8	room floor	10 YR 6/1 - Gray
16018	02 EH	278	634	phytolith	MFe/8	surface deposit, EH room 278 of Assyr blg, Middle Iron Age	10 YR 6/1 - Gray
16348	02 EH	278	682	phytolith	MFe/8	surface deposit, EH room 278 of Assyr blg, Middle Iron Age	10 YR 6/1 - Gray
17043	02 EH	332	757	phytolith	MFe/9	contents of EH pit 332, Middle Iron Age	10 YR 6/1 - Gray
17530	03 G	21	43	ash	Medieval/1	pit	10 YR 7/1 - Light gray
18966	03 M	84	128	phytolith	MB I/18	pit	10 YR 6/2 - Light brownish gray
21813	05 M	137	312	phytolith	MB I/18	pit	10 YR 6/1 - Gray
22764	05 M	190	302	phytolith	EB III/23	pit	10 YR 6/1 - Gray
24308	07 EH	619	1515	phytolith	LB/14	pit	10 YR 6/1 - Gray
24674	07 M	281	493	phytolith	EB II/27	room deposit	10 YR 6/1 - Gray
25166	07 M	304	545	phytolith	EB II/28	room deposit	10 YR 6/1 - Gray

The Kinet Höyük excavations used a locus/lot system for finds and Operation numbers for the excavation units. All samples have their unique Kinet numbers (KT nnnnn) for easing the data management. Each area shown in Fig 7 is an Operational area (abbreviated as OP). The samples studied for this thesis are exclusively recovered from the mound, no samples from the Tüpraş Field area were included. The majority of the samples were recovered from the west slope of the mound, in the OPs M and E/H. OP M is characterized by the Early Bronze citadel. OP E/H covers the Late Bronze citadel. From OP G, a single Medieval sample (KT 17530) was studied. OP A/D yielded finds from the Iron Age. Further information about each lot and locus were recorded in lot/locus books and daily notes of excavators were kept in daybooks. For archaeobotanical samples, additional forms were filled out by thr trench supervisors. Figure 3.2 illustrates the settlement plan and the distribution of the samples. The sample numbers which are in bold are the pit samples, the samples which are in regular font are room samples and the italicized sample numbers indicate fiber samples.

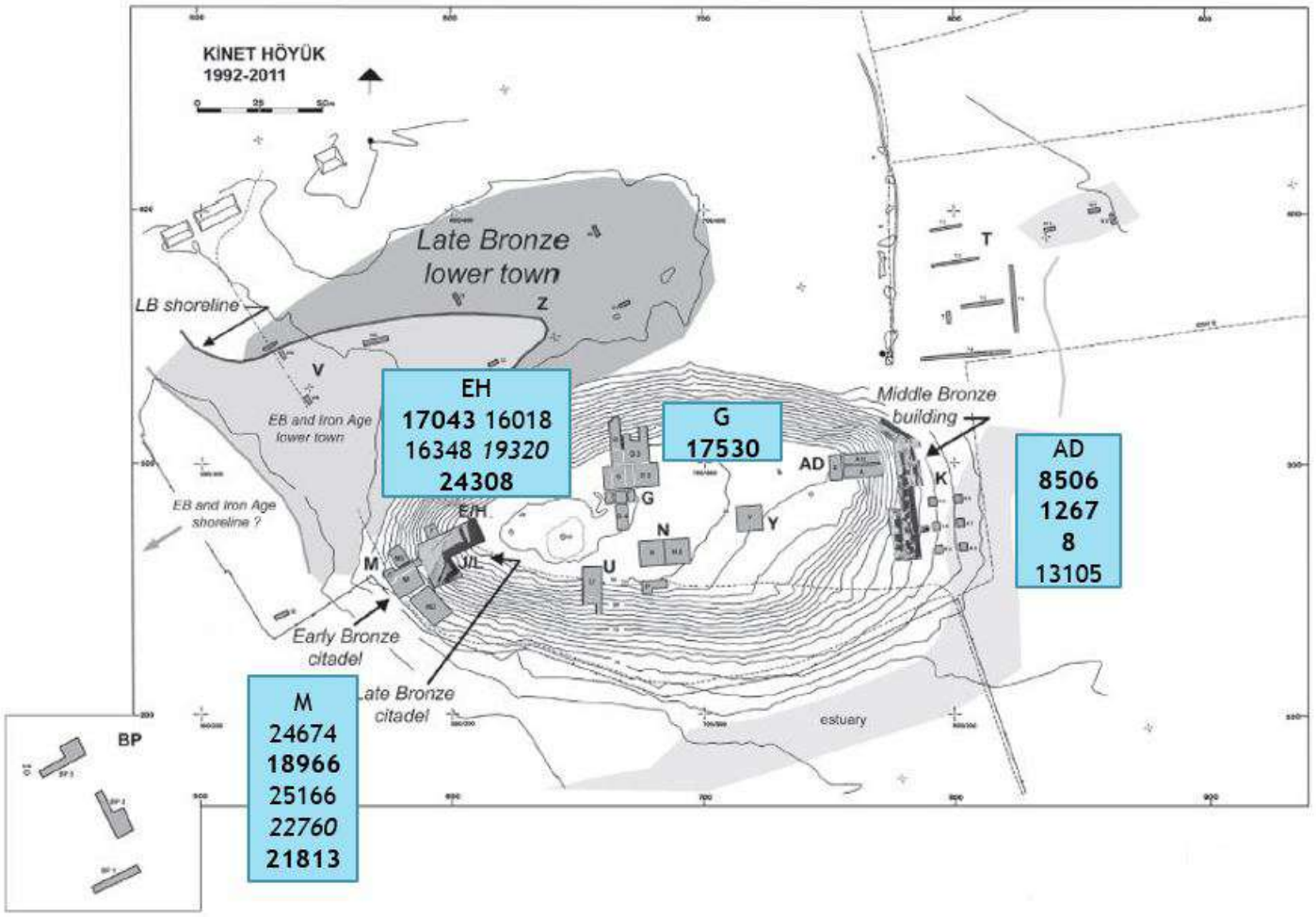


Figure 7: Site map locating the finds spots of the processed samples. Courtesy Kinet Höyük Project archives.

CHAPTER 4

THE THESIS HYPOTHESES: THREE OBJECTIVES

This thesis is based on three main questions, as mentioned above in the introduction chapter. It is crucial for any research that a starting hypothesis must be formed. For this study, three questions were of importance and due to the nature of the samples, they needed to remain as general as possible. With the emergence of additional information, new questions were included.

4.1 Chronology

As explained above, Kinet Höyük was inhabited for a long time in prehistory and history. Such occupation enables the Kinet Höyük researchers to explore the diachronical changes in many subjects. The question here for phytoliths from the site was a general one to begin with: is there a difference perceptible among the contexts as a result of chronological changes? If there is a change, could this observed change relate to chronological differences? The null hypothesis in this case is *"The two ages will yield the same compositions of phytoliths"*

because Kinet Höyük was inhabited for a long time as well as in this time period. It is hypothesized that especially there could be different phytolith compositions observed before and after, for instance on either side of the "Bronze Age collapse", since it was a great natural event that directly impacted plant-use habits (Weiss, 1982).

In the process of question forming, the samples were selected according to the questions asked. One of the criteria for choosing these samples is that in the pit contexts it was possible to acquire one sample from most of the major periods observed in Kinet Höyük, which would give a comprehensive idea about the chronological changes over a broad timescale. Bearing this criterion in mind, samples from EBA II, EBA III, MB I, LB, Middle Iron (MFe), Late Iron (LFe) and the Medieval era were selected. The higher number of samples date to the Bronze Age and Iron Age.

4.2 Room Deposits

The second important question about contexts for finds is intended to clarify the functions of the rooms. The initial question was whether the phytoliths could shed some light about plant-related activities carried in the rooms. Hypothetically, the room samples are secondary fills which include residues from roofing, flooring, mudbrick, basketry and other plant related activities. The question about room deposits aims to detect a significant sign of plant use and human agency, if possible. The room fill samples also showed a good amount of distribution chronologically.

By further continuing in the analysis, it was becoming evident that *Phragmites sp.*, or common reeds, are well represented in the room deposits. The presence of freshwater diatoms also suggested that the use of reed was an important question, for which phytoliths could provide evidence. Therefore, in the later stages of preparing the thesis more attention was paid to the use of reed in room contexts.

4.3 Storage Pits vs. Room Deposits

The last hypothesis of this thesis concerns the contextual differences. The null hypothesis here is that, *"The two contexts must yield the same compositions of phytoliths."* The null hypothesis is formed in response to the alternative (i.e opposite) hypothesis, that the two contexts must yield different compositions. Initially, this hypothesis assumed that storage pits were mainly used for seed storage, therefore there should be an evident difference between the two context types. This difference could have been illustrated by phytoliths, since they are a tool capable of distinguishing the plant's anatomical origin. Ideally, the pits should have yielded more inflorescence phytoliths than leaf/culm phytoliths if seed storage was their intended purpose. The rooms, on the other hand, should have been rich in leaf/culm phytoliths since anthropogenic activities (roofing, flooring, tempering, basketry, etc.) prefer leaf and culm.

4.4 Methodology

The methodology of this thesis heavily derives from Madella's 2001 publication. The Çatalhöyük phytolith corpus was also a good resource, yet Madella's study of a comparable timeframe and similar contexts presented a more appropriate model for this thesis.

The samples were the starting point. Since the Kinet Höyük excavations finished in 2012, sampling methods were already documented and the contextual information was ready. Based on the 37 samples taken for further phytolith studies during excavation, 17 samples were initially taken. The most important criterion here was the contexts of the samples. Generally, samples are taken from the field according to a specific research agenda, however for Kinet's case this was not possible since the excavation was no longer active. Therefore, the questions were formed after the selection of suitable samples. To eliminate researcher bias and to perform a blind research, the excavation notebooks and day sheets were not consulted at this stage.

After sample selection, the phytolith extraction procedure was carried out. Because of problems in the first extraction procedure, a second one was performed on a new set of prepared soil samples.

After the extraction, the initial aim was to identify the different types of plants or phytolith morphologies. Silica skeletons would have been preferable to distinguish under the microscope for morphometric analyses. However, first impressions from the microscopic analyses of the Kinet samples indicated that the

silica skeletons themselves were insufficient to answer the stated hypothesis. It became clear that both single cells and silica skeletons needed to be counted.

The challenge of counting the single cells and identification of silica skeletons was the lack of a reference collection for comparative material. Therefore, published resources about Near Eastern phytoliths, especially with the help of the phytolith bibliography in Evett 2016 and many other articles were scanned for comparison and possible ways to conduct a morphological analysis. Phytolith recognition in its early stages is especially difficult since most of the morphotypes cannot be easily distinguished under the microscope. Eventually, after an adequate amount practice and by consulting to the reference articles, a technical system for counting phytoliths was achieved. Essential reference articles, books and book chapters included Madella 2001, Madella et al. 2005, Miller 1989, Twiss et al. 1969, Schellenberg 1908, Pearsall 2016, Fredlund and Tieszen 1994, Kaplan, Smith, and Sneddon 1992, Bozarth 1992 and Rosen 1992. In addition, ArchaeoScience (n.d.) PhytCore DB supplied comparative pictures.

Once the necessary basis for identification of morphotypes and possible sources of silica skeletons was established, a need for quantification arose. This was intended to eliminate the subjective bias of a simple descriptive report. First, a counting system and recording sheet were needed. Pearsall (2016) was a great source to understand the nature of the counting process and to provide an example of a counting sheet. However, since Pearsall's nomenclature and classification system were not coherent with the aims of this thesis, an appropriate counting method was devised adapting Pearsall's methodology.

Later in the process, the initial counting of the Kinet phytoliths was not sufficiently elaborate to perform statistical analysis. For this reason, a database was created using Microsoft Office Access 2018. In this database, single cell counts and silica skeleton counts were kept separate. Single cell counts only considered the intact and the taphonomized morphotypes, whereas silica skeletons were counted individually. Anatomical origin, taphonomy, taphonomy type, possible subfamily and species, multilayering and partial silicification were recorded as separate categories.

Based on the acquisition of these specified informations, enough data was present for further quantitative analysis. Statistical analyses were needed to be able to propose answers to the thesis questions. Two-way independent t-tests and Principal Component Analysis were found suitable and applied using R language and RStudio (RStudio Team, 2018).

CHAPTER 5

SYNTHESIS

Any phytolith study starts with the extraction process. It is followed by data acquisition and interpretation steps. The data acquisition part is mainly performed with the help of a light microscope. After the data acquisition step is done, the main issue is data interpretation. For this step, statistical tools are essential and they help the researcher to give further meaning to the recovered assemblage.

In this chapter, the results and their relative discussions will be simultaneously presented. They are described in some detail to guide beginners who are faced with extracting phytolith samples for the first time.

5.1 Lab Procedure

The lab procedure is crucial to acquire the phytolith assemblage. The fiber samples are easy to handle, whereas the soil samples can be more time consuming. For example, in this thesis the soil samples were subject to chemical extraction

processes whereas the fiber samples were not. Phytolith studies do not only require botanical, archaeological and biological knowledge, it is very helpful to consult geologists and soil scientists especially at this stage since soils have different compositions. Even in the same archaeological site, it is possible to encounter different types of soils. Therefore, according to the different soil types the extraction procedure must be tailored. The aim is to clean all the soil components except silica based particles, which include phytoliths.

For this thesis, the extraction and data acquisition process was carried out in the Bilkent University Molecular Biology Department General Lab and Ali Osmay Güre Lab under the supervision of Prof. Dr. Ali Osmay Güre. For the extraction procedure, there exist several necessary types of machinery, chemicals, glassware and other consumables. The most suitable infrastructure setup for phytoliths is to have a laboratory specifically designed for phytolith studies, yet this is not always possible. The most crucial elements of a phytolith lab's hardware are listed below.

- **Fume Hood:** Fume hoods are special equipment to provide a safe space for handling hazardous chemicals like HCl. Fume hoods provide ventilation and protect the researcher from the toxic fumes of several chemicals. Also, because of the ventilation system it is easy to decontaminate the area. Fume hoods with acid sinks are preferable.

- **Centrifuge:** Centrifuges are machines which use the centrifugal force to achieve gravimetric separation. Piperno (2006) advises a tabletop centrifuge with interchangeable rotors that includes a head compatible with

50 mL tubes. The number of tubes put in the rotor changes according to the brand or the head of the centrifuge. For this thesis, a centrifuge of Eppendorf brand with interchangeable rotors was used.

- **Microscope:** A biological light microscope is essential for the data acquisition part. Objective lenses of x4 to x60 are sufficient. For more detailed analyses, an oil immersion objective (x100) can be used. In addition, a microscope suitable for digital image acquisition is preferred. For this thesis, Zeiss Axio Imager A1 was the primary microscope.

- **Oven:** A high temperature oven which can reach 500^o is useful for both modern phytolith reference collections and soil sample phytolith extraction procedures. However, they can be expensive. Therefore, as an alternative, a low-temperature oven is enough to dry to soil samples.

- **Analytical balance:** An analytical scale is essential to note the sample weights. According to Piperno (2006), an analytical scale which can measure to four decimals is ideal. For very fine weightings, an analytical balance up to five decimals is even better. In these instruments, the last digit is highly sensitive, therefore the scale must be placed in a secure position.

- **Sieves:** To separate big particles from the soil and ease the extraction procedure, sieves should be used. According to Piperno (2006), sieves with 250-mm mesh and 53-mm mesh are recommended. In addition Rosen (1999) advises that a sieve with 500-mm mesh is most useful for capturing the most intact silica skeletons since they are bigger than the single cells. The sieves can be brass and their mesh can be stainless steel.

- **Hotplate:** Hotplates are very useful for mixing solutions, especially the magnetic stirring eases the dissolution of sodium hexametaphosphate.

- **Shakers:** Mechanical shakers are not particularly necessary, however they ease the process of clay dispersal.

- **Vortex:** A vortex machine is also not essential, yet it is very useful for disaggregating the soil samples. When the soil samples are liquid, the vortex can be used for speeding up the reaction. However, the vortex should be used with caution and manual stirring should be preferred since the silica skeletons can break under excessive force.

- **Glassware and disposables:** Probably, one of the most crucial elements for the extraction process is the disposable equipment. The falcon tubes, labels, microscope slides, plastic pasteur pipettes, gloves, washing bottles, filter papers, waterproof pens etc. are all consumable supplies. For this thesis, 50 mL falcons were used.

  The glassware include beakers, graduated cylinders, baguettes, petri dishes, glass vials etc. In addition, small equipment like forceps, spatulas, spoons, funnels, mortars, tube stands facilitate life in the laboratory. For phytolith extraction, it should be noted that glass pipettes are much more efficient than plastic pasteur pipettes.

  Plastic pasteur pipettes proved to be problematic for collecting the phytolith samples since they are not washable. Also, when they are used for mounting, they can leave microscopic residues on the slide and make background noise under the microscope.

A slide archive for horizontal or vertical storing is also advised to create a reference collection and to store the slides safely.

Chemicals are also essential for the extraction process. Each chemical serves a purpose for eliminating a soil component. The chemicals used for this thesis and procedure are listed below.

- HCl: Hydrogen chloride is mainly used to get rid of the carbonates. The carbonates can be already present depending on the soil type or presence of shells or bones. The acid reacts with carbonates and CO_2 gas is released. The remaining salts are washed away as part of the procedure.

- H_2O_2: Hydrogen peroxide is mainly used for cleansing organic residues. It can be replaced by other strong acids like nitric acid (HNO_3) if necessary (Piperno, 2006).

- Sodium hexametaphosphate ($(NaPO_3)_6$): Commercially known as Calgon, this chemical is used to aid the dispersal of clay. For better results, a lab grade version should be used.

- Sodium polytungstate ($3Na_2WO_4 \cdot 9WO_3 \cdot H_2O$): SPT for short, this is the heavy liquid used to "float" the phytoliths. SPT is a good alternative for most heavy liquids. It is non-toxic and reusable after filtration. For this procedure, the density of SPT should be at 2.35 g/cm^3. According to the SPT mixture chart, it is possible to mix the solution at the desired density. The only drawback with SPT is its expense. However, Madella et al. (1998) notes that filtration reduces the overall cost of the chemical.

- MeOH: Methyl or ethyl alcohol is used for decontaminating the workspace.
- Entellan: Entellan is an adhesive used to mount the slides.
- Glycerin: It is used for non-permanent mounting.

As noted in Chapter 2, phytolith extraction procedures have six main stages. The procedure developed by Madella et al. follows the six main stages perfectly and suits most soil types. It incorporates the use of sodium polytungstate (SPT) as the heavy liquid. By replacing centrifuging instead of water columns, this procedure is relatively quicker than the others. The procedure below is derived from this protocol and enhanced by Marco Madella and his team. Next to each step, the approximate time for completing that step is noted in bold.

Extraction Procedure

1. Weigh each tube. Note it in the section "TUBE". **(15 mins)**
2. The soil samples are weighted and 2-4 g are put into tubes. Note it in the section "TUBE+SED [1]". **(25 mins)**
3. In each tube, add 15 mL of HCl (1 N, app. 7%). Wait until the sizzling is stopped. This step should not last more than 4 hours. **(2-4 hours)**
4. Add distilled water into the tubes up to 50 mL. Centrifuge the tubes in 1000 rpm for 3 minutes. Decant the water. **(6-8 mins)**
5. Repeat the distilled water wash 3 more times. **(18-24 mins)**

[1]SED: short for sediment.

6. Add 10% sodium hexametaphosphate up to 50 mL of the tube. (For 10% solution, add 100 gr of sodium hexametaphosphate, 900 gr dH_2O.)

7. Leave the solution overnight. In this step, constant stirring is important to disperse soil. Manual or mechanical stirring is crucial. **(16-24 hours)**

8. Wash the tubes as in Step 4 until the water is clear, not yellowish. Do not wash the samples more than 8 times.[2] **(24-60 mins)**

9. Add 15% H_2O_2 solution into each tube up to 15 mL. Wait until the gas escape stops. This step can take longer than 8 hours. The gas escape should finish as much as it can before proceeding into the next step. **(4-8 hours)**

10. Add distilled water until 50 mL. Centrifuge the tubes in 1000 rpm for 3 minutes. **(24-60 mins)**

11. Repeat the distilled water wash 3 more times. **(18-24 mins)**

12. The soil sediments are left for drying.[3]**(16-20 hours)**

13. When the soil is completely dry, the acid insoluble fraction (AIF) weight is noted. [4]**(16-20 hours)**

14. Write labels and stick them on the vials. Use sticky labels. Weigh the vials with their labels on and note the weights as "VIAL".**(35 mins)**

15. Label the falcon tubes in which the phytoliths will be collected.**(20 mins)**

[2]It is very useful to count the cycles in a separate notepad. After a couple of cycles it becomes hard to keep track of their number.

[3]It is possible to use low-temperature ovens or heat lamps to quicken the process.

[4]To be sure that the samples are dry, weigh the samples twice in an hour. If there is no difference less than 0.001, the samples are completely dry. Samples may look dry but there can be trapped water in the mixture.

16. Add 15 mL of 2.35 g/cm^3 SPT.**(35 mins)**

17. Centrifuge the tubes for 3 mins at 1500 rpm. **(6-8 mins)**

18. Carefully remove the tubes from the centrifuge. Avoid shaking them. Pipette the phytoliths three times with a glass pipette.

19. Centrifuge the tubes for 3 mins at 1500 rpm. **(6-8 mins)**

20. This time, try to collect all the phytoliths on the surface. When you're done, wash the glass pipettes and collect the waste in glass waste bins.

21. Fill the falcons you collected the phytoliths in up to 50 mL. Centrifuge the tubes for 3 mins at 1000 rpm. Do not decant the water, it contains trace amounts of SPT. Store it for filtering. **(6-8 mins)**

22. Centrifuge three more times under the same conditions with distilled water. **(18-24 mins)**

23. Decant the water. Leave as little water as you can in the tubes. Transfer the phytoliths to vials.

24. Dry the phytoliths in the vials.

25. After the phytoliths in vials are fully dry, note down the weights of vials as "VIAL + PHYTO".

From time to time the procedure requires noting several different values of weight. These are crucial for calculating the concentration of phytoliths as well as their taphonomical qualities.

Practical Comments

The extraction process of Kinet Höyük soils proved to be difficult, and required two attempts, after the first one was unsuccessful. In the first attempt, the amount of acid added to the soils was too much and may well have been responsible for dissolving small phytoliths. Also, the soil samples had not been sieved properly, and contained big particle residues. The amount of organic material left was also a problem in the first attempt. In the second attempt, several of these problems were resolved. The samples were sieved properly with 500-mm and 250-mm sieves. The acid amount was reduced to a lower recommended level. However, the problem of organic material residue and clay persisted. It took a much longer time than expected to properly cleanse out the organic material. As for the clay, sodium hexametaphosphate did not fully remove it despite the fact that the samples were shaken manually. Based on the suspicion that the soil was rich in humic acids and organic material, the samples were treated with 10% solution of KOH. Unfortunately, in the second attempt the AIF weights were not noted due to an oversight.

Permanent Mounting Procedure

In the last step of the wetlab, there is a short procedure for mounting the phytoliths on the slides. There are two types of mounting, permanent and non-permanent. For permanent mounting, adhesives like Entellan or Canada balsam are used. Entellan is preferred because of its refractive index. However, it should be noted that prolonged inhaling of Entellan can cause side effects such

as headache. Therefore, this procedure should be carried out as much as possible under the fume hood. The procedure for permanent and non-permanent mounting is outlined below.

1. Label the slides. In this study, labeling the slides with Kinet number and the type of sample was sufficient. It is optional to add other information. Weigh the slides after labelling and and note them as "SLIDE".

2. Gently spread out the phytolith residues with a sharp object. Place a sufficient amount of phytoliths on the slide.

3. Note the slide and pellets as "SLIDE + PHYTO". 0.005 to 0.0010 g of phytoliths is sufficient.

4. Add enough Entellan to cover the slides. Be careful to put the cover slide and do not leave air bubbles. Gently tap on the cover slide to remove the air bubbles. Use glass pipettes and discard them properly into glass waste.

5. Dry the slides in air, or preferably under the fume hood.

Non-Permanent Mounting Procedure

For non-permanent mounting, labeling or weights are not important since they are made for screening or purposes other than storing.

1. Gently spread out the phytolith residues with a sharp object. Place a sufficient amount of phytoliths on the slide.

2. Prepare a glycerin solution of 50% weight. Add a few drops of this solution and carefully attach the cover slip.

5.2 Results

As the next step of chemical extraction, phytolith samples must be counted under a light microscope and statistical analyses are performed based on the quantified data. For this thesis, the counting procedures were carried out in the Bilkent University Molecular Biology and Genetics General Laboratory under the supervision of Prof. Dr. Ali Osmay Güre. The microscope used was Zeiss Axio Imager A1 which could support magnification from x40 to x1000. The microscope has an attached digital camera with the necessary software for photo acquisition.

The phytolith identification process requires either a reference collection of modern samples, or an extensive file of published images. For this thesis, a reference file was compiled from published photographs of phytoliths. The Kinet phytoliths were identified according to these photos.

For this thesis, the viable phytolith count number for a single slide was determined as minimum 250 single cells and 50 multicellular cells after Zurro (2017). Two slides (KT 12678 and 17043) out of the 13 extracted soil samples could not reach the viable count number for single cells, and are not included in the scope of the results. The statistical analysis of the extracted soil samples was therefore based on 11 samples.

To calculate the number of phytoliths in a sample, Weiner & Albert, 2001 was followed. Since the AIF weights are absent, only the number of phytoliths in the pellet were counted. For counting the slides, the slide was divided into a virtual

grid by referring to the rulers on the stand of the microscope. The average size of a cover slip is 24 x 24 mm. Each row or column corresponds to a 1 mm slice of the overall cover slip, therefore a column or row corresponds to 24 mm^2 of the slide. The grid columns were given coordinates to keep track in counting the phytoliths.

Information about the samples is provided in Appendix A Table 9, and a balloon plot in Appendix A Fig. 21. This balloon figure shows the most abundant morphotypes present in a sample. It should be noted that during the detailed explanations of each slide's assemblage, ELONGATE ENTIRES were not always mentioned. This is due to the fact that with a few exceptions, it is generally the most abundant morphotype in all the samples.

5.2.1 The Kinet Soil Samples

5.2.1.1 KT 8506

This sample is categorized as pit fill and it is dated to Late Iron Age (LIA), Kinet period 7. It has a Munsell color of 10 YR 7/1 light gray. According to the locus sheet it was collected from OP AII Locus 199 and Lot 321, excavated in 1997. The soil was assessed as unburnt and has a heterogeneous color of gray and brown. The texture is soft. The daybook notes that this sample was collected as a scientific soil sample since during excavation a white, ashy layer with particles like charcoal was encountered. For illustrations, see Appendix C, Fig. 36.

For this sample, a total number of 247 single cells and 59 multicellular phytoliths was counted. The taphonomized single cells are 69 in total. The total number of phytoliths counted is 365. The weight of the initial sample is 3.0005 gr, the pellet is 0.5016 gr, for the permanent mounting 0.0012 gr was used. The overall number of phytoliths per slide (pps) is 3893, the number of phytoliths present in this pellet is ca. 1,627,413.

The sample composition suggests that the ELONGATE DENDRITIC, ELONGATE DENTATE and RONDEL morphotypes were abundant (See Appendix Fig. A1a). This single cell composition suggests the presence of leaves and inflorescence together. The abundance of morphotypes ELONGATE DENTATE and RONDEL proves that leaves were present, probably used as pit lining as the daybook suggests. The presence of ELONGATE DENDRITIC is lower than expected, yet suggests presence of parts of the inflorescence in the sample.

Out of the 59 silica skeletons counted, 7 of them are grass inflorescence, 46 of them are grass leaf/culm. 5 of them are unidentified and there is one possible wood phytolith. In addition, five of the grass inflorescence silica skeletons were identified as Panicoidae after Out et al. (2006). One of the unidentified silica skeleton is not identified due to its highly taphonomized nature. Out of the total, 13 are taphonomized, with aggregation being the most problematic issue.

5.2.1.2 KT 13105

This sample is categorized as room fill and it is dated to Middle Iron Age (MIA), Kinet period 8. It has a Munsell color of 10 YR 6/2 light brownish gray.

According to the locus sheet it was collected from OP. D Locus 183 and Lot 472, excavated in 1999. Lot 472 is the fill between two surfaces in a room. The soil was assessed as burnt and has an orange color. It has a compact texture. The daybook notes that this sample was collected as a scientific soil sample during excavation. For illustrations, see Appendix C, Fig. 37.

For this sample, a total number of 264 single cells and 61 silica skeletons was counted. The taphonomized single cells are 61 in total. The total number of phytoliths counted is 390. The weight of the initial sample is 3.0347 gr, the pellet is 0.3607 gr, for the permanent mounting 0.0008 gr was used. The overall number of phytoliths per slide is 5505, the number of phytoliths present in this pellet is ca. 2,482,464.

The single cell composition suggests a high number of Elongate dendritic, Rondel, Elongate dentate and Saddle present (See Appendix Fig. B1a). This suggests some inflorescence again dominated by leaf/culm phytoliths. The presence of Saddles combined with Bilobates indicate a possible C4 grass type. It is, however, interesting that the number of Elongate dendritic is high.

Out of the 61 silica skeletons counted, 14 of them are grass inflorescence, 37 of them are grass leaf/culm. 14 of them are unidentified due to taphonomy. Out of the total, 28 are taphonomized because of mainly aggregation and chemical attack. In addition, seven of the grass inflorescence silica skeletons were identified as Pooidae, possibly belonging to *Triticum sp.*

5.2.1.3 KT 16018

This sample is categorized as room fill and it is dated to Middle Iron Age (MIA), Kinet period 8. It has a Munsell color of 10 YR 6/1 gray. According to the locus sheet it was collected from OP. E/H Locus 278 and Lot 634, excavated in 2002. The daybook notes that this sample was collected as reed/straw matting. This sample is associated wiith another sample, KT 16348 and it has yielded fiber samples for further identifications. For illustrations, see Appendix C, Fig. 39.

For this sample, a total number of 261 single cells and 53 silica skeletons was counted. The taphonomized single cells are 20 in total. The total number of phytoliths counted is 334. The weight of the initial sample is 3.0098 gr, the pellet is 0.1349 gr, for the permanent mounting 0.0012 gr was used. The overall number of phytoliths per slide is quite high at 28,126, the number of phytoliths present in this pellet is ca. 3,161,866. Overall, this sample is well populated with phytoliths.

The single cell composition suggests that the number of Rondels, Saddles and Blockys is quite high (See Appendix Fig. A1c). Bearing in mind that the numbers of Bulliform flabellates and Crenates and other indicators of leaves are high, it is safe to assume that this assemblage is dominated by leaves.

Out of the 53 silica skeletons counted, 5 of them are grass inflorescence, 21 of them are grass leaf/culm. 16 of them are unidentified due to taphonomy. In this

sample, 11 silica skeletons were identified as *Phragmites sp.* after Ramsey, Maher, Macdonald, and Rosen (2016). In addition, there is one grass inflorescence silica skeleton identified as Pooidae, possibly belonging to *Triticum sp.*. Out of the total, 28 are taphonomized, aggregation and clay aggregation being the most problematic issues.

Luckily, from the same context another archaebotanical sample (KT 16019) was collected. The archaeobotanical data suggest the presence of *Triticum sp.* (wheat), *Hordeum vulgare* (barley), *Lolium sp.* and indeterminate grasses (Harding, 2019). Compared to the archaebotanical data, the phytoliths also confirm the presence of grasses. In addition, the initial identification of the sample as being reed or straw is confirmed. The sample has 11 identified *Phragmites sp.* (common reed) leaf/culm type silica skeletons. Given the nature of the sample, it is more likely that instead of straw, the observed white layer consisted of reed leaf phytoliths.

5.2.1.4 KT 16348

This sample has the exact description of the previous sample KT 16018. It is categorized as room fill and dated to Middle Iron Age (MIA), Kinet period 8. It has a Munsell color of 10 YR 6/1 gray. According to the locus sheet it was collected from OP. E/H Locus 278 and Lot 682, excavated in 2002. As the daybook notes, this was collected as a scientific sample since it contained white, ashy residues. For illustrations, see Appendix C, Fig. 40.

For this sample, a total number of 301 single cells and 53 silica skeletons was

counted. The taphonomized single cells are 5 in total. The total number of phytoliths counted is 334. The weight of the initial sample is 2.704 gr, the pellet is 1.016 gr, for the permanent mounting 0.0011 gr was used. The overall number of phytoliths per slide is quite high at 25,192, the number of phytoliths present in this pellet is ca. 23,269,154. Overall, this sample is well populated with phytoliths.

The single cell composition suggests that the number of RONDELS and ELONGATE DENDRITICS is quite high (See Appendix Fig. A1d). This composition is found to be not clearly dominated by leaves, however the presence of inflorescence phytoliths is without doubt.

Out of the 53 silica skeletons counted, 36 of them are grass inflorescence, 16 of them are grass leaf/culm. There is only one unidentified silica skeleton due to taphonomy. 30 of the grass inflorescence silica skeletons were identified as Pooidae, possibly belonging to *Triticum sp.*. This offers an interesting contrast compared to its neigbouring sample's composition, where leaves/culm predominate.

This silica skeleton assemblage is clearly dominated by grass inflorescence phytoliths and supported by the single cell signatures of inflorescence. It is safe to assume grass inflorescence in this particular sample. Out of the total silica skeleton assemblage, 6 are taphonomized, aggregation and clay aggregation being the most problematic issues.

5.2.1.5 KT 17530

This sample is categorized as pit fill and it is dated to the Medieval era, Kinet period 1. It has a Munsell color of 10 YR 7/1 light gray. According to the locus sheet it was collected from OP G. Locus 21 and Lot 43, excavated in 2003. According to the locus sheet, the soil was burnt, light, and gray. The interpretation notes that this pit may explain an interruption between two other contexts. The daybook notes that this sample was collected as ash. This sample is the only one which represents Middle Age Kinet. For illustrations, see Appendix C, Fig. 41.

For this sample, a total number of 278 single cells and 44 silica skeletons was counted. The taphonomized single cells are 35 in total. The total number of phytoliths counted is 357. The weight of the initial sample is 2.3043 gr, the pellet is 1.3985 gr, for the permanent mounting 0.0010 gr was used. Pps is 7,140, the number of phytoliths present in this pellet is ca. 9,985,290.

The single cell composition indicates that the number of Elongate dendritics is exceptionally high, followed by Rondels (See Appendix Fig. A1b). This seems to be a mixed composition with few indicators of leaves except Rondels. The high number of Elongate dendritics is notable (approx. 65).

Out of the 44 silica skeletons counted, 11 of them are grass inflorescence, 29 of them are grass leaf/culm. There are three unidentified silica skeletons due to taphonomy. Interestingly there is one Phragmites sp. leaf/culm type silica

skeleton. Out of the total, 9 are taphonomized, mainly because of chemical attack, followed by clay aggregation.

This sample paints a rather odd picture as the single cell and silica skeleton compositions are not entirely overlapping. However, this may be reasonable considering the context of the sample. This pit is located in a room and in the "doorway" as the daybook notes. Since this is a pit and an ashy layer, it is logical to assume that the inflorescence and the grass leaf/culm silica skeletons are the ashy residues from a fire. There was no deformation noted on the phytoliths, hence it is thought to be a low-temperature fire. The daybook notes that a mandible, which probably belonged to a cow (Rt&left cojoined) was unearthed in the same locus but in a neighbouring lot. In the daybook, the lot next to 21 (Lot 23) was described to have a dark color which indicates organic residue. Combining the facts, it is very possible that this was a barn-like place where the cows were kept and fed. Based on the faunal and floral evidence, it is possible to hypothesize different explanations. To further support this idea, the botanical sample KT 17483 can be studied.

5.2.1.6 KT 18966

This sample is categorized as pit fill and it is dated to the MBA I, Kinet period 18. It has a Munsell color of 10 YR 6/2 lightish brown gray. According to the locus sheet it was collected from OP. M Locus 84 and Lot 128, excavated in 2003. According to the locus sheet, the soil was burnt, brown and red. The locus sheet notes that this locus was a pit deposit with one surface about 10 cm

from the top and another at the bottom. Lot 128 is mixed soil due to being a pit. There was also animal disturbance detected. Also, it was noted that the soil was relatively clean of faunal and floral materials. For illustrations, see Appendix C, Fig. 42.

For this sample, a total number of 335 single cells and 10 silica skeletons were counted. The silica skeletons fall short of the desired number, nevertheless the single cell count was viable. The taphonomized single cells are 18 in total. The total number of phytoliths counted is 363. The weight of the initial sample is 3.0046 gr, the pellet is 0.0550 gr, for the permanent mounting 0.0010 gr was used. Pps is 8,142, the number of phytoliths present in this pellet is ca. 447,813.

The single cell composition suggests that the number of Rondels is exceptionally high, followed by Rondels and Saddles (See Appendix Fig. A1c). This seems to be a mixed composition again.

Out of the 10 silica skeletons counted, 7 of them are grass inflorescence, 3 of them are grass leaf/culm. Out of the total, 3 are taphonomized by chemical attack.

Due to the small number of the silica skeletons it is hard to comment on the nature of the sample fully. However, the low weights and counts suggest that as the locus sheet notes the phytolith presence is low in this sample. Most probably, the phytoliths present were either from wild grasses or animal distruption. However, the photos taken from the sample suggest the presence of at least one *Phragmites sp.* silica skeleton.

5.2.1.7 KT 21813

This sample is categorized as pit fill and it is dated to the MBA I, Kinet period 18. It has a Munsell color of 10 YR 6/1 gray. According to the locus sheet it was collected from OP. M Locus 137 and Lot 312, excavated in 2005. According to the locus sheet, the soil was burnt and unburt, gray, brown and black. The lot is of good quality. The pit is identified as a bell-shaped pit. From this locus another phytolith sample was collected (22227). The daybook notes that this sample was collected from the bottom of the pit as a phytolith sample. For illustrations, see Appendix C, Fig. 44.

For this sample, a total number of 356 single cells and 6 silica skeletons were counted. The silica skeletons fall short of the desired number, nevertheless the single cell count was viable. The taphonomized single cells are 82 in total. The total number of phytoliths counted is 444. The weight of the initial sample is 3.0022 gr, the pellet is 1.5673 gr, for the permanent mounting 0.0009 gr was used. Pps is 21,312, the number of phytoliths present in this pellet is ca. 37,113,664. This sample was crowded with phytoliths.

For this sample, the single cell composition is highly interesting. The sample is dominated by Saddles and Bilobates, even more than the total of Elongate entires. Intact Saddles are high in number, however combined with the taphonomized single cells, Bilobates are the most ubiquitous morphotype in this sample. Other morphotypes also indicate a good presence of leaves in this assemblage.

Out of the 6 silica skeletons counted, 3 of them are grass inflorescence, 3 of them are grass leaf/culm. Out of the total, 4 are taphonomized, mainly by chemical attack.

This sample is interesting because it has a strikingly different single cell composition from the other samples. It is also coming from a secure pit context, already identified as a bell-shaped pit. The daybook explicitly notes that there was a 10 cm thick white layer at the bottom of the pit, which was suspected to be phytoliths. According to Fairbairn and Omura (2005), this type of bell pits is called ESÀG in Hittite texts and they are generally lined with cereal straw or grass stems. The authors also note that sometimes there can be plaster with tempering. The single cell composition of the OP. M pit assemblage strongly suggests that there was lining present. However the phytoliths from this pit are leaf/culm in general, inclining towards leaf dominance: the high number of single cell phytoliths are indicative of leaves. More interestingly, Saddles and especially Bilobates are generally found in C4 plants. Presence of Crosses and Polylobates are also confirming this. A comparison with Lu (2003) gives some ideas about the Bilobates overall and suggests that *Sorghum sp.* leaves can be present.

This sample strongly suggests that this pit was lined with not only leaves and culms, but they were specifically from a C4 plant. Although general assumptions cannot be based on a single pit, it does give ideas for further research. In addition, the lack of silica skeleton evidence prevents further comments. This sample may require more examination under the microscope. Lastly, given the

fact that this is a pit, inflorescence phytoliths are not surprising in this context.

5.2.1.8 KT 22764

This sample is categorized as pit fill and dated to the EBA III, Kinet period 23. It has a Munsell color of 10 YR 6/1 gray. According to the locus sheet it was collected from OP. M Locus 190 and Lot 302, excavated in 2005. According to the locus sheet, the soil was unburt, brown and yellow. The lot is of good quality yet root disturbance was present. For illustration, see Appendix C, Fig. 46-a.

For this sample, a total number of 314 single cells and 6 silica skeletons was counted. The silica skeletons fall short of the desired number, nevertheless the single cell count was viable. The taphonomized single cells are 17 in total. The total number of phytoliths counted is 337. The weight of the initial sample is 2.9285 gr, the pellet is 0.7519 gr, for the permanent mounting 0.0009 gr was used. Pps is 14,950, the number of phytoliths present in this pellet is ca. 12,489,971.

This sample has a straightforward composition with Rondels standing out. The other morphotypes only hint at the presence of leaves and culms. Interestingly, Elongate dendritic is low in number.

Out of the 6 silica skeletons counted, 3 of them are grass inflorescence, 3 of them are grass leaf/culm. Out of the total, 4 are taphonomized, mainly due to chemical attack.

Again, to understand the sample further, the daybook and locus sheets play a vital role. According to the locus sheet, this is a pit with plaster lining, not with straw lining. The sample was collected a white layer from the bottom of the pit. The plaster lining of this pit was also studied for possible phytolith fibers (KT 23175). The key word here is "the white layer". The excavators note that they sampled from "the white layer". The plaster also seemed to be covered with white layer. However, the examination of the pit lining suggests that this is not directly phytoliths, probably a white clay or another mineral added for strengthening the pit lining. Therefore, the phytoliths present in this sample can be explained as a part of the plants used for tempering the lining.

5.2.1.9 KT 24308

This sample is categorized as pit fill and it is dated to the LBA, Kinet period 14. It has a Munsell color of 10 YR 6/1 gray. According to the locus sheet it was collected from OP. E/H Locus 619 and Lot 1515, excavated in 2007. This pit cuts through a channel which was built before it. The sample was collected as a phytolith sample. For illustration, see Appendix C, Fig. 46-b.

For this sample, a total number of 303 single cells and 9 silica skeletons was counted. The silica skeletons fall short of the desired number, nevertheless the single cell count was viable. The taphonomized single cells are 17 in total. The total number of phytoliths counted is 329. The weight of the initial sample is 2.7129 gr, the pellet is 0.2232 gr, for the permanent mounting 0.0008 gr was used. Pps is 4,008, the number of phytoliths present in this pellet is ca.

1,118,232.

This sample has a straightforward composition with RONDELS standing out. The other morphotypes present only hint at the presence of leaves and culms. Interestingly, ELONGATE DENDRITIC is low in number.

Out of the 9 silica skeletons counted, only one of them are grass inflorescence, 8 of them are grass leaf/culm. There is one unidentified silica skeleton due to taphonomy. Out of the total, 4 are taphonomized, mainly by chemical attack.

This sample's nature is unclear. There are hints about the presence of leaves yet the context is also a little problematic. There is no clear indication whether this was a lined or plastered pit. It was adjacent to a channel that may have cut into it. Therefore, it is hard to make a conclusion either about the sample or the pit.

5.2.1.10 KT 24674

This sample is categorized as room fill and it is dated to the EBAII, Kinet period 27. It has a Munsell color of 10 YR 6/1 gray. According to the locus sheet it was collected from OP. M Locus 281 and Lot 493, excavated in 2007. Soil sample was burnt, unburnt, dark and brown. The texture is average and the quality of the lot is good. There is animal disturbance. This sample's locus is located above the locus of sample KT25166. The context is identified as a courtyard. For illustration, see Appendix C, Fig. 47.

For this sample, a total number of 327 single cells and 45 silica skeletons was counted. The silica skeletons fall short of the desired number, nevertheless

the single cell count was viable. The taphonomized single cells are 23 in total. The total number of phytoliths counted is 395. The weight of the initial sample is 3.0564 gr, the pellet is 0.2042 gr, for the permanent mounting 0.0008 gr was used. Pps is 5,180, the number of phytoliths present in this pellet is ca. 1,322,278.

This sample's single cell composition is clearly leaning towards leaves since Rondels are dominating the sample even more than Elongate entires. The major signs of leaf remnants are the Bulliform flabellates and Blockys. Other morphotypes confirm this.

Out of the 45 silica skeletons counted, only one of them are grass inflorescence, 35 of them are grass leaf/culm. There are three unidentified silica skeleton due to taphonomy. Out of the total, 16 are taphonomized, mainly due to chemical attack. Interestingly, in this sample 12 Phragmites sp. were identified.

This sample is not actually a room fill, rather than a sample from the courtyard. The daybook notes fragments of mudbrick found. The single cell composition clearly indicates that this sample contains *Phragmites sp.* leaves. The presence of *Phragmites sp.* can be attributed to the mudbrick pieces.

5.2.1.11 KT 25166

This sample is categorized as room fill and it is dated to the EBAII, Kinet period 28. It has a Munsell color of 10 YR 6/1 gray. According to the locus sheet it was collected from OP. M Locus 304 and Lot 545, excavated in 2007. The soil

sample was burnt in patches, brown and yellow. The texture is average/compact and the quality of the lot is good. There is animal disturbance. This sample's locus is located below the locus of the sample KT 22674. For illustration, see Appendix C, Fig. C46-d.

For this sample, a total number of 327 single cells and only two silica skeletons was counted. The silica skeletons fall short of the desired number, nevertheless the single cell count was viable. The taphonomized single cells are 15 in total. The total number of phytoliths counted is 329. The weight of the initial sample is 2.9466 gr, the pellet is 0.7747 gr, for the permanent mounting 0.0009 gr was used. Pps is 6,580, the number of phytoliths present in this pellet is ca. 5,663,917.

This sample has a straightforward composition with Rondels standing out. The other morphotypes only hint at presence of leaves and culms. The interesting aspect of this sample is its high amount of Elongate dentates.

The number of silica skeletons is unfortunately too low for any interpretation.

Despite the fact that single cells are the only reliable source about the nature of the sample, the daybook yields more information. It states that the phytolith sample was collected very close to the base of the lot, where there were patches of ash and plaster debris. It is possible that this sample represented plaster pieces disintegrated into the soil.

5.2.2 Fiber Samples

Fiber samples were selected this thesis for a general assessment of their nature. Rather than quantitative data, qualitative data was acquired from them to supplement the quantitative data of the soil samples. These samples were also mounted non-permanently and they have not undergone the chemical extraction from soil. They were directly mounted.

5.2.2.1 KT 1224

According to the locus sheet, KT1224 was collected from OP. C Locus 32 and Lot 89, excavated in 1993. This sample was collected as a soil sample, yet there were enough visible white fibers for closer inspection. The sample was also recorded as ash/phytolith. This locus is actually part of a deep sounding rather than a trench. The sample is dated to LBA, Kinet period 13.1. For illustrations, see Appendix C, Fig. 35.

Under the microscope, it was confirmed that it contains phytoliths. Especially leaf/culm epidermis, leaf mesophyll, stomate from the leaf and vascular tissue were observed. There is no appearent trace of inflorescence.

5.2.2.2 KT 16018

This fiber sample was taken from the soil sample KT 16018, therefore it has the same context information as the soil sample.

There was a need to further analyze the fiber sample since it was crowded with silica skeletons upon first observation. This sample was permanently mounted twice unlike the other fiber samples. Again, unlike the other fiber samples, this sample was devoid of background noises such as clays or other minerals. It was a very pure sample. For illustrations, see Appendix C, Fig. 38.

Initial observations noted large silica skeletons. One silica skeleton is about 3 mm long (2933, 64 microns) and it is a *Juncus sp.* (rush) type of silica skeleton. Other than this, it is filled with leaf and culm type phytoliths. The presence of general grass culm and stomate silica skeletons indicates this perfectly.*Phragmites sp.* leaf phytoliths were also observed, based on the shape of stomata as well as the *Phragmites sp.* culm phytoliths. In addition, there are a few fragmented inflorescence phytoliths, possibly belonging to *Triticum sp.*.

This sample also contained visible single cells such as Rondels, Saddles, Bulliform flabellates and Acute bulbosus and other long single cells like Elongate entire and Elongate dentate. The Saddles were both found intact in the tissue and as single cells, together with Acute bulbosus morphotype phytoliths and also stacked Bulliform flabellates. According to Ramsey et al. (2016), this is a sign of leaves which grew in a wet environment where silica was readily available. More than one variant of Bulliform flabellates could be distinguished.

Therefore, it is confirmed that this sample contains a high amount of phytoliths and it is dominated by mostly leaf/culm types.

5.2.2.3 KT 19320

According to the locus sheet this sample was collected from OP. E/H Locus 410 and Lot 969, excavated in 2003. It is dated to MIA (Middle Iron Age) A, Kinet period 11. This sample was collected from a white circular area, perhaps the bottom of a pit. The daybook notes that it can be possibly straw. It is confirmed that this sample is indeed straw since grass culms and some stomate were observed in this sample. For illustrations, see Appendix C, Fig. 43.

5.2.2.4 KT 22760

According to the locus sheet this sample was collected from OP. M Locus 178 and Lot 364, excavated in 2005. The sample is dated to EBA II, Kinet period 25. There is root disturbance in this locus. The soil is reported as red and compact. This locus consists entirely of a mudbrick wall, 60 cm wide, which was preserved for a length of 2.2 m. The color of the soil is reddish since the mud brick is also reddish. This wall is identified as a fortification wall. For illustrations, see Appendix C, Fig. 45.

The photos available from this lot visibly prove that between the layers of mudbrick there was a white layer of phytoliths. It is thought by the excavators that these are the remaining phytoliths of reed mats put between the courses of mudbrick to strenghthen the fortification wall. The phytolith evidence from this sample shows primarily well preserved *Phragmites sp.* leaves and culms. It proves that this white layer's phytoliths are indeed from reeds. Their function

as a support is also very possible since reeds have big leaves and strong culms, making them a good candidate for this purpose.

5.2.2.5 KT 24791

According to the locus sheet sample KT 24791 was collected from OP. M Locus 285 and Lot 501, excavated in 2007. The sample is dated to EBA II, Kinet period 28. The soil is brown, soft and tough according to the sheet. This locus is a fill between two walls, hence it has a soft texture combined with a tough one since there are also mud brick falls. For illustration, see Appendix C, Fig. C46-c.

This sample did not yield numerous silica skeletons, however the identified ones are again mostly PHRAGMITES SP.. This is in coherence with the previous sample which was also coming from a mudbrick wall.

5.3 Statistical Analyses

After the data acquisition, some statistical analyses were performed to understand the overall picture of the assemblage. Mainly, box and whisker plots were used for visualization and Welch's t-test for understanding the variance in a deeper sense. In addition, Principle Component Analysis was applied to test the hypotheses introduced in previous chapters.

Box and whisker plots, or box plots, are a way to display batches of data. They show five values: the two extremes, the upper and lower hinges (quartiles) and

the median (McGill, Tukey, & Larsen, 1978). R Studio version Version 1.2.1335 was used to construct these plots. The ggplot2 package was especially useful.

T-tests compare the variances of two groups. There are different versions of t-tests. For this thesis, Welch's t-test was used because it was the built-in function in R Studio Version 1.2.1335. Welch's t-test is a two-sample location test, and it is an adaptation of Student's t-test. The samples are independent and assumed to have unequal variances or to be of different sizes. The other assumption is the same for Student's t-test, where the samples have normal distribution (Welch, 1947).

It should be disclosed here that these data can show different p-values for Welch's t-test and Student's t-test according to the observations. Also, it should be noted that some data did not follow a normal distribution (which means they are either skewed to the right or to the left), therefore to normalize the distribution their logarithms (base 10) were used (pers. comm., Francesco Carrer).

5.3.1 Statistical Analyses of Single Cells

Data should be grouped according to certain criteria to perform t-tests. The reason to perform t-tests is to detect variation between two groups. The presence of variance is proof that two groups of value are significantly different from each other. The difference in variance may point to further detection of pattern in the data. For this reason, different groups were subjected to t-tests with the

hope of detecting patterns that will yield to further discussion. P-value is of importance for t-tests, therefore the threshold for significance is the basis to dismiss or examine the sample further. The following t-tests did not yield significant results:

- *Counts in 1 gr of phytoliths: Pit vs Room*: The number of phytoliths were examined. Since the numbers were too high, they were normalized using their logarithms. P-value: 0.53 (Appendix A fig. 22)

- *Inflorescence: Pit vs Room*: ELONGATE DENDRITICS and ELONGATE DENTATES are the best way to understand the inflorescence composition. For this test, the total of two morphotypes were compared for pits and rooms, yet the results were indifferent in variance. P-value: 0.86 (Appendix A fig. 23)

- *Leaf: Room vs. Pit*: For this analysis, leaf phytoliths were defined as the total number of trapezoids, rondels, saddles, bilobates, crosses, polylobates, bulliform flabellates, blockys and crenates. P-value: 0.99 (Appendix A fig. 24)

- *Diatoms: Pit vs. Room*: The number of diatoms was subject to t-test. P-value: 0.38 (Appendix A fig. 25)

Unfortunately, these tests did not show any significance in variance. In addition to the t-tests, the box plots of each attempt did not show clear distinctions in data. It is entirely possible that different groups of data or different tests may yield significant results about single cell compositions.

Fortunately, some t-tests produced significant results. Phytoliths are especially useful for detecting the presence of C_3 and C_4 grasses. Interestingly, the Kinet samples clearly show different compositions for C_3 and C_4 grasses. The following t-tests and boxplots showed significant difference of variance, therefore they will be discussed in more detail.

5.3.1.1 Room C_3 vs C_4

As noted in the second chapter, grasses can be grouped as C_3 or C_4 according to their phytosynthetic pathways. This difference is also observable in their leaf morphology, hence their phytoliths can differ. It is possible to generalize the morphotypes found in C_3 and C_4 grasses. Panicoideae and Chloridoideae subfamilies are mostly C_4 Poaceae and they can be identified by Cross, Saddle and Bilobate short cells. Respectively, Panicoideae produce Bilobate [5] and Cross; Chloridoideae produce Saddle. On the other hand Pooideae C_3, are identified by Rondel, Trapezoid and Crenate cells (Böhme et al., 2017). For this analysis, the phytolith groups were summed and their variance were compared for the samples which are from room contexts.

The result is very significant. P-value is 0.002. Rondels are accounting for the bulk of C_3 sums. This could be due to the fact that only in rooms were *Juncus sp.* and *Cyperaceae sp.* present. In addition, research shows that mature leaves of *Phragmites australis* species show a leaf morphology close to the C_3 grasses (Srivastava, Kalra, & Naraian, 2014). Therefore, it is possible that some reed

[5] Bilobate are characteristic of Panicoidae but they can occur in Chloridoideae in addition to some Arundinoideae, Pooideae, and Bambusoideae (Böhme et al., 2017).

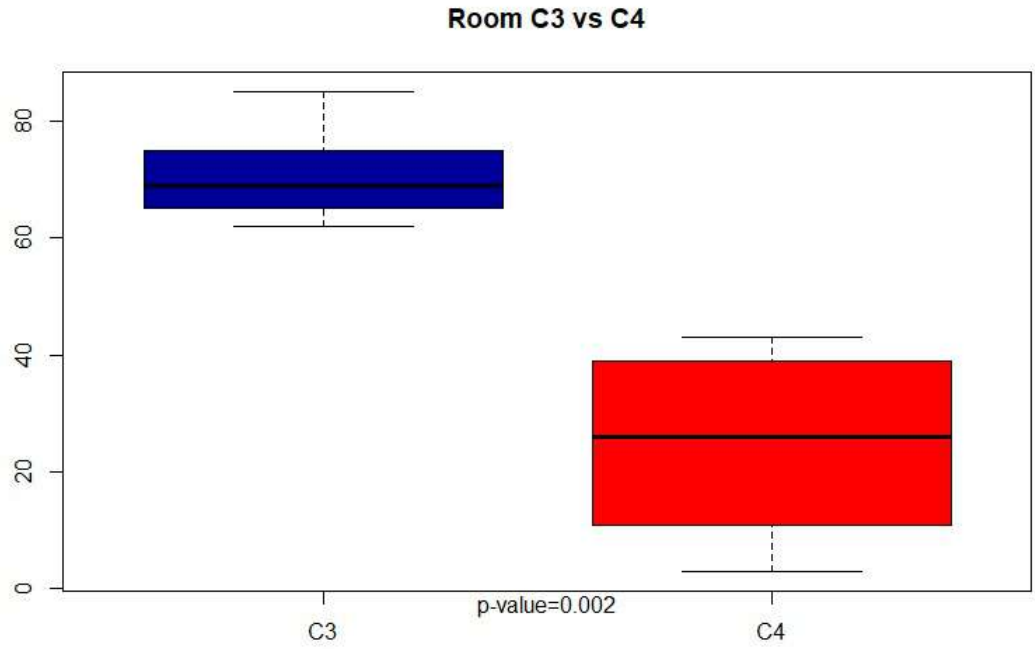


Figure 8: Room C_3 vs C_4

ecotypes have rondels. Sedges and rushes are under Poales order and explain the higher mean of C_3 types.

5.3.1.2 Pit C3 vs C4

This analysis was also performed in the same way as the room fills. The p-value is not necessarily significant (0.19), however it is worth exploring this analysis in detail.

At first, the t-test and the box plot suggest that pits also have a more abundant C_3 composition. However, it is probably due to what was stored in them rather than the linings. KT 21813 is the outlier, it is most probably from the pit lining itself and it has a significant C_4 signature. The other possibility is that in most

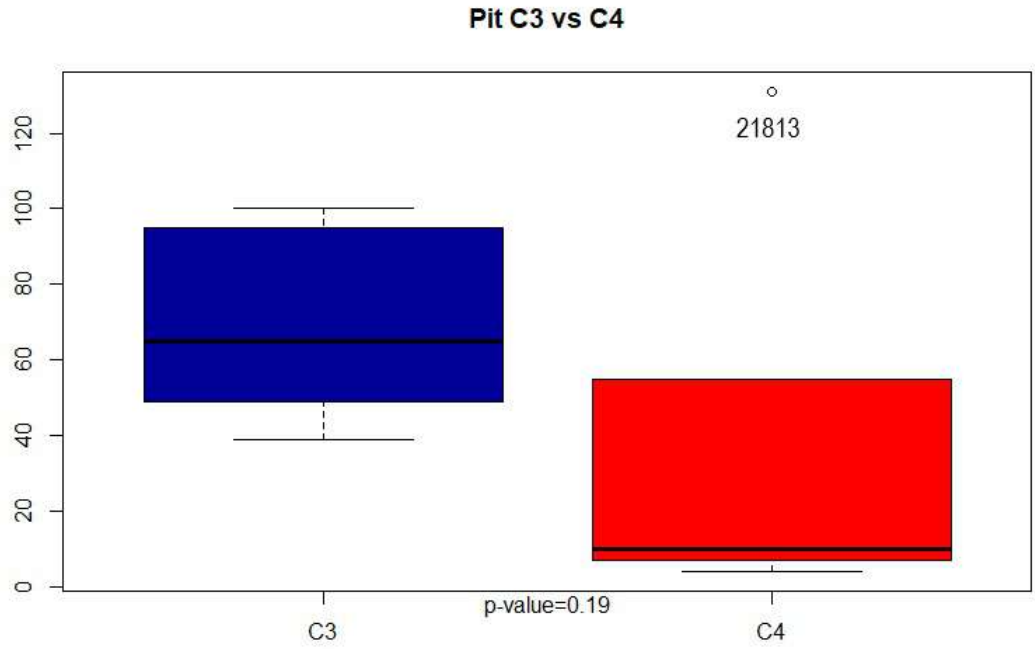


Figure 9: Pit C_3 vs C_4

of the pits, wheat and barley, in other words a C_3 crop was stored. However, this is not the case for KT 21813.

It should also be noted here that Rondels are found more abundantly than Saddles or other morphotypes that indicate a C_4 presence. Hence, it is not surprising that both of these analyses showed higher values for C_3 types. What is surprising here is that Kinet's past climate is not favorable for C_3 plants. Most probably, Kinet's ancient climate was also temperate and damp like the current climate. The high numbers of rondels, therefore C_3 plants, is probably a reflection of the anthropogenic selection rather than the presence of wild flora.

5.3.2 Statistical Analyses of Silica Skeletons

For silica skeleton statistical analyses, the idea is the same as for the single cell ones. The groups were straightforward for the silica skeletons since they are direct evidence for inflorescence or leaves/culms. However, these t-tests did not yield significant results:

- *Silica Skeleton Inflorescence Room vs Pit*: P-value: 0.41 (Appendix A fig. 26)
- *Silica Skeleton Leaf/Culm Room vs. Pit*: P-value: 0.31 (Appendix A fig. 27)

Silica skeleton taphonomy room vs. pit is the only analysis that yielded a result close to a significant result but it is still not very robust (0.21). It seems that the silica skeletons found in rooms were somewhat more taphonomized than in pits. This is mostly related to overly used acids or clay aggregations. Also, since these taphonomical issues are related to physical attributes, it is possible that room silica skeletons were initially bigger than the ones found in the pits, therefore they were more prone to taphonomical effects.

The taphonomy pie chart suggests that the silica skeleton assemblage was especially taphonomized (about 27%). The taphonomical problem encountered most often is chemical attack, with clay aggregation coming second. (Appendix A fig. 28)

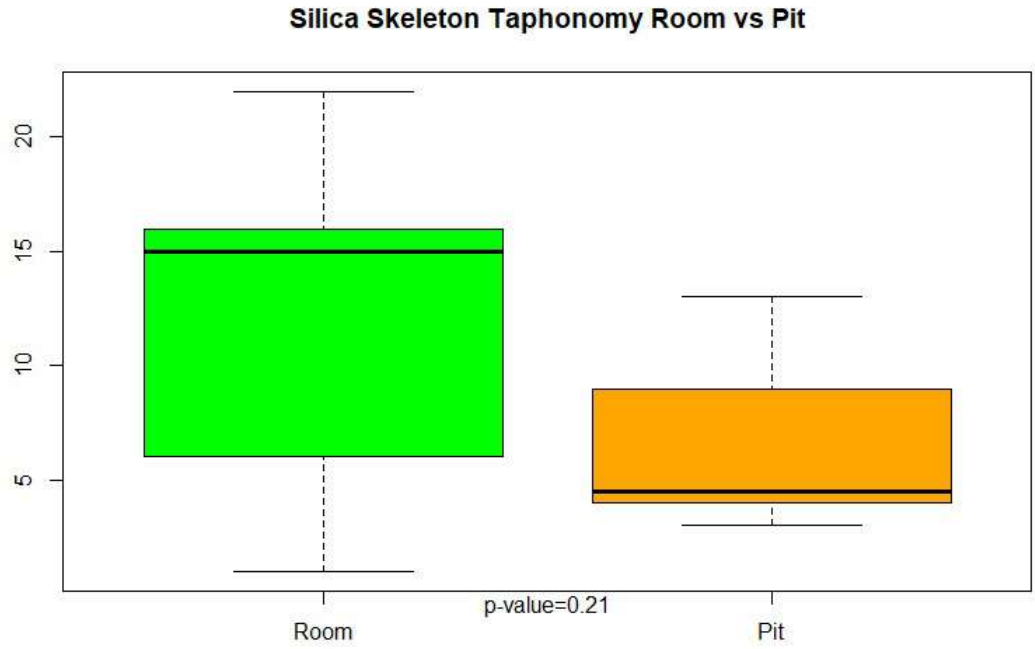


Figure 10: Silica skeleton taphonomy room vs. pit

5.3.3 PCA

Principle Component Analysis (PCA) is another multivariate analysis used in this thesis. The main idea of PCA is to reduce the dimensions of a data set which has numerous interrelated variables while maintaining the variation. For this, a new set of variables called principle components (PCs) are acquired through transformation, so that the PCs are not correlated directly (Jolliffe, 2002).

For this thesis, the variables are the morphotypes. Since there were at most 18 variables, the best way to visualize them and their variance was to apply PCA. By reducing the variables into two PCs or two dimensions, the variance was

more visible for comparison and certain groupings or the lack of it were accurately visualized in a diagram.

5.3.3.1 Contextual

As mentioned before, PCA is a great tool to visualize complex data. For this thesis, one of the main questions is about the contextual differences. PCA was applied to the data to see if there is a difference of variance between the morphotypes observed in pit fills and room fills. This analysis was able to capture 56.2% of the total variance.

Results clearly show that there are no significant groupings between the pit and room assemblages. This could be due to the fact that the pits had leaf linings which would contribute to the assemblages. Considering ÈSAG pits studied by Fairbairn and Omura (2005), it is known that pits have plant lining or plaster tempered with plants can affect this result significantly. In addition, Wright, Fairbairn, Üstünkaya, and Faith (2017) also found no significant grouping between the pits and room fills in their research about anthracological signatures.

The only interesting point here is feature 8, sample KT 25166, which is almost like an outlier. The same sample is also an outlier for the other PCA about the chronological groupings. Upon closer inspection, the only outstanding morphotype of 25166 is *Elongate dentate*. These single, long cells can be found in the leaves as well as inflorescence of grasses. Therefore, it is not possible to comment further about their presence.

It is very likely that this analysis would have yielded better groupings if the feature (or sample) number were higher than 11.

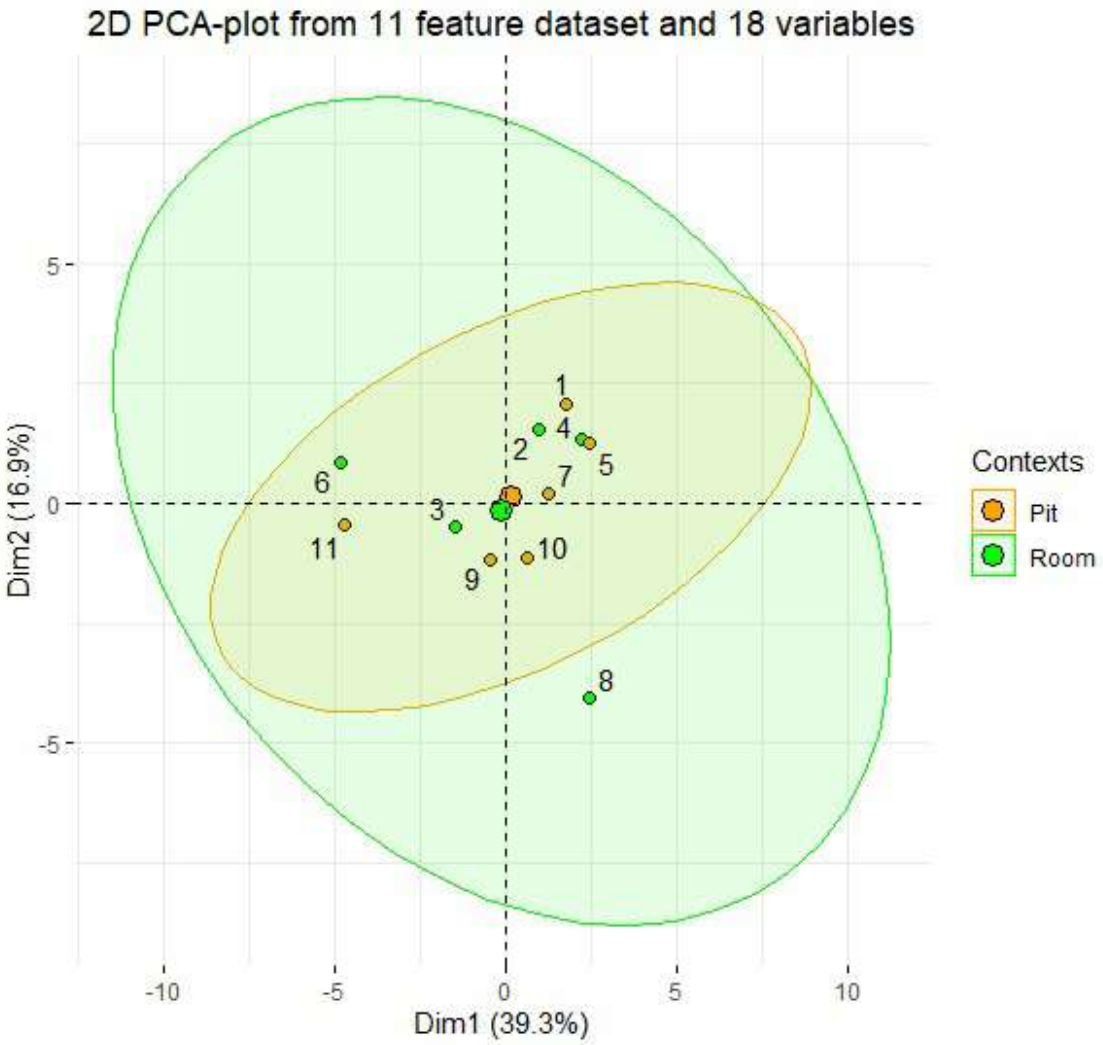


Figure 11: PCA of rooms vs. pits

5.3.3.2 Chronology

Another important question for this thesis was to understand if phytolith compositions were changing in time. Samples were grouped as "Bronze Age" and "Iron Age" according to their dating information. PCA was applied to see whether these groups had different variances. This analysis was able to capture

59.8% of the total variance.

For this analysis sample KT 17530 was left out deliberately due to the fact that it is the only sample from the Medieval era, therefore its representation is not significant. This PCA was performed with 10 features.

This analysis has yielded interesting results. The Iron Age and Bronze Age samples show overlapping groups Feature 8 and 6, respectively KT 25166 and KT 24674, have the profiles defining the Bronze Age samples. Unlike with textual analysis, it is possible to say that the phytolith assemblage profiles of those two periods are actually varying. It is intriguing that again feature 8 is almost an outlier.

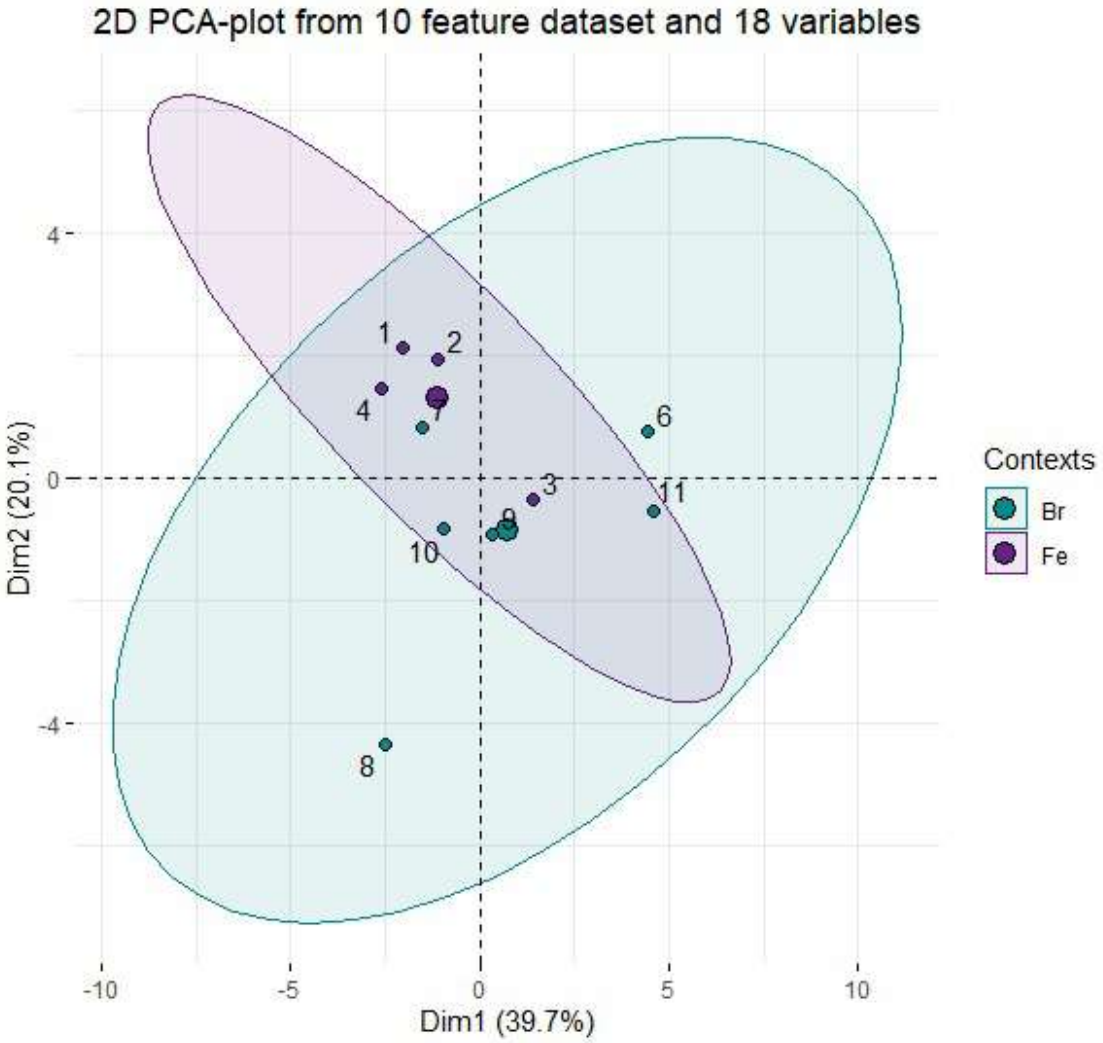


Figure 12: PCA of Bronze Age vs. Iron Age

CHAPTER 6

3D RECONSTRUCTIONS OF THE KİNET HÖYÜK PHYTOLITHS

As seen in previous chapters, phytoliths are part of the plant tissue and are formed after the intracellular or extracellular matrix was filled with SiO_2. These microfossils are generally observed under a light microscope, because light microscopes are more accessible compared to other types, such as SEM (scanning electron microscopes). However, light microscope pictures taken with the help of portable or built-in cameras cannot capture the three-dimensional nature of phytoliths since the images are always two-dimensional. Therefore, the need to further visualize the three-dimensional nature of phytoliths should be explored.

Because phytoliths are essentially cells infused with silica over time, they have a shape similar to their parent tissue. In contrast to the fiber samples, however, phytoliths are not opaque: they have a refractive index ranging from 1.41 to 1.7 (Piperno, 2006: 15). This is the most crucial characteristic of phytoliths which enables them to be observed under the light microscope. However light microscope images are observable as planes, therefore the phytoliths can only be assessed based on their two-dimensional images.

This is essential, since the phytolith sample under the microscope is being viewed lying in many different positions and from many angles. To improve visual recognition of individual phytoliths, 3-D digital renditions of the various morphotypes would offer a powerful reference tool. The capabilities of this visualization project are illustrated here by 6 digitally recreated morphotypes which can be rotated and viewed from multiple angles. These artistic renditions are based on scientific drawings and pictures taken by light and scanning electron microscopes. They do not take account of the morphometric studies.

6.1 Methods

The preparation for this task began with extensive research. Various pictures from different articles and books were gathered to have a better grasp of the 3-D shapes of the available morphotypes. The morphotype selection was based on their presence in the Kinet Höyük phytolith assemblages and the published phytolith illustrations comparison availability.

Sources used for creating the illustrations were: Rossouw, Stynder, and Haarhof (2009) for 2-D photos of a saddle morphotype which reflects its overall shape and shadows; Zuo et al. (2017) for SEM photos reflecting Bulliform flabellate morphotype; Rashid, Mir, Zurro, Dar, and Reshi (2019) for many SEM pictures of morphotypes; Madella et al. (2005) for their overall shapes; Ball et al. (2019) for further descriptions of morphotypes and several pictures; Kaplan et al. (1992) for Elongate dendritic and Crenate morphotypes; Lu and Liu (2003) for Rondel morphotype drawings and pictures; Fredlund and

Tieszen (1994) for several drawings to comprehend the 3-D shapes and some base drawings.

As the first step of the process dough models of the selected morphotypes were made, to see the overall shape in a solid form and to aid the 3-D reconstruction methodology. The primary computer program used to illustrate the 3-D solid structure was Autodesk Fusion 360 (2.0.6231 Student Version). The primary step for illustrating the solid structures was to create a base drawing of the phytolith morphotype in question. More layers were then added to it and the solid shape was formed using the appropriate method of shape completion. A general procedure applicable to 3-D illustrations of all types of morphotypes could not be formulated since the solid illustrations were created intuitively.

After this step, the solid illustrations were saved as .skp files for so that they could be viewed in the SketchUp Viewer (Version 19.1.174). These files are easy to distribute because SketchUp Viewer is an open source and accessible computer program to view the 3-D shapes instantly.

The finished solid shape was opened in Autodesk 3ds Max 2017 (19.0 Student Version). With the help of this program, the morphotypes were filled with the suitable texture that can reflect the nature of material better. According to Faick and Finn (1931), SiO_2 glasses can have a refraction index from approximately 1.49 to 1.52. It is established that phytoliths have a similar refraction index, therefore the primary assumption for the texture of phytoliths were based on glass textures. Weathering details were applied through additional textures. Appropriate lighting for 3-D shapes was also added to highlight the overall

shape and significant decorations on morphotypes. The solid illustrations with proper lighting and texture were rendered and the output was sent to Adobe Photoshop® CS3 Extended (Version 10.0) for post-production. This program provided details like a contrasting background and additional brightness/contrast modifications to highlight the morphotype's overall shape.

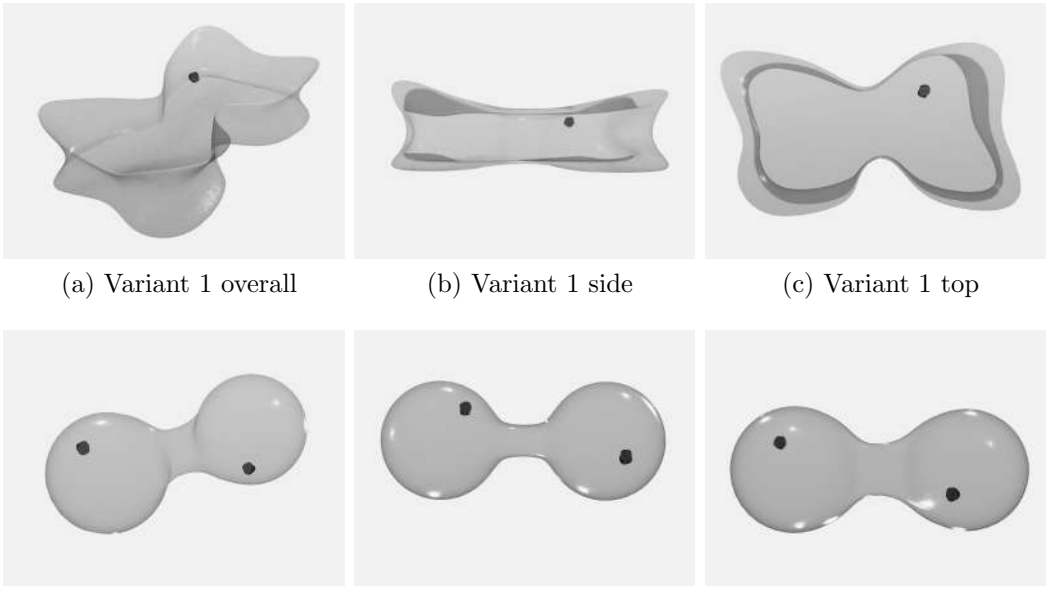
6.2 Results

In general, the produced pictures are satisfactory enough to provide a better understanding of the overall shape, texture and some morphological changes of these six phytolith models. The only reservation concerns the carbon occlusion pockets, which can be understood as "black dots". These pockets are not in fact black matter. Close inspection under the microscope, shows that they resemble trapped air bubbles rather than black, compact dots. This distinction is crucial for trapezoids since their morphotypical assessment includes carbon occlusion pockets (Ball et al., 2019).

Bilobate

For the Bilobate morphotype, two variations were produced. Variant 1 is observed in Kinet Höyük phytolith samples (see Appendix B, Fig. 29); Variant 2 was not observed. Bilobates are especially important for morphological assesments since their variables identify the subfamily of the original plant (Lu & Liu, 2003a). Bilobates are only found in the leaves (Ball et al., 2019).

Bulliform flabellate



(a) Variant 1 overall (b) Variant 1 side (c) Variant 1 top

(d) Variant 2 overall (e) Variant 2 top (f) Variant 2 side

Figure 13: Bilobate variants and their 3-D illustrations.

Bulliform flabellates are very specialized cells thet are only found in leaves. They help the movement of leaves by swelling. In the Kinet Höyük phytolith samples, the illustrated variant and other variants were observed. However, bulliform cells don't give specific information except for some studied species. (See Appendix B, Fig. 30 for Kinet Höyük examples.)

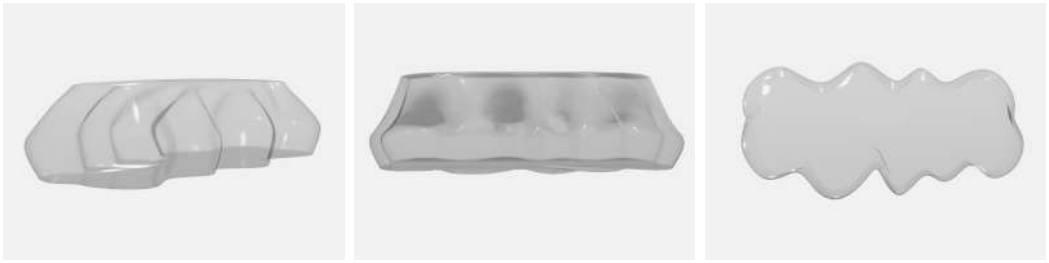
(a) Overall (b) Side (c) Top

Figure 14: Bulliform flabellate 3-D illustrations.

Crenate

This morphotype is observed in the Kinet assemblage, however due to its very fractal nature it is hard to capture a coherent variant of this morphotype.

Therefore the 3-D reconstruction of this morphotype depended heavily on artistic interpretations. In addition, the carbon occlusion pockets were not depicted, however they are present [1]. (See Appendix B, Fig. 31 for Kinet Höyük examples.)



(a) Overall (b) Side (c) Top

Figure 15: CRENATE 3-D illustrations.

ELONGATE DENDRITIC

ELONGATE DENDRITIC phytoliths were essential for this thesis since they are mostly produced in the inflorescence of grasses. This morphotype is difficult to capture fully since it has minute dendritic structures which are easily lost in taphonomic processes or mechanical disturbance. In the 3-D reconstructions the basic shape is captured well. ELONGATE DENDRITIC phytoliths were observed in the Kinet Höyük assemblage in nearly all of the samples. Some specimens were intact, therefore an accurate artistic reconstruction was possible for the overall shape. A Kinet Höyük phytolith served as a base for this reconstruction. For the presence of a cylindrical body, ICPN 2.0 description was used (Ball et al., 2019). Due to technical problems, this morphotype was entirely modeled in Autodesk 3ds Max 2017 (19.0 Student Version). (See Appendix B, Fig. 32 for Kinet Höyük examples.)

[1] For 2-d pictures and comparison, consult to ICPN 2.0, section "Crenate".

(a) Overall (b) Side (c) Top

Figure 16: Elongate dendritic 3-D illustrations. Notice the protuberance at the center in the side view.

Rondel

This morphotype was our very first attempt to model a phytolith in 3-D. The overall shape is consistent with the 2-D images acquired from the Kinet Höyük phytolith microscope photographs. Due to the highly variable nature of Rondels, the image is a general reconstruction showing the basic characteristics of rondels. However, as noted before, the black dot is not depicted correctly and will need revisions. It will be possible to fully summarize the rondel variants observed in Kinet Höyük assemblage in a more detailed study. (See Appendix B, Fig. 33 for Kinet Höyük examples.)

(a) Overall (b) Side (c) Top

Figure 17: Rondel 3-D illustrations.

Saddle

This morphotype was the initial reason for creating volumetric illustrations.

Due to their small size and shape, their identification under the microscope posed problems. For this study, two variants of SADDLE morphotype were reconstructed. Both of them occur in Kinet Höyük assemblage. The first variant is named "short saddle" and the second variant is named "long saddle". Although they may seem like two different morphotypes at first, they are variants of the same morphotype. These reconstructions are based on Fredlund and Tieszen (1994)'s drawings. (See Appendix B, Fig. 34 for Kinet Höyük examples.)

(a) Variant 1 overall (b) Variant 1 side (c) Variant 1 top

(d) Variant 2 overall (e) Variant 2 top (f) Variant 2 side

Figure 18: SADDLE variants and their 3-D illustrations.

6.2.1 Overall Conclusions

These 3-D models were created to help the researchers, especially newcomers to this field, to grasp the 3-D structure of phytoliths. Initially, phytoliths can be perceived as two-dimensional particles. This approach neglects the overall shape of phytoliths and impedes the researcher from thinking in 3-D. These models

can be used for self-educational purposes as well as educating the groups of students. As the next step for this initiative, more morphotypes will be modeled. Even so, the morphometric data can be implemented for accurate models.

CHAPTER 7

CONCLUSION

This thesis was initially planned to conduct a qualitative analysis rather than a quantitative one. However, in the couse of this project a quantitative study became a more rewarding option with the results by supported with statistical analyses.

The Kinet Höyük soil samples are the results of an undoubtedly uncommon practice. The excavators were aware of the importance of phytolith samples and collected scientific soil samples whenever they deemed necessary. Therefore, this project was possible even years after the excavation was finished. The only encountered problem with sample locations was because this thesis was conducted after the excavation was finished, the excavation logs and pictures were the only source to locate the exact spots of the samples. It was not possible to examine the site itself during the project. Nevertheless, the information collected in excavation was extremely helpful for exploring the archaeological contexts of the samples.

For this thesis, sample-wise there were two major problems. The first is that

sample size was small and did not allow for pattern detection. The second problem was they were collected during the excavation and most of the samples are secondary fills. Bearing these in mind, it is still possible to say that they produced interesting results. This thesis fulfills the aim to answer several questions previously mentioned and even draws attention to other archaeobotanical questions.

7.1 Questions

The initial three questions were about chronology, the room functions and the contextual differences between storage pits and rooms. There are certain answers or possibilities provided for each question. In addition, there are other topics that emerged during the closer inspection of samples.

7.1.1 Room Functions

One of the initial questions for this thesis to shed more light on the functions of rooms. It was possible to learn more about the grass presence in rooms as much as the samples allowed. In this thesis, it is observed that the rooms yield much more information about the possible uses of reeds in domestic life. The phytolith evidence is a great proxy to reveal more about the possible uses of reed, instead of relying on secondary information.

One example is sample KT 16018. The white layers indicate weaving of leaves. This sample is clearly not from a basket since there were no impressions of a

basket on the soil. Most probably, the white matting found in this sample was a part of the building's roofing, however it is not clear that this roofing system was permanent or not. Even in modern day houses, reeds continue to be used as roofing material. The presence of culms and leaves show that this may be the case for the Middle Iron Age buildings as well. The environment of Kinet is well suited for collection of reeds since it was located on the estuary of a river. Similarly, Kinet's environment is still marshy like the ancient times.

In another example, phytoliths can give us more idea about the room function combined with other finds like bones. Sample KT 17530 is a clear instance of this for a Medieval building. Combined with the cow mandible found on the sampled surface, it can be proposed that this context was similar to a barn. The phytolith evidence suggested that inflorescence, leaf and culms of grasses were present. The most parsimonious explanation is that they were from the straw placed on floor and the animal food. Through phytoliths, it is possible to learn more about the room functions.

7.1.2 Storage Pits vs. Room Deposits

As the initial assumption, it was thought that storage pits would have different compositions from room fills. Even more, it was assumed that the pits would yield more inflorescence phytoliths than the room deposits. However, these assumptions were shown to be invalid on the basis of the available samples. In fact, the two soil samples that were eliminated because of insufficient phytolith counts (KT 12678 and KT 17043) were both from trash pits.

Statistical analysis of phytoliths from the full range of soil samples showed no contextual difference. Their leaf and inflorescence compositions are more or less the same. The PCA results and other t-tests cohere with this statistically. This result may be relate to pit linings. The pit linings were documented previously in different publications and by other proxies (Fairbairn & Omura, 2005). In addition to this one difference stood out as significant: the lined and plastered pits recorded different phytolith signatures. This is the case for samples KT 21813, which is a lined bell-shaped pit, and KT 22678, which has direct evidence of plastered pit lining. Their phytolith compositions are widely different. Due to small number of samples it is not possible to fully establish a pattern, but the results can be proposed as a working hypothesis.

It should be noted here that with better sampling methods, it is possible to learn more about the grains stored in any pit. The phytoliths may be especially helpful if there are no charred seeds left in the pits. This thesis also succeeded in demonstrating this possibility. The results of C_3 vs. C_4 comparisons also hint at this, especially for pits. There is no direct archaeobotanical research for most of the pits mentioned in this study, however the overall phytolith composition of the pits show that there are C_3 plants in those contexts. This is an indirect evidence of possible cereal storage in those pits.

7.1.3 Chronology

At the initial stages of this thesis, a major question about phytoliths concerned the long chronology of Kinet Höyük and how the phytolith assemblage reflected

the long occupational history of the settlement. At first, a chronological approach to the samples was thought to be not possible. The main reason for this was the samples were not consecutively collected from a few select loci in a chronological manner. However, the bulk of samples were divided into two main ages, the Bronze Age and the Iron Age. It is still not possible to clearly distinguish the two ages based on a small and non-consecutive sample group, however the PCA was able to detect some preliminary results about this question. It should be also noted that the ages lasted for more than a few centuries, therefore these results can only superficially indicate change in time.

Interestingly, there is a considerable overlapping yet distinct grouping of Bronze Age and Iron Age samples. The possible reasons could be the reflection of Bronze Age climatic changes, cultural preferences changing in time and human agency.

The relationship between humankind and environment is a mutualistic relationship, therefore the changes or disruption in one system can visibly affect the other one. As Weiner (2012) noted, the collapse in the Late Bronze Age coincided with draught between two eras, which is a significant ecological change. Nevertheless, there is no solid evidence that the drought was a main reason for the change in the phytolith assemblage of Kinet Höyük between these ages.

It is not possible to detect a pattern on the use of reeds in a chronological context, however there are some indications. The Bronze Age samples show that reeds were utilized in the Bronze Age as a part of fortification walls. Because

there are no fortification walls dated to the Iron Age, it is not possible to comment on the continuity of using reeds in this context. In the Iron Age, reed phytoliths were only encountered in enclosed rooms. It is evident that reeds were still used, however there is no clear shift in one direction. Therefore, the use of reeds does not account for the observed chronological changes.

If the environment is not a major explanation for the changes in the Bronze Age and the Iron Age, another possible explanation can be human agency. As the chronology of Kinet suggests, different cultural groups have occupied the settlement or even re-settled in the area throughout its history. This may suggest that different groups had different habits about plant consumption and use, therefore their phytolith signatures could be different. It is more possible that this is the case in Kinet rather than environmental agents.

According to the archaeobotanical investigations, a change between the Late Bronze Age and the Iron Age is evident with raising numbers of glume chaffs found in the assemblages (Harding, 2019). However, she notes that this does not necessarily imply the climatic changes, cultural preferences may play a major role as well. The phytolith evidence from silica skeletons also support this idea since most of the identifiable inflorescence phytoliths are coming from the Iron Age samples. There are only a few inflorescence phytoliths from the Bronze Age samples and they were not assessed as a crop plant like wheat or barley, unlike the Iron Age samples.

7.1.4 Presence of Inflorescence Phytoliths

Initially, the presence of inflorescence phytoliths was not a surprising result of this project by itself since grasses produce more phytoliths in their inflorescence than their leaves or culms (Tsartsidou et al., 2007). Also, previous research shows that phytoliths are rarely found in grains (Tsartsidou et al., 2007), therefore inflorescence phytoliths are generally produced in other anatomical parts like palea and lemma, or simply called glumes or chaffs. However, as the archaeobotanical evidence suggested Kinet samples were not populated with glumes or chaffs. Therefore, the sheer presence of inflorescence phytoliths is intriguing.

As established before, Kinet has more of a "consumer" profile than an agricultural producer based on the archaeobotanical evidence. The archaeobotanical samples suggest a small collection of charred glumes. In this thesis, there is evidence to support this idea. Harding (2019) notes that in contrast to the Bronze Age samples, more glumes were found in the Iron Age samples. It is possible that by solely focusing on the inflorescence phytoliths, more can be understood about the storage practices and what types of wheat (hulled or naked) were mostly stored in the pits. However, the small sample size and the lack of a physical reference collection limited these inquiries.

7.1.5 Concluding Remarks

Overall, this thesis achieved to answer most of the questions it concerned. Additionally, it was a project which demonstrates the power of phytoliths, or the shortcomings of this proxy, fairly well. The preliminary results of this thesis is satisfactory enough to further examine the other available samples for a more accurate picture of Kinet Höyük. This thesis also contributes to the current research about phytoliths in Anatolia and especially reveals more insights about the daily life in Bronze Age and Iron Age Kinet.

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APPENDIX A

Charts

These figures are the general single cell composition of each individual sample. The codes are assigned to the morphotypes according to the suggestion of ICPN 2.0. In addition, "DIA" stands for diatoms, "S_SPI" stands for sponge spicules.

Table 6: The table of the samples used for this thesis

Kinet No	OP	Lot	Locus	Type	Period	Context	Munsell Color
8506	97 A II	199	321	phytolith	LFe/7	pit fill	10 YR 7/1 - Light gray
12678	99 D	175	444	ash	MFe/8	trash deposits, late in Period 8	10 YR 6/2 - Light brownish gray
13105	99 D	183	472	ash	MFe/8	room floor	10 YR 6/1 - Gray
16018	02 EH	278	634	phytolith	MFe/8	surface deposit, EH room 278 of Assyr blg, Middle Iron Age	10 YR 6/1 - Gray
16348	02 EH	278	682	phytolith	MFe/8	surface deposit, EH room 278 of Assyr blg, Middle Iron Age	10 YR 6/1 - Gray
17043	02 EH	332	757	phytolith	MFe/9	contents of EH pit 332, Middle Iron Age	10 YR 6/1 - Gray
17530	03 G	21	43	ash	Medieval/1	pit	10 YR 7/1 - Light gray
18966	03 M	84	128	phytolith	MB I/18	pit	10 YR 6/2 - Light brownish gray
21813	05 M	137	312	phytolith	MB I/18	pit	10 YR 6/1 - Gray
22764	05 M	190	302	phytolith	EB III/23	pit	10 YR 6/1 - Gray
24308	07 EH	619	1515	phytolith	LB/14	pit	10 YR 6/1 - Gray
24674	07 M	281	493	phytolith	EB II/27	room deposit	10 YR 6/1 - Gray
25166	07 M	304	545	phytolith	EB II/28	room deposit	10 YR 6/1 - Gray

Table 7: The single cell count of the samples

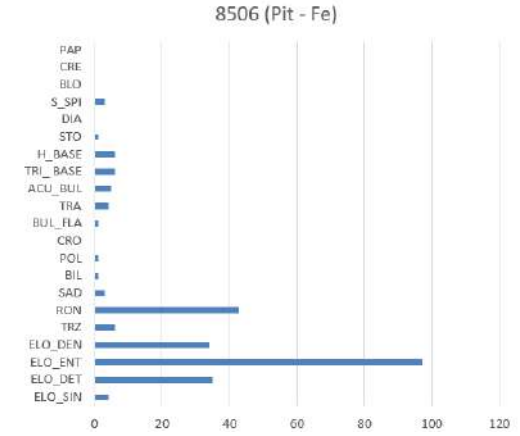
Slide No	Columns	E. sinuate	E. dentate	E. entire	E. dendritic	Trapezoid	Rondel	Saddle	Bilobate	Polylobate	Cross	Bulliform fl.	Vascular cell	Acute bulbosus	Trichome base	Hair base	Stomate	Diatoms	S. Spicules	Blocky	Crenate	Papillae
8506	2.25	4	35	97	34	6	43	3	1	1	0	1	4	5	6	6	1	0	3	0	0	0
13105	1.7	11	33	71	46	7	55	22	4	0	0	3	4	4	1	3	0	0	1	0	0	0
16018	0.285	15	23	57	2	5	50	31	11	0	1	21	4	5	1	0	0	1	17	23	10	2
16348	0.342	8	43	97	46	0	71	7	3	1	1	1	2	3	6	5	1	0	0	2	3	1
17530	1.2	23	30	71	65	2	34	3	3	1	1	2	1	6	14	10	1	0	1	3	3	5
24674	1.83	12	5	56	16	8	64	27	8	1	4	40	2	24	3	1	5	7	2	37	12	2
24308	2	27	14	108	29	5	83	9	1	0	1	1	1	2	0	2	0	10	9	10	7	3
25166	1.2	31	70	84	16	2	45	3	0	0	0	1	4	8	10	0	0	1	0	1	22	15
18966	1.07	27	28	69	43	4	57	42	11	1	2	8	3	8	2	0	0	20	1	8	19	3
22764	0.541	12	53	91	12	7	74	9	0	1	0	3	5	9	4	0	0	1	7	13	19	2
21813	0.5	7	19	60	17	5	34	66	61	13	4	12	1	21	1	0	1	0	1	19	11	4

Table 8: The single cell taphonomy count of the samples

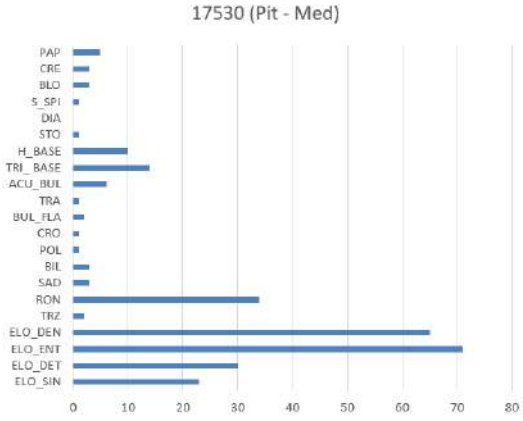
Slide No	EC_Taph	EE_Taph	EP_Taph	DEN_Taph	TRA_Taph	RON_Taph	SAD_Taph	BIL_Taph	POLY_Taph	CRO_Taph	BUL_Taph	VC_Taph	PRI_Taph	TB_Taph	HB_Taph	STO_Taph	Stacked Bul.	MCTotal	PhytTotal	TaphTotal
8506	2	4	27	22	1	0	0	0	2	0	0	0	0	1	0	0	0	59	247	59
13105	0	3	7	33	1	1	0	3	1	0	0	2	0	7	3	0	0	65	264	61
16018	2	6	8	0	0	0	0	3	0	0	1	0	0	0	0	0	4	53	261	20
16348	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	53	301	5
17530	8	1	10	12	3	0	0	0	0	0	0	0	0	1	0	0	0	44	278	35
24674	4	1	5	6	0	0	0	4	0	0	3	0	0	0	0	0	0	45	327	23
24308	4	1	11	6	1	0	0	1	1	0	0	0	0	0	0	0	1	6	303	25
25166	3	3	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	2	312	15
18966	3	1	0	12	0	0	0	2	0	0	0	0	0	0	0	0	0	10	335	18
22764	7	4	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	6	314	17
21813	11	11	36	1	1	0	1	16	1	2	2	0	0	0	0	0	0	6	356	82

Table 9: The silica skeleton count of the samples

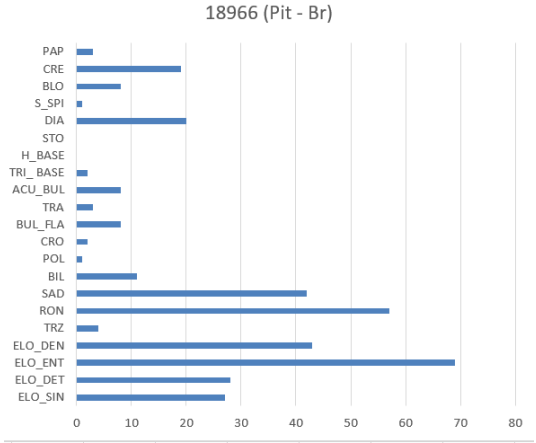
Slide No	Morphotype	Count
8506	Grass Inflorescence	7
8506	Grass Leaf/Culm	46
8506	Unknown	5
8506	Woody	1
13105	Grass Inflorescence	14
13105	Grass Leaf/Culm	37
13105	Unknown	14
16018	Grass Inflorescence	5
16018	Grass Leaf/Culm	32
16018	Unknown	16
16348	Grass Inflorescence	36
16348	Grass Leaf/Culm	16
16348	Unknown	1
17530	Grass Inflorescence	11
17530	Grass Leaf/Culm	30
17530	Unknown	3
18966	Grass Inflorescence	7
18966	Grass Leaf/Culm	3
21813	Grass Inflorescence	3
21813	Grass Leaf/Culm	3
22764	Grass Inflorescence	3
22764	Grass Leaf/Culm	3
24308	Grass Inflorescence	1
24308	Grass Leaf/Culm	8
24308	Unknown	1
24674	Grass Inflorescence	1
24674	Grass Leaf/Culm	47
24674	Unknown	3
25166	Grass Inflorescence	1
25166	Grass Leaf/Culm	1



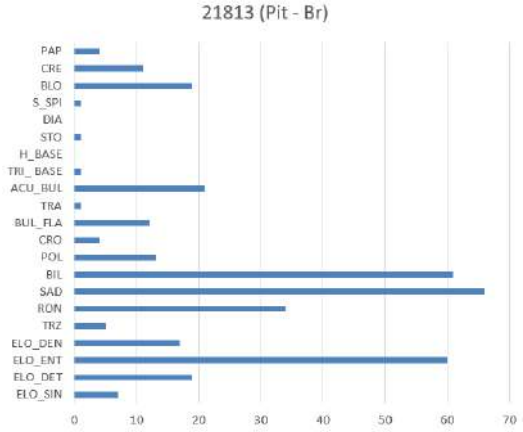
(a) 8506



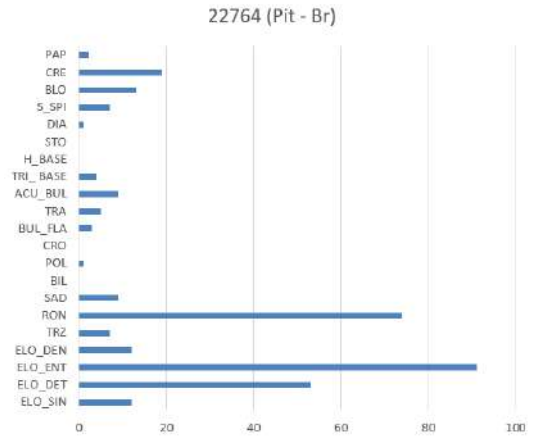
(b) 17530



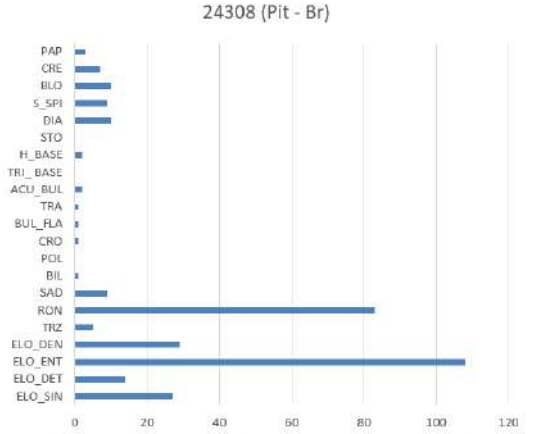
(c) 18966



(d) 21813

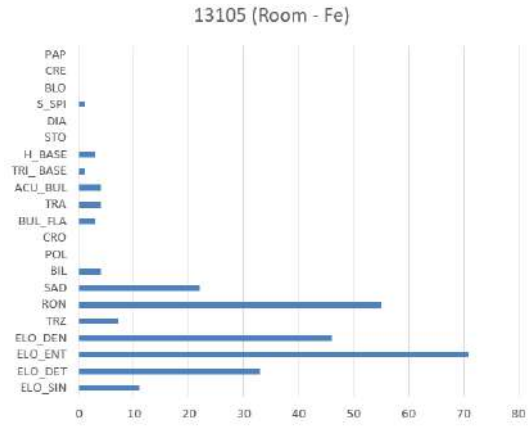


(e) 22674

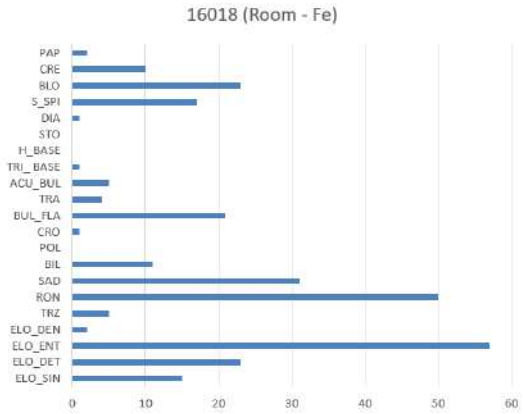


(f) 24308

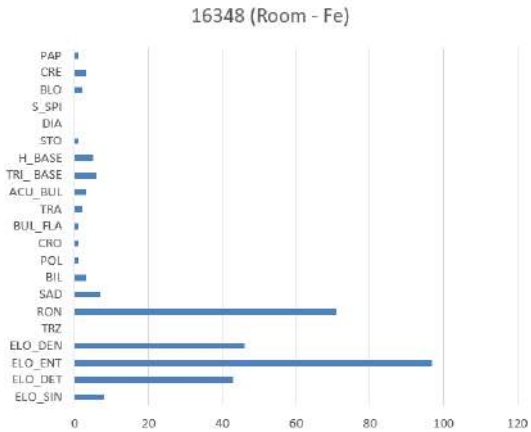
Figure 19: Pits



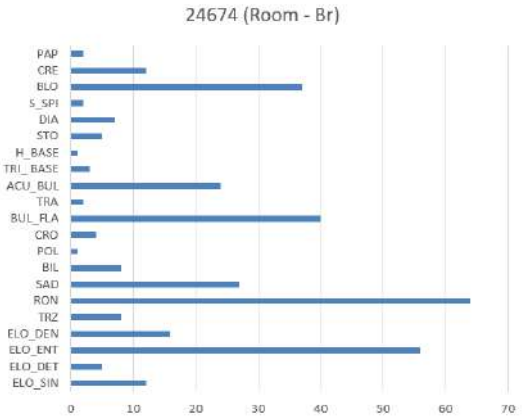
(a) 13105



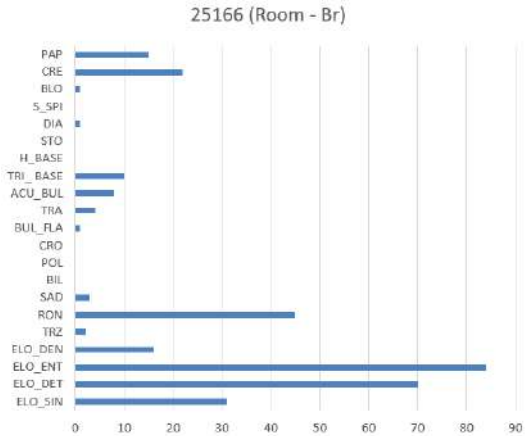
(b) 16018



(c) 16348



(d) 24674



(e) 25166

Figure 20: Rooms

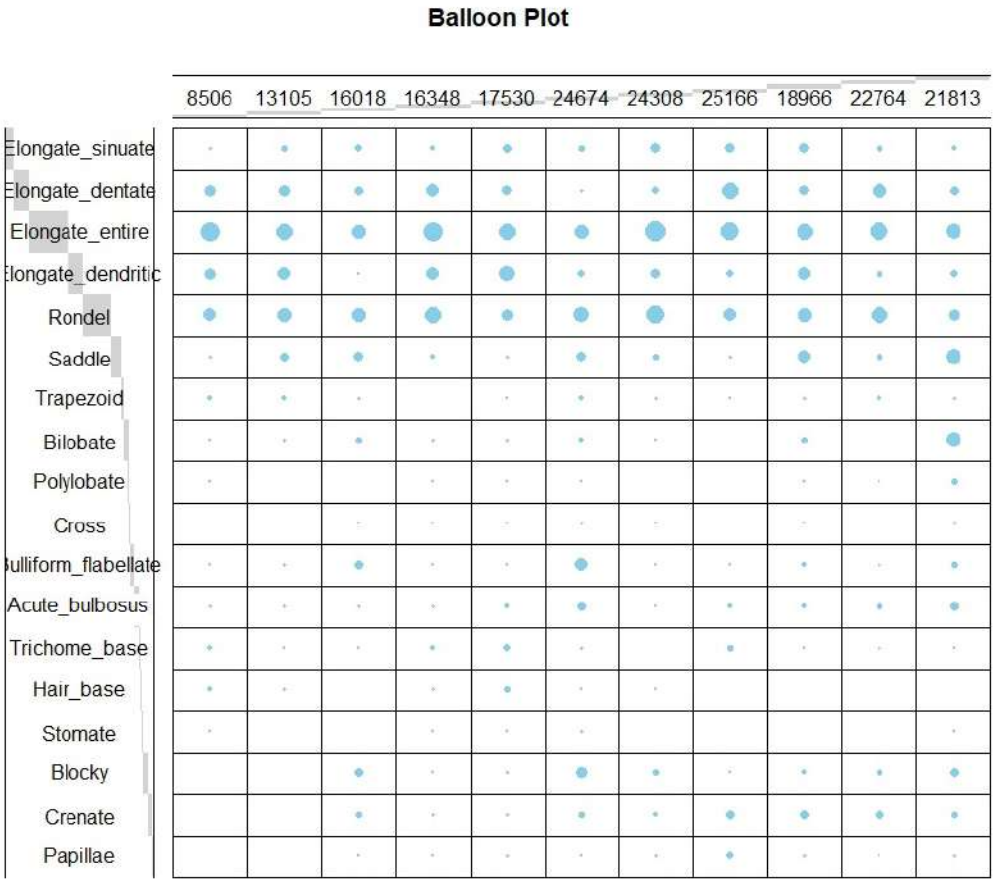


Figure 21: Balloon plot

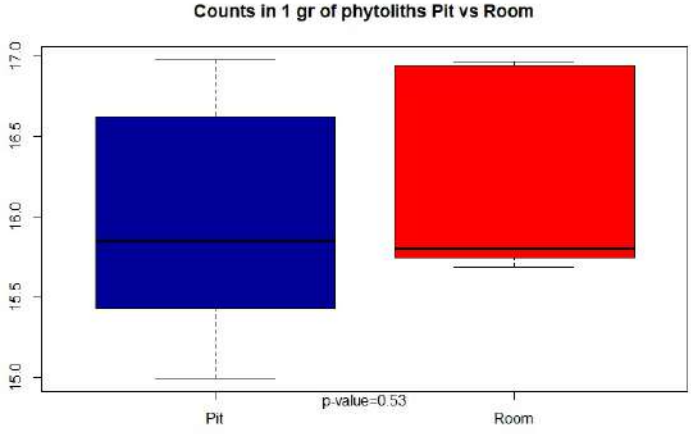


Figure 22: Counts in 1 gr of phytoliths: Pit vs Room

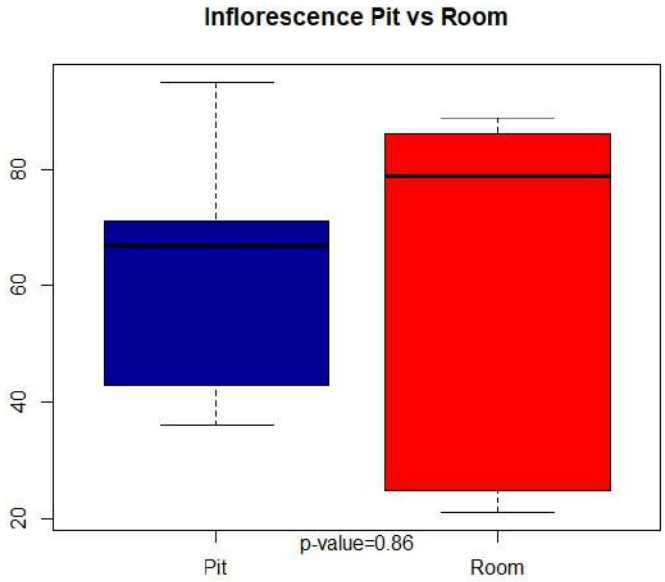


Figure 23: Inflorescence: Pit vs Room

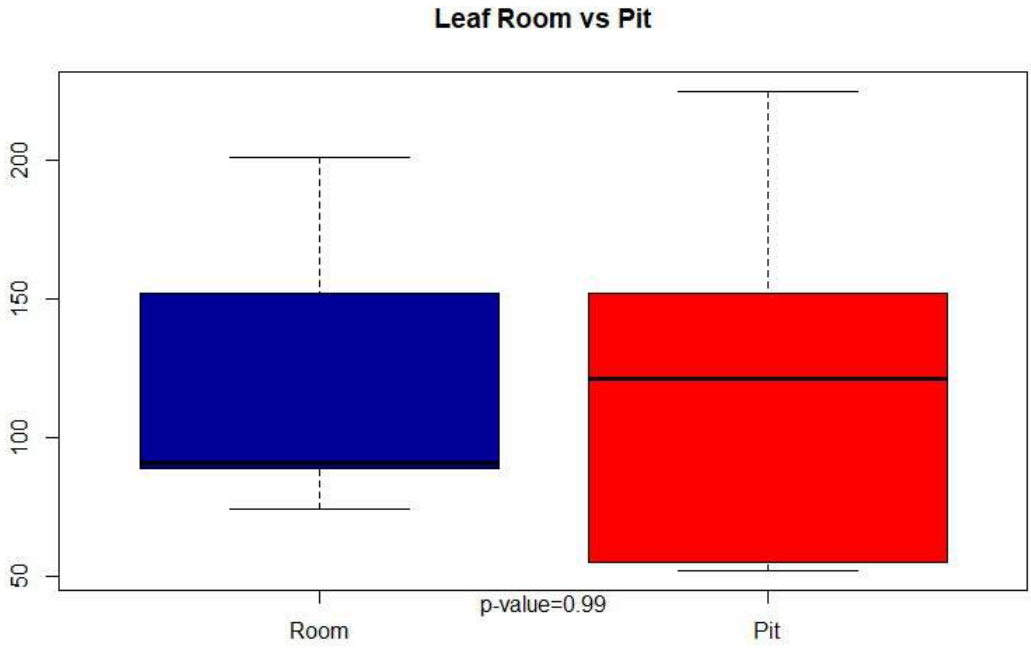


Figure 24: Leaf: Room vs. Pit

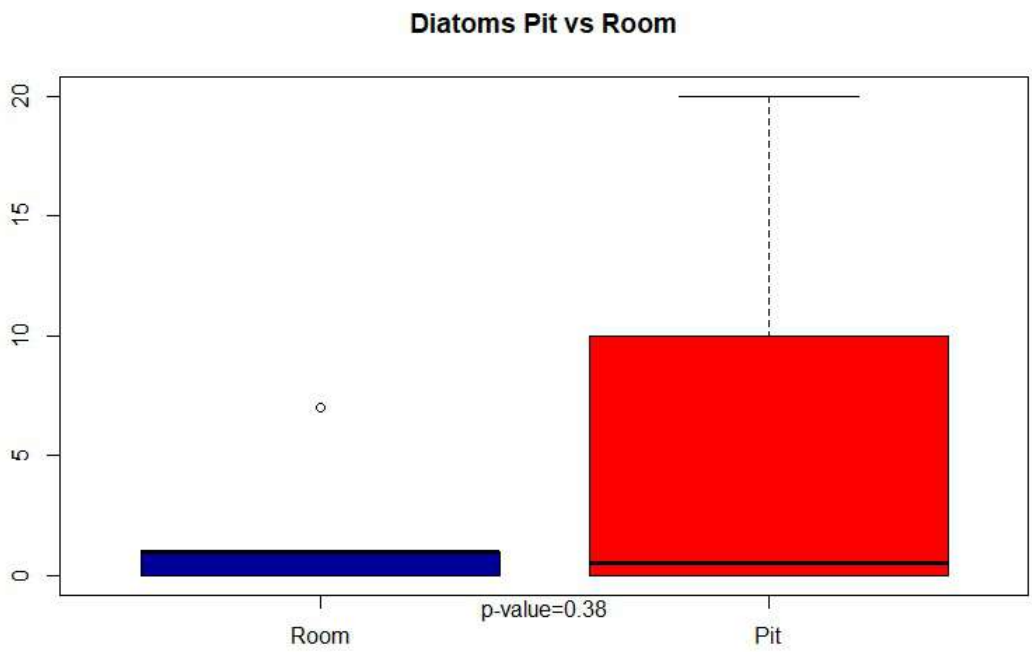


Figure 25: Diatoms: Room vs. Pit

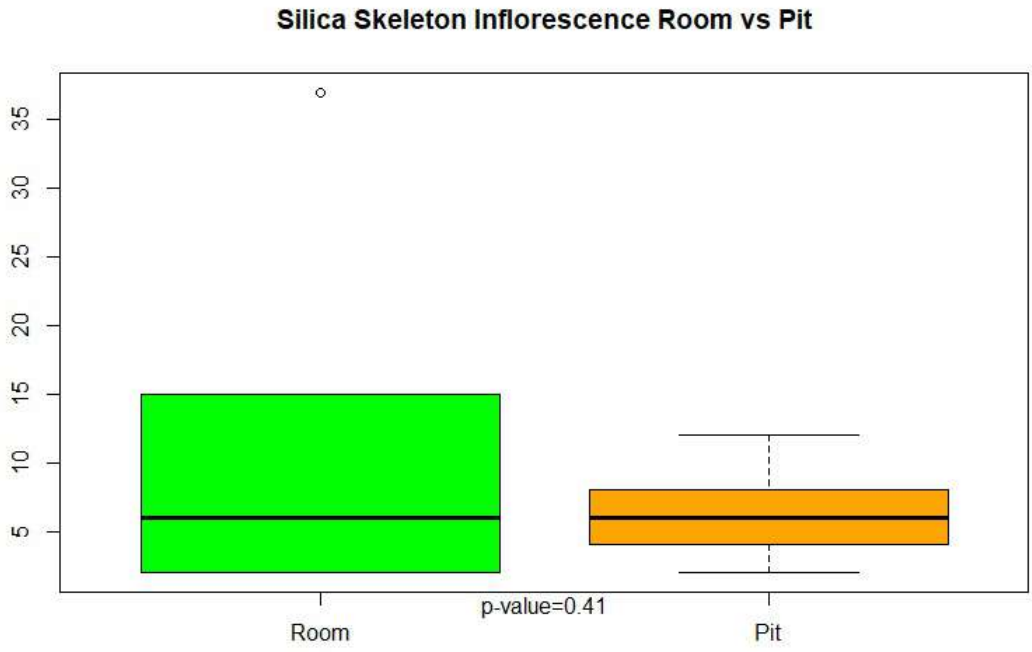


Figure 26: Silica Skeleton Inflorescence Room vs Pit

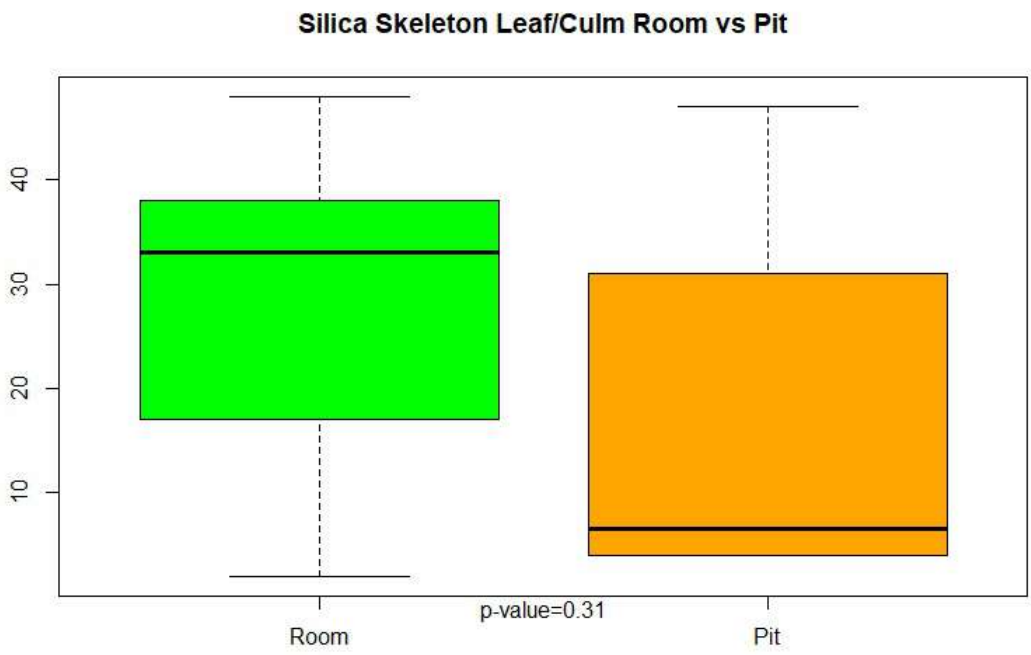


Figure 27: Silica Skeleton Leaf/Culm Room vs. Pit

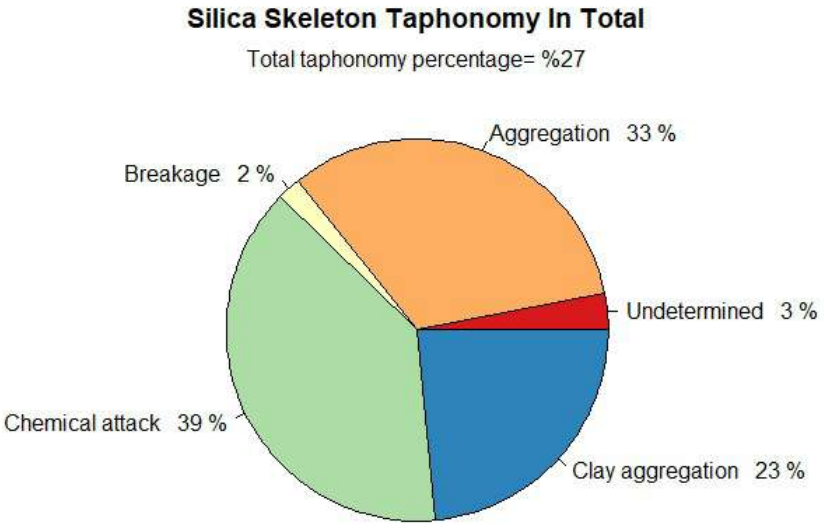
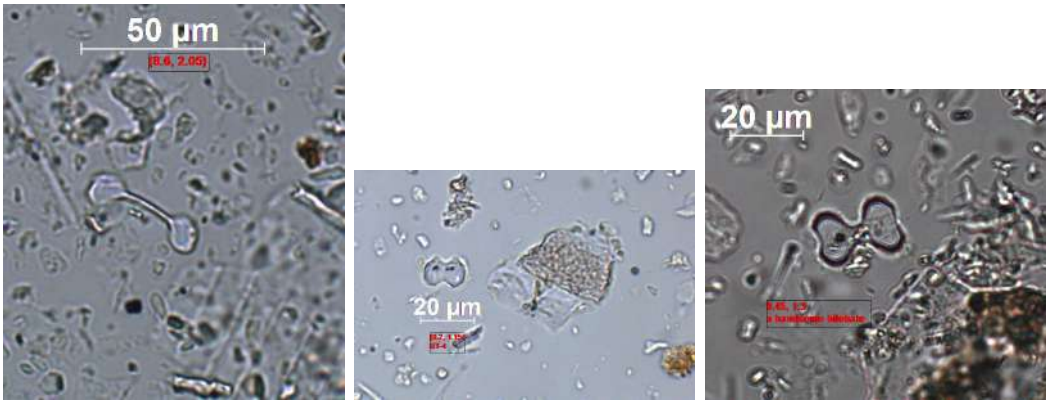


Figure 28: Silica Skeleton Taphonomy Total

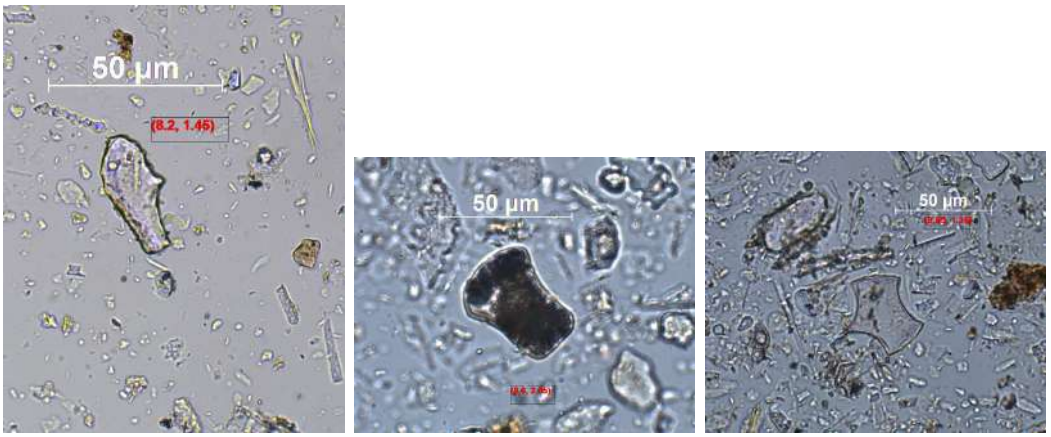
APPENDIX B

Kinet Höyük Phytolith Photos For 3-D Models



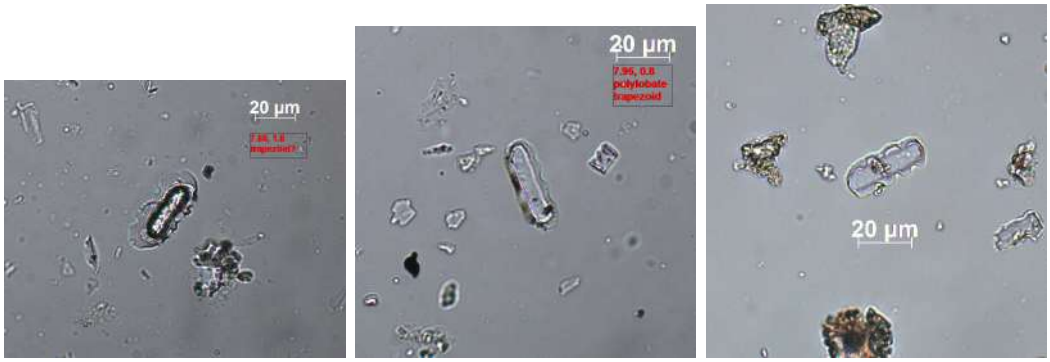
(a) From sample KT 13105 (b) From sample KT 13105 (c) From sample KT 16018

Figure 29: BILOBATE morphotype and variants. Magnification varies, scale bars are included.



(a) From sample KT 13105 (b) From sample KT 13105 (c) From sample KT 13105

Figure 30: BULLIFORM FLABELLATE morphotype and variants. Magnification varies, scale bars are included.



(a) From sample KT 8506 (b) From sample KT 8506 (c) From sample KT 21813

Figure 31: CRENATE morphotype and variants. Magnification varies, scale bars are included.

(a) From sample KT 8506 (b) From sample KT 8506 (c) From sample KT 8506

Figure 32: ELONGATE DENDRITIC morphotype and variants. Magnification varies, scale bars are included.

(a) From sample KT 8506 (b) From sample KT 8506 (c) From sample KT 8506

Figure 33: RONDEL morphotype and variants. Magnification varies, scale bars are included.

(a) From sample KT 16018 (b) From sample KT 21813 (c) From sample KT 8506

Figure 34: SADDLE morphotype and variants. Magnification varies, scale bars are included.

APPENDIX C

Kinet Höyük Phytolith Photos of the Samples

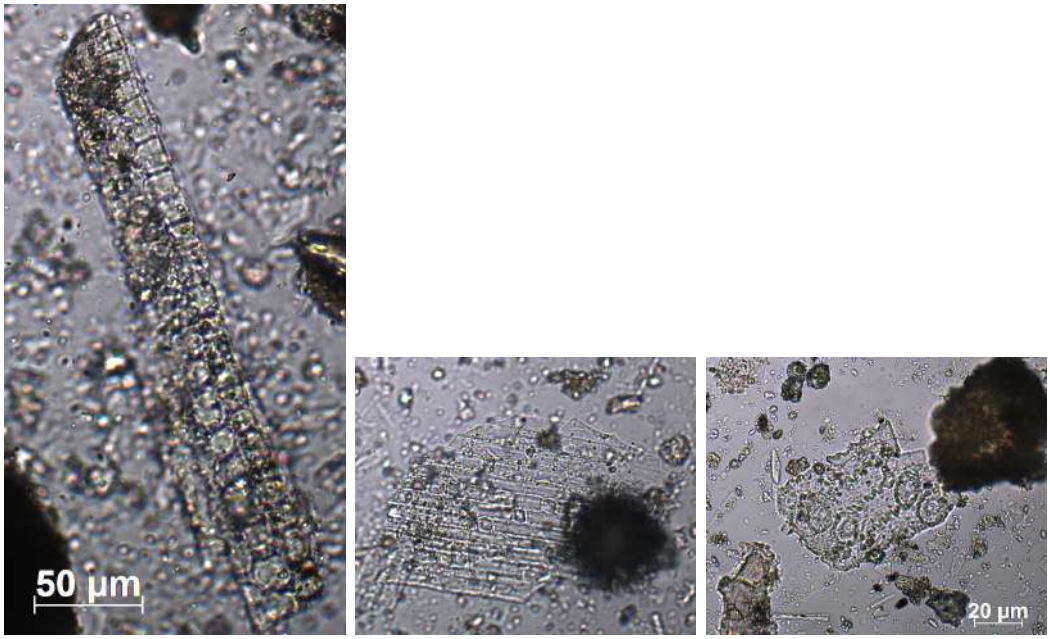


Figure 35: Select photos from fiber sample KT 1224

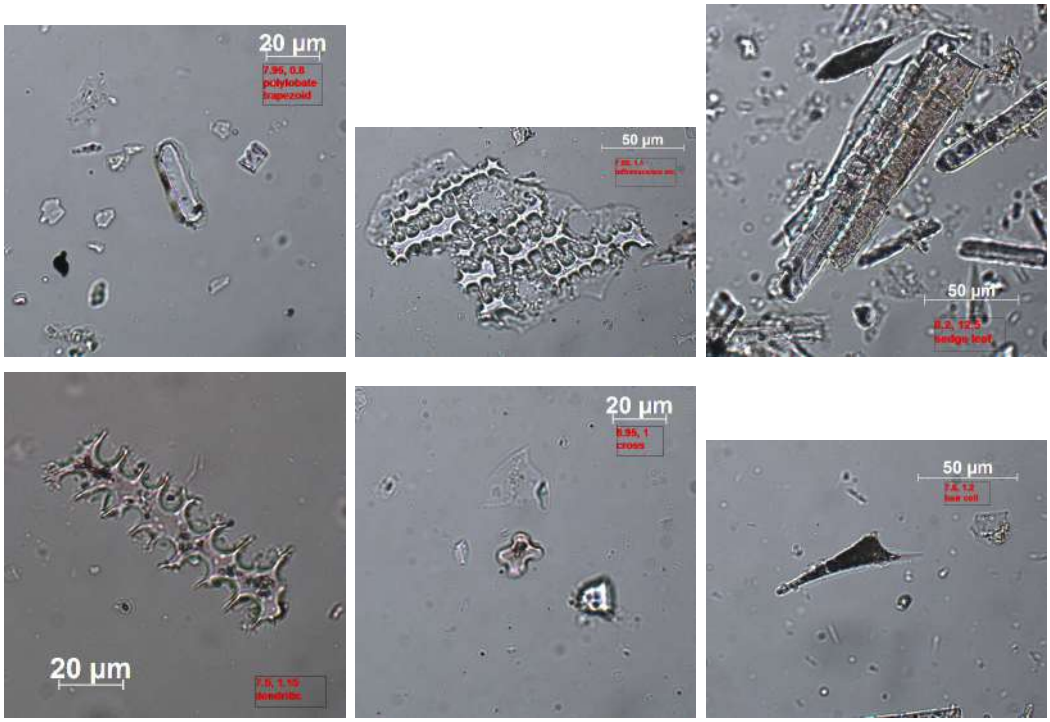


Figure 36: Select photos from soil sample KT 8506

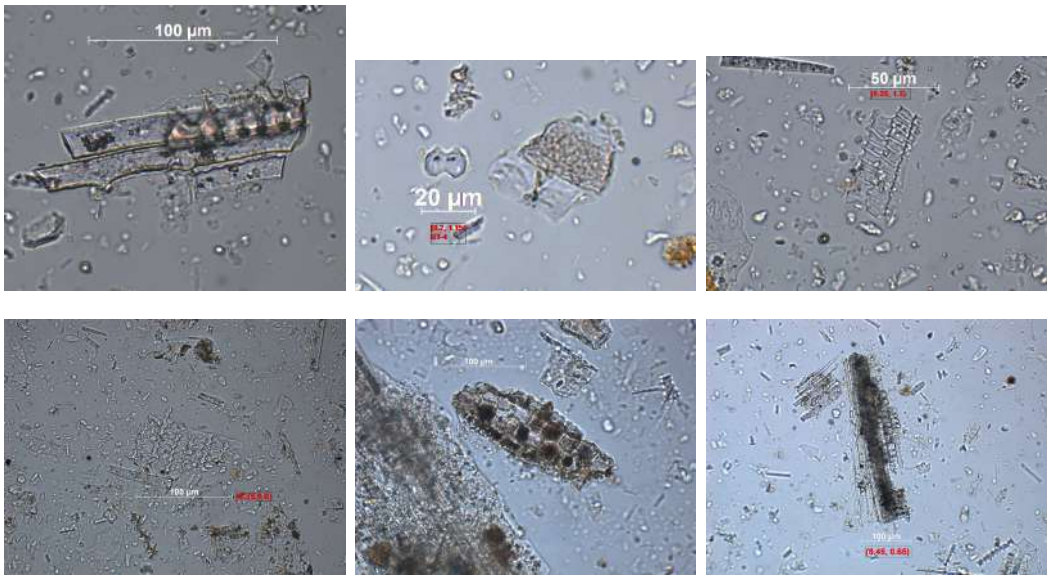


Figure 37: Select photos from soil sample KT 13105

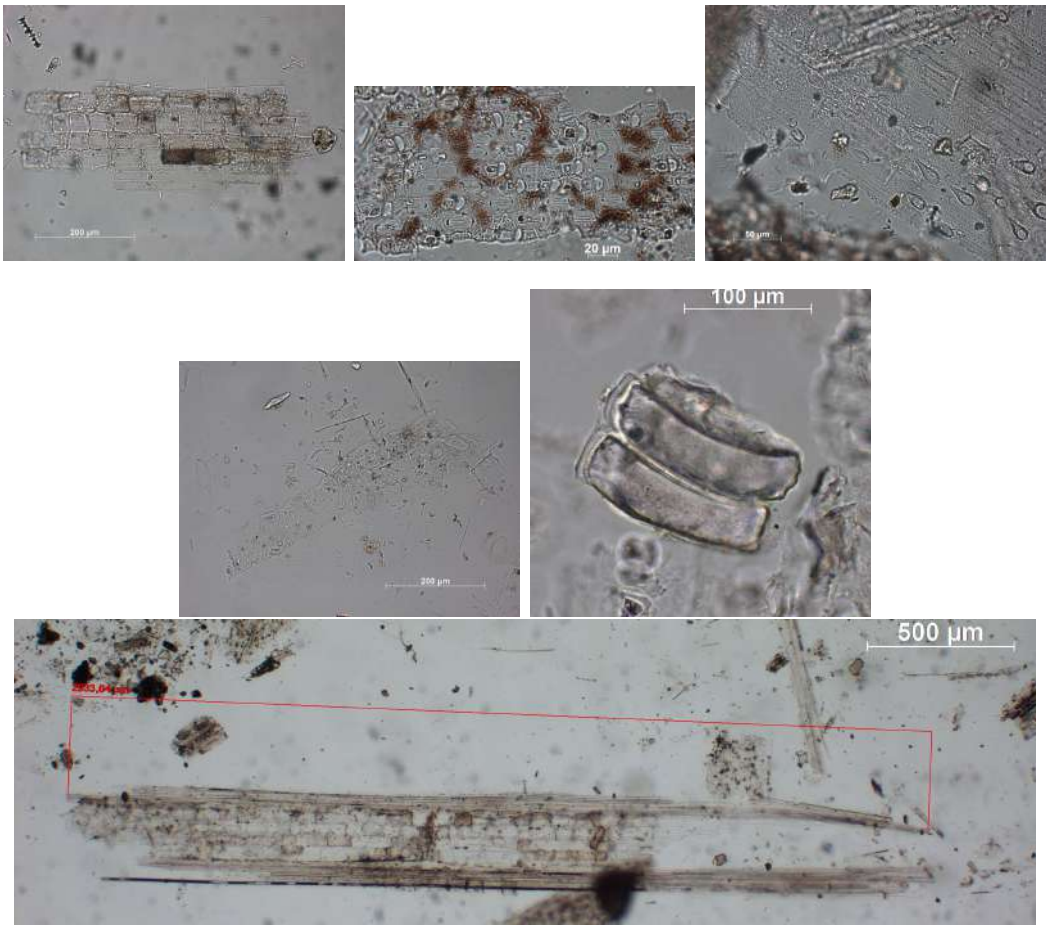


Figure 38: Select photos from fiber sample KT 16018

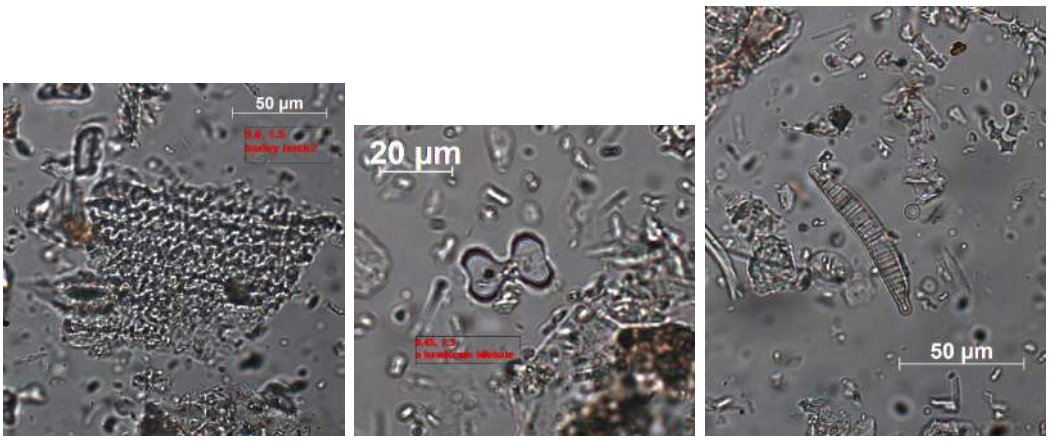


Figure 39: Select photos from soil sample KT 16018

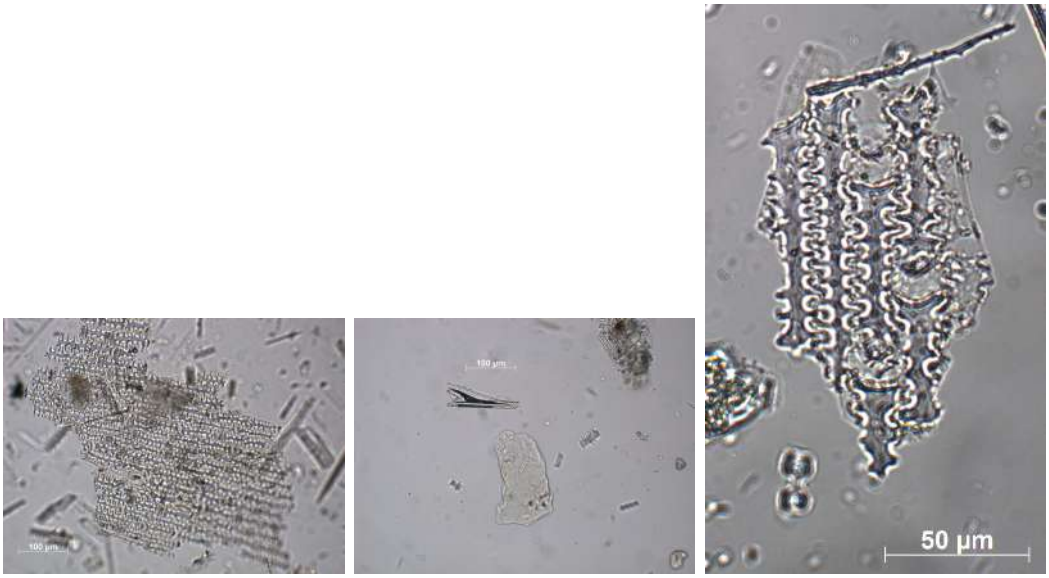


Figure 40: Select photos from soil sample KT 16348

Figure 41: Select photos from soil sample KT 17530

Figure 42: Select photos from soil sample KT 18966

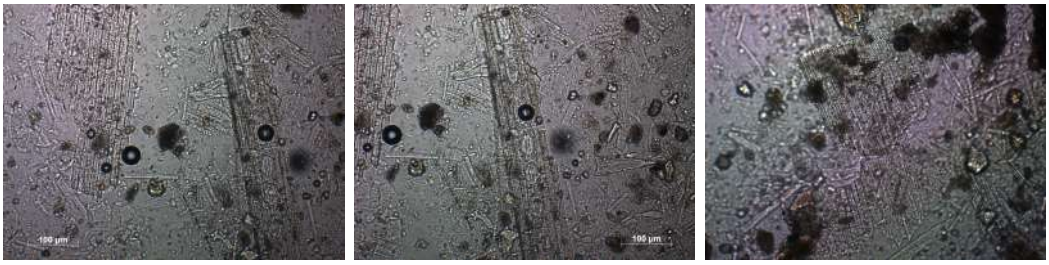


Figure 43: Select photos from fiber sample KT 19320

Figure 44: Select photos from soil sample KT 21813

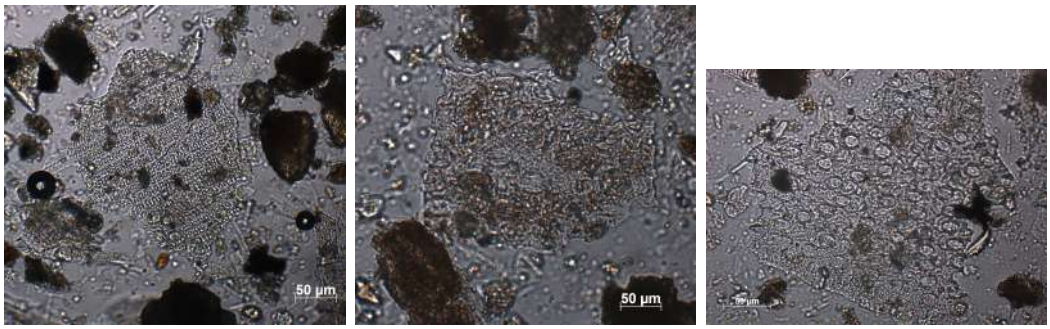
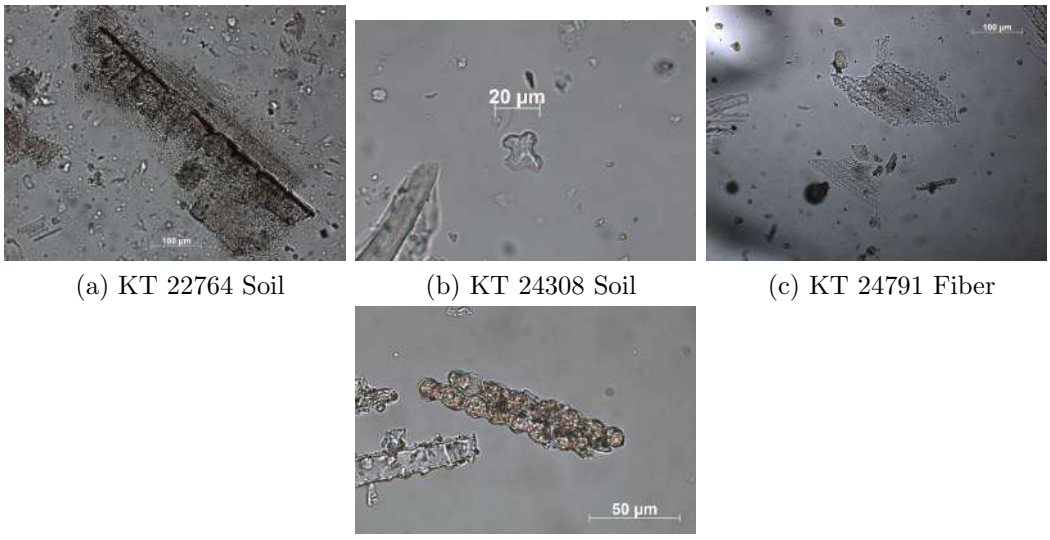


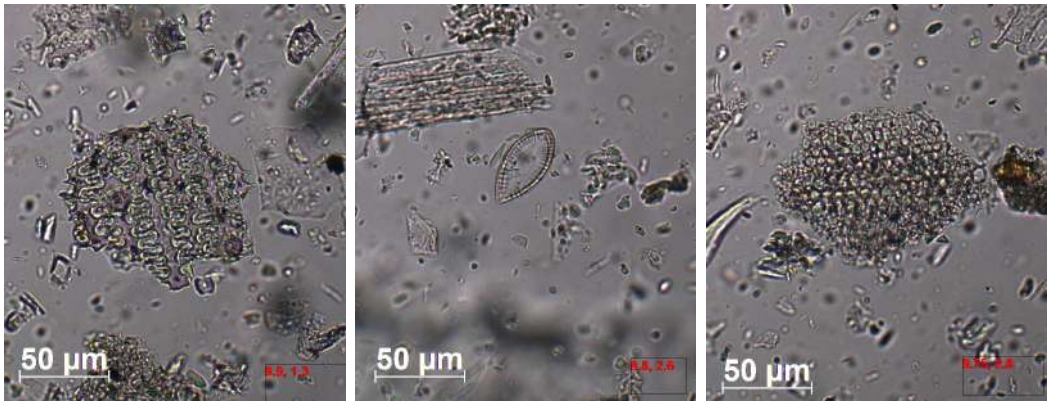
Figure 45: Select photos from fiber sample KT 22760



(a) KT 22764 Soil (b) KT 24308 Soil (c) KT 24791 Fiber

(d) KT 25166 Soil

Figure 46: Select photos from samples KT 22764, 24308, 24791, 25166



(a) KT 22764 Soil (b) KT 24308 Soil (c) KT 24791 Fiber

Figure 47: Select photos from sample KT 24674