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Dental Microwear and Diet Change during the Greek Bronze and Iron Age in Coastal East Lokris, Greece

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By

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This research utilizes two analytical methods to examine the dental microwear of two skeletal samples from East Lokris, Greece. The samples are from the Bronze age/Early Iron age sites of Mitrou and Tragana Agia Triada. The samples were tested according to various temporal and geographic designations in an attempt to determine if any differences in dietary constituent could be discerned from their dental microwear signatures.

Both traditional dental microwear analysis using a scanning electron microscope and dental microwear texture analysis employing scale sensitive fractal analysis and a Sensofar Plμ Confocal Profiler were used. The results of analysis for both methods differ in regards to their level of statistical significance but both suggest a general trend of coarsening of masticated materials during the Bronze/Iron age transition. Current evidence suggests that the changes in the dietary texture are due to changes in pottery production and are likely not due to dietary changes.

DEDICATION

To my family and friends that have held my hand when needed and kicked me in the backside when warranted. Much love and respect for you all.

"Goonies never say die!"

The Goonies 1985

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That's right other Barry! It's done.

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CHAPTER I

INTRODUCTION

Diet is perhaps one of the most important factors relating to human health, behavior, and development (Larsen, 1997). All organisms must ingest nutrients to survive. All organisms must convert the foodstuffs consumed into energy. For many species, including humans, this process starts with mechanically processing food with their teeth. The main purpose of teeth is to aid in the breaking down and digestion of food. The contact teeth have with ingested food makes them one of the most direct indicators of dietary textures and diet (Harmon and Rose, 1986). The mechanical processing of food by teeth creates small microscopic features on the surface of the dentition referred to as microwear. This microwear has been used by a number of researchers (Bullington, 1991; El Zaatari, 2007; El Zaatari et al., 2005; Gordon, 1982; Gordon and Walker, 1983; Mahoney, 2007; Scott et al., 2009) to examine the diet of a number of species including humans and extinct members of our family and genus. The research presented within this document examines the dental microwear signatures of burial samples from Mitrou and Tragana Agia Triada, two archaeological sites in central Greece (Figure 1). Two different forms of dental microwear analysis will be utilized to determine if there are any significant differences in the dietary textures of the two burial samples.

Problem Statement

As stated above the aim of this research is to examine the dental microwear signature of the samples from Mitrou and Tragana Agia Triada. To this end, four hypotheses were tested using traditional dental microwear and dental microwear texture analysis. The first hypothesis tested all samples to determine if there is any diachronic variation from the Late Helladic (LH) to the Protogeometric (PG) period. The second hypothesis to be tested used only LH samples from each site in order to determine if any variation existed between the two sites. The third hypothesis tested all palatial samples against all post-palatial samples to determine if a difference exists. The final hypothesis grouped all samples by site regardless of period and tested them against each other to ascertain if the microwear signature between the two sites differs significantly. These hypotheses were tested in order to provide perspective into the dietary patterns at both sites and offer additional insight into the history of a region, which has received relatively less attention than its surrounding areas.

Mitrou and Tragana Agia Triada

The sites, Mitrou and Tragana Agia Triada, are located in the region of East Lokris, which is situated approximately 90 km north of Athens. A distance of approximately 3 km separates the sites (Figure 2). Scholars have hypothesized that due to the temporal and spatial proximity of the two sites, Mitrou and Agia Triada may have been associated, and that Agia Triada represents the Mycenaean necropolis used by the population of Mitrou (Fossey, 1990; Kramer-Hajós, 2008; Van de Moortel, 2007). This hypothesis is based on the temporal and geographic proximity of the two sites (Fossey, 1990; Kramer-Hajós, 2008). Positioning of the entrance of the tombs also lends support

to this hypothesis as LH chamber tombs often face the settlement of the interred individuals (Van de Moortel, 2007).

Agia Triada was excavated by the 14th Ephorate of Prehistoric and Classical Antiquities between 1992 and 1997. The Triada burials were recovered from nine Mycenaean chamber tombs in the hills southwest of Mitrou. Herrmann et al. (n.d.) are currently reassessing the Agia Triada remains and the exact number of individuals represented is unknown at this time (Kramer-Hajós, 2008).

Later excavations at Mitrou, undertaken by the University of Tennessee and the 14th Ephorate of Prehistoric and Classical Antiquities, have uncovered 76 graves dating to the Bronze Age (BA) and Iron Age (IA). Due to the condition of these remains and the age of these samples, Mitrou and Agia Triada burials represent key comparative samples for other BA and IA sites in central Greece, and are important resources for understanding diet, health, and status in East Lokris.

Examination of Diet in Aegean Archaeology

The most common methods for investigating diet in the Aegean are paleoethnobotany (Hansen, 2000; Megaloudi, 2006; Tyree, 2000; Valamoti, 2009), pottery residue analysis (Margomenou, 2008; Vitale et al., 2010), and stable isotope analysis (Heaton et al., 2009; Patroutsa et al., 2009; Petroutsa and Manolis, 2010; Richards and Hedges, 2008; Triantaphyllou et al., 2008). Aggregated data from dental microwear studies, like data from stable isotope, residue analysis, and paleoethnobotanical studies highlight dietary patterns in a generalized fashion.

Studies of botanical remains identify the species of plants found at a site and quantify the specimens recovered. Documentation of the recovery of botanical remains

in Aegean archaeology goes back to the late 19th century, yet it was not until the 1970s that paleoethnobotanical studies became an important part of Aegean archaeology (Megaloudi, 2006). This development occurred as a result of the New Archaeology's desire to become more scientific and systematic in nature (Johnson, 1999). In most cases, analysis cannot specify the intended use of recovered species. Certain botanical remains survive taphonomic factors better than others, and this is a preservation bias specific to ethnobotanical studies (Megaloudi, 2006). Thus, the presence of a specific plant species does not indicate dietary inclusion, just as the absence of a species does not indicate its exclusion from the diet. While these forms of dietary analysis allow for insight into the diet of a sample, it is important to remember that like dental microwear studies, they represent only one line of evidence. When these methods are used in tandem with one or more techniques, they potentially provide a border picture of past diets.

Residue analysis is similar to paleoethnobotany in that it can only determine if something was contained in a vessel. Often it cannot inform us as to how it was used and/or processed once removed from the containing vessel. For example, the detection of lipids indicating that oil was contained in a vessel does not directly indicate how it was used (e.g. fuel for a lamp or for cooking). Both residue analysis and paleoethnobotanical studies need bridging arguments to connect the materials under study to actual human consumption.

Stable isotope studies on the other hand discern a general dietary signature from the sampled material (e.g. bone, enamel, or hair). Over time, as we consume food, the elemental structure of that substance is incorporated into our chemical structure (Katzenberg, 2007). For example, elevated levels of ^{15}N indicate consumption of marine resources but cannot be used to identify species or the amount of that species consumed

(Katzenberg, 2007). Changes in the type of foodstuffs ingested, over time, will alter the chemical structure of an individual.

Dental microwear studies, like stable isotope analysis, examine the direct impact that diet has on the hard tissues of an individual's body, specifically the enamel surfaces of teeth. The topographic features created during mastication are observed during dental microwear analysis. Dental wear studies do not directly indicate the specific food or the quantity that was consumed, but they can examine the nature of the material, which was masticated in general terms. For example, microwear research can distinguish between hard brittle material (i.e. nuts or seeds) and tough substances (i.e. leaves and grasses). These studies (Bullington, 1991; Butler, 1952; El Zaatari, 2008; El Zaatari et al., 2010; Schmidt, 2001) have focused on determining changes in diet as represented by changes in the texture of diet for a number of species including humans.

Although dental microwear analysis (DMA), paleoethnobotany, residue analysis, and stable isotope studies are capable of producing informative results in and of themselves, the significance of these findings can only be assessed when placed within the larger archaeological and cultural context. Diet is not exclusively determined by natural factors. Rather, it is the result of the dynamic interaction between environment and culture.

The relationship between culture, diet, and health is extremely complex (Knudson and Stojanowski, 2009). Culture influences all aspects of diet, from what we eat to who eats with us (Haviland et al., 2007a). Like all cultural groups, dietary habits during the Aegean BA and IA would have been internally variable and dependent on a number of factors. These factors would have possibly included an individual's age and sex, health, and socio-political and economic status, all of which have a significant impact not only

on an individual's access to resources, but also on the quality and quantity of his/her diet and also by social standing (Haviland et al., 2007a).

Because diet is such an important component of everyday life, data regarding diet is often used in conjunction with other factors such as demographic, temporal, or geographic information, to examine socio-cultural differences between and within groups. Botanical and chemical analyses of human remains have been studied in tandem with demographic and contextual information to examine health, dietary changes, and social class differences in relation to diet (See Katzenberg, 2007; Margomenou, 2008; Richards and Hedges, 2008; Triantaphyllou et al., 2008). DMA can be used in a similar fashion to address these issues. Correlations between differences in microwear and specific demographic or contextual attributes may expose differences in health or social status within or between populations.

Previous studies indicate that the Late Bronze Age (LBA) or Late Helladic and the Early Iron Age (Protogeometric) cultures on mainland Greece had a stratified social class system (Dickinson, 2006). This is supported by various mortuary practices and burial goods found at numerous BA and IA sites (Dickinson, 1994; Dickinson, 2006; Schepartz et al., 2009). Typically, in a stratified society, members of various social classes would have differential access to food stuffs (Haviland et al., 2007b). This statement is the exception and not the rule for the Greek mainland during the BA and IA. A number of stable isotope studies using eastern Mediterranean skeletal samples have shown that the chemical signature of the diet on mainland Greece (Heaton et al., 2009; Ingvarsson-Sundström et al., 2009; Patroutsa et al., 2009; Petroutsa and Manolis, 2010; Triantaphyllou et al., 2008), and some Greek colonies (Keenleyside et al., 2006) was homogenous across social statuses. Stable isotope studies have shown that the diet of the

Greek BA was primarily composed of terrestrial plant and mammalian sources, while aquatic resources comprised a small to insignificant percentage of the overall diet. It also appears that the diets of different social classes consisted of the same species. The only exception to this pattern comes from Mycenae, where individuals found in "elite" burials appear to have had a broader diet, which included marine food sources (Richards and Hedges, 2008). The study may indicate that only members of the highest social class had access to resources from the sea.

The analysis of dental microwear to test the hypotheses stated above will allow for greater insight into the dietary habits and changes across the LBA as well as the EIA. The LBA-EIA transition is a period characterized by significant changes in the social, economic, and political organization of Aegean communities, all of which would have had a significant impact on cultural practices including dietary habits (Dickinson, 1994; Whitley, 2001). By recognizing these issues, this research will allow for a greater understanding of the diet of LBA and EIA inhabitants of central Greece. The results of this research may potentially lend support to the previous isotope, residue, and paleoethnobotanical studies showing homogeneity of the constituents that formed the Aegean diet during these periods.

Figure 1 Map of the Aegean with research area location and several key sites in Greece identified.

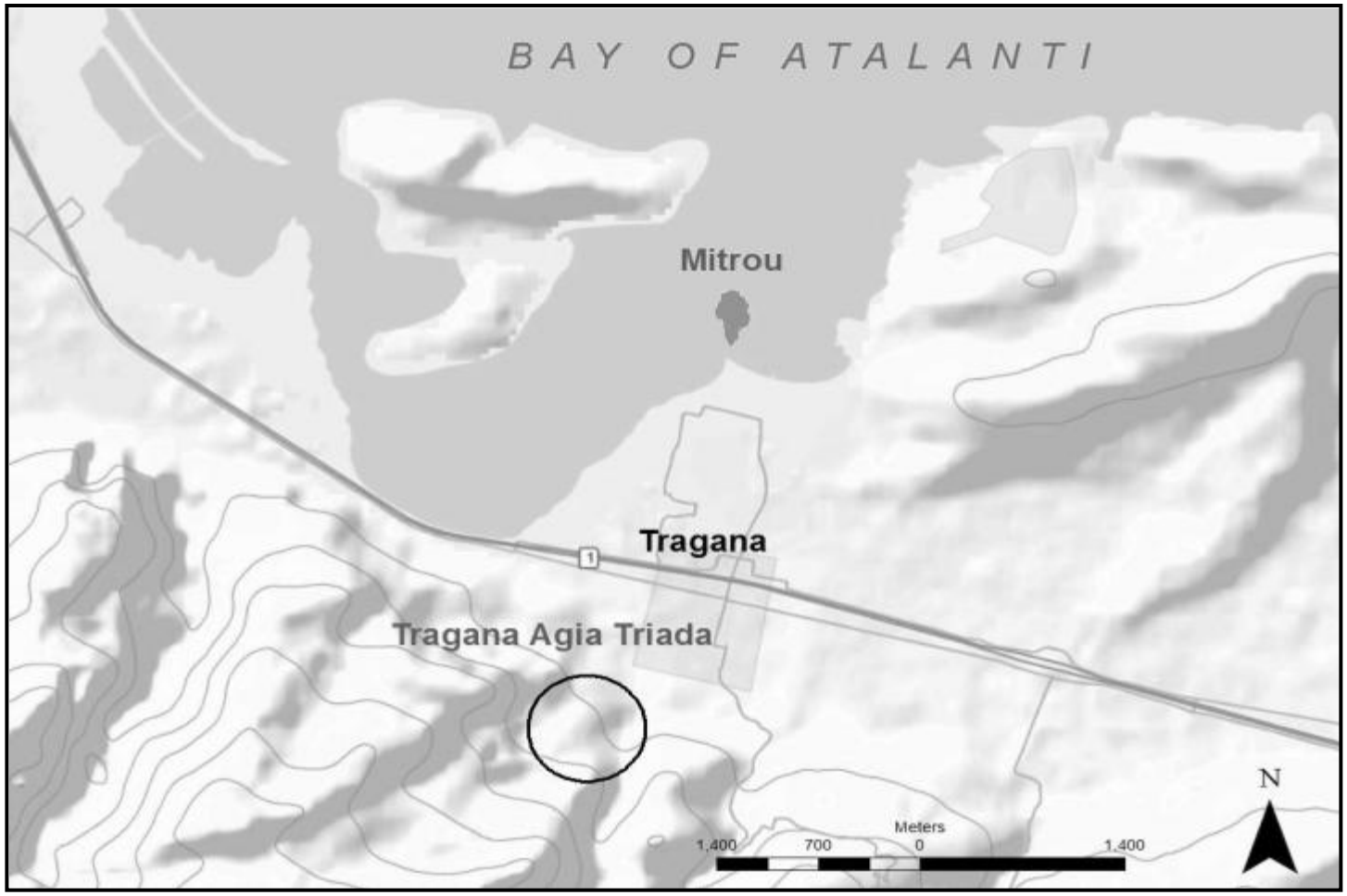

Figure 2 Detail map of the research area with Mitrou and the Tragana Agia Triada site locations highlighted.

CHAPTER II

REVIEW OF DENTAL MICROWEAR

Dental Wear

Dental attrition, documented as macrowear and microwear, is caused by three different processes referred to as sliding wear, abrasive wear, and erosive wear (Hillson, 2005). Sliding wear is created as the cusps of isomears slide across on another and catch. As the occlusal surfaces of two teeth slide across one another, these projections can catch and the force of this movement can cause them to break or fracture. Abrasive wear is caused by force being applied to a particle caught between two teeth during the chewing cycle. Erosive wear is caused by hard particles brought into the mouth with liquid, and works in the same way that salt water works to erode coastlines.

In humans, the chewing cycle has three motions: the opening stroke, the power stroke (which is divided into phase I and phase II, discussed below), and the closing stroke. For microwear research, the power stroke of the chewing cycle is of great importance as this is the physical mechanism that produces microwear. The first phase, power stroke phase I, involves the lingual surface of the upper molars moving across the occlusal surface of the lower molars. This motion ends with the lingual cusps of the upper molar coming into contact with the buccal cusps of the lower molar (Hillson, 2002). The second phase of the power stroke drags the two molars against each other ending with the lingual surface of the buccal cusps of the upper molars against the buccal surface of the lingual cusps of the lower molars (Hillson, 2002). This shearing/grinding motion creates

large amounts of pressure on the surface of both teeth. If the food stuff is harder than the enamel, which has a hardness value of 5 (Gwinnett and Gorelick, 1977) on the Moh scale, small microscopic features will form on the surface of each tooth (Hillson, 2002).

Not all areas of a tooth experience the same amount of pressure during the chewing cycle, consequently this has been shown to create different microwear signatures (Mahoney, 2006a). The areas of a tooth that are worn during the power stroke are referred to as facets. Some of these facets develop during phase I of the power stroke while others form during phase II of the power stroke (Hillson, 2002). Phase II facets form during the grinding and shearing that occurs during the power stroke. Specifically, these facets are created as the lower molar slides against its isomer, into a position lingual of the centric position (Hillson, 2002). Microwear observed on phase II facets has been shown to more accurately represent the dietary texture of an individual as this is the phase of the chewing cycle that actually grinds the material (El Zaatari, 2008; Mahoney, 2006a; Mahoney, 2006b; Scott et al., 2006; Ungar et al., 2006).

Dental Macrowear

Dental macrowear is the loss of enamel and eventually dentin (Schmidt, 2009). This can be thought of as the loss of dental tissue visible with the naked eye. As food is masticated, the cusps of each tooth will become more rounded. As each tooth is subjected to more material, the cusps will become flat and dentin will become exposed. Dental microwear can contribute to overall macrowear (Schmidt, 2010). This relationship is discussed below. Dental macrowear, like dental microwear, has been used to examine the diet of past human populations and of a variety of other animals (Deter, 2009; Kaiser and Brinkmann, 2006; Molnar, 2008; Smith, 1984).

Dental Microwear

Dental microwear is the microscopic loss of dental tissue. Microwear manifests itself in the form of scratches and pits. These features are created by either intrinsic or extrinsic sources found in consumed food. Intrinsic sources are materials found within food which are hard enough to damage the enamel surface of each tooth (for example phytoliths or bone), while extrinsic sources are materials which become incorporated into food (sand, grit or material from cooking pots or grinding stones for example) (Baker et al., 1959; Reinhard and Danielson, 2005; Schmidt, 2009). Microwear on the occlusal surface of a tooth manifests as pits or scratches. Researchers have demonstrated that microwear features in the form of scratches do contribute to the overall macrowear of a tooth (Schmidt, 2010).

Both extrinsic and intrinsic sources have been shown to contribute to dental microwear (Baker et al., 1959). Further research showed that the microscopic scratches analyzed in dental microwear studies were not caused by tooth on tooth activity but by the extrinsic and intrinsic sources found in the consumed diet (Teaford and Walker, 1983). As previous studies have shown, the creation of microwear features is caused by what enters the mouth during mastication, not by tooth on tooth contact. Due to the formation processes of microwear features, DMA and dental microwear texture analysis (DMTA) have been utilized to study a number of topics. DMA studies focus on examining the texture of a sample's diet, and diet change of hominids, prehistoric humans, various animal species, as well as the biomechanics of the power stroke (Bullington, 1991; El Zaatari, 2008; Goillot et al., 2009; Gordon and Walker, 1983; Mahoney, 2006b; Ungar, 2004). It is important to note that microwear is a reflection of the dietary textures of masticated foods. As a variety of specific foods can create the

same types of microwear features microwear studies lack the ability to pinpoint a direct change in specific foods. That being said microwear studies do have the ability to determine textural changes in diet between samples.

History of Dental Microwear Studies

Microscopic wear of teeth has been studied since the 1930s (see Ungar et al., 2008a for review of early literature). In the 1950s, researchers began to investigate how the two components of various animal jaws worked together during the chewing cycle, and whether or not samples had a preferential orientation for masticating food (Butler, 1952). To do this, some scholars used the shape of worn cusps and the microscopic scratches they observed on each sample (Butler, 1952; Mills, 1955). In 1962, Dahlberg and Kinzey conducted the first published study examining human dental microwear.

For the next decade, microwear studies of any type were sparse. Early studies, such as that conducted by Dahlberg and Kinzey (1962), utilized an optical light microscope to view the occlusal surface. This method has some major problems. First, optical light microscopes do not have a great depth of field, which would have allowed for a greater focal plane and more detailed images (Ungar et al., 2008a). Second, they do not provide the high level of resolution other microscopes are capable of providing. Finally, they are not capable of high magnification, like other microscopes such as a scanning electron microscope (SEM) (Ungar et al., 2008b). These limitations, as well as the lack of standards for quantifying dental microwear features, made it apparent, that while DMA was capable of answering many questions about the biomechanics of chewing and diet it was necessary to develop better methods for conducting these analyses.

The late 1960s and 1970s saw the development and application of two technologies that would aid in the accuracy, efficiency, and expansion of DMA study populations. The first was increased access to scanning electron microscopes (SEM) (Teaford, 1988). Although SEMs had been used in other fields since 1938 (Postek et al., 1980), they were not used in DMA until the 1960s. The second was the development of high quality casting materials which revitalized DMA (Teaford, 1988). The ability to make accurate replicas of rare or fragile samples allowed researchers to study species of extinct hominids, non-human primates, and various human samples from rare contexts without fear of causing damage to them (Bernal et al., 2007; El Zaatari, 2008; Galbany et al., 2006; Grine, 1986; Homes and Melsheimer, 2008; Mahoney, 2007; Rose, 1983; Teaford and Oyen, 1989). These technological advances made dental microwear studies a more reliable analytical tool.

In the mid to late 1960s, several studies (e.g. Hoffman et al., 1968; Hoffman et al., 1969) dealing with dental development showed that the SEM was capable of observing the smallest details of a tooth. The SEM, with its increased resolving power, resolution, and magnification, was quickly incorporated into DMA studies. It has been used to conduct DMA on a number of primate species (Gordon, 1982; L., 1976; Teaford and Walker, 1984), other non-primate animals (El Zaatari et al., 2005; Gordon and Walker, 1983; Kaiser and Brinkmann, 2006; Rivals and Deniaux, 2005; Strait, 1993; Teaford and Walker, 1983), hominid species (Grine, 1986; Ungar et al., 2006), and anatomically modern human populations (Bullington, 1991; Harmon and Rose, 1986; Mahoney, 2006a; Mahoney, 2007; Organ et al., 2005; Schmidt, 2001; Schmidt, 2009; Schmidt, 2010; Teaford et al., 2001; Teaford and Lytle, 1996; Ungar and Spencer, 1999).

Even with the SEM becoming an intricate component of DMA, problems still exist in this type of research. A critical issue is that researchers still lack a repeatable and consistent method for quantifying microwear features. Many studies used acetate overlays and markers or tablet digitizers to quantify microwear features (Gordon, 1982; Gordon, 1984; Strait, 1993). Due to the variety of methods for quantifying microwear features caused DMA to become very subjective. In an attempt to make the quantification of these features more standardized and repeatable, several researchers have created both automated and semi-automated computer programs for this purpose. However, because automated programs had problems differentiating between microwear features and casting defects, they quickly fell out of favor (Grine et al., 2002; Ungar et al., 2008a).

Currently the most commonly used method is a semi-automated computer program called *Microware* (Ungar, 1991; Ungar, 1995; Ungar, 2002). This method of quantification was quickly accepted into DMA research. It is still used in traditional microwear studies and although the repeatability of measurements is still an issue (Ungar et al., 2008a), *Microware* (Ungar, 1991; Ungar, 1995; Ungar, 2002) has made quantification less time consuming and easier. Using a mouse, the user selects four points of a feature; two on the major axis and two on the minor axis. *Microware* (Ungar, 1991; Ungar, 1995; Ungar, 2002) automatically distinguishes pits from striations by converting all features with a length to width ratio of $\leq 4{:}1$ into a pit feature (Ungar, 1995). Length and width of all features, as well as their orientation are also automatically measured and recorded by *Microware.* The mean and standard deviation for each category is automatically calculated, speeding up analysis. While *Microwear* made analysis more expedient, it did not alleviate the fundamental problems found in DMA. Galbany (2005)

showed the use of this program did not remove the subjectivity of traditional SEM based dental microwear analysis or increase the reliability of analysis.

Traditional SEM based DMA still has not found a resolution to its fundamental problems of repeatability and its subjective nature. Both of these factors introduce a large amount of both intar and interobserver error. Both inter- and intra- observer error rates for the quantification of microwear features are between 7% and 9%, even for experienced users (Grine et al., 2002). Error rates this high make it hard to compare results between researchers and different quantification methods. The reliance on a human to determine the start and end of a feature, adds a level of subjectivity, which introduces an undesirable amount of error. Reliability and the subjective nature of DMA analysis are two areas that limit it as an analytical technique.

Although these issues have continued to persist, regardless of the scoring methods used, DMA is still a useful method that continues to be used today. Comparisons can be made from collection to collection if the same individual scores all collections. It is also important that this individual checks for errors in a systematic and orderly fashion. This can be accomplished by rescoring a percentage of a collections' samples at regular intervals.

Dental Microwear Texture Analysis

In response to the issues associated with SEM based DMA, new instruments and methods were evaluated to conduct DMA. The latest progression within DMA is dental microwear texture analysis (DMTA) , which utilizes a confocal profiler instead of the more traditional SEM. Fortelius (1991) first suggested the use of confocal microscopes as an instrument to be utilized in microwear studies. With its three-dimensional imaging

capabilities, Fortelius felt that the confocal microscope was the next logical step to advance microwear studies. Although, the suggestion of a Confocal microscope held promise, it was not until 2003 that researchers started to use Confocal microscopes in dental microwear analysis (Ungar et al., 2003). DMTA collects topographic data from the surface of a sample. These data are then turned into a point cloud that is converted into a three dimensional image. Scale-sensitive fractal analysis is employed to measure all surface features on a sample. This method was developed by meteorologists and used since the 1930 to measure surface texture of a variety of materials and objects (Ungar et al., 2003).

All measurements are conducted by automated computer programs (Scott et al., 2006; Scott et al., 2005). Two programs, *ToothFrax* and *SFrax* (Surfract, www.surfract.com), were both developed for analyzing surface textures; with the former specifically designed for DMTA. As both programs are automated, they remove observer error and allow for repeatable results (Ungar et al., 2008b). By removing observer error, DMTA allows for comparisons of sample populations studied by different researchers.

As seen above, dental microwear studies have come a long way since the 1930s. The teeth of numerous species from a variety of periods and geographic locations have been examined. Nevertheless, traditional dental microwear studies still lack the repeatability common to other forms of analysis. As suggested above traditional dental microwear studies using an SEM or stereoscopic microscope continue to be conducted. This is due to the importance of understanding the diet of past populations and species and the ability of dental microwear to inform us about the nature of these diets. It is the opinion of this author that dental microwear texture analysis is the next step, both technologically and scientifically. The use of SSFA and 3-D surfaces removes the

subjectivity out of dental microwear studies and allows for comparisons between different researchers as well as the ability to repeat results.

CHAPTER III

GREEK ARCHAEOLOGY

Chronology

There are many chronologies used for different areas of the Aegean. The chronology and cultural sequence employed in this study is the one developed for mainland Greece (see Figure 3). On mainland Greece, the BA lasted from c.a. 3100 B.C. to c.a. 1050 B.C (Dickinson, 1994). This period is a modern construction based on the interpretation of technological and cultural developments by researchers in the field of Aegean prehistory. The BA is typically divided into three sub-periods, namely the Early, Middle, and Late BA. These three periods generally correspond to what are considered to be coherent historical and cultural phases (Rutter, 2000). The earliest of these periods is referred to as the Early Helladic (EH). There is much debate concerning the appropriate dates for this period (See Dickinson, 1994; Rutter, 2000; Whitley, 2001 for further discussion) and it is often divided into three further sub-periods which are beyond the scope of this work. The following phase, the Middle Helladic (MH), begins around 2100 B.C at the end of the EH phase. (Dickinson, 1994; Rutter, 2000).

The final period of the BA, and the focus of this study, is the Late Helladic (LH), also referred to as the Mycenaean (Rutter, 2000). For this research, the more standard terminology, Late Helladic (LH), was used. The LH period is conventionally dated between c.a.1500 -1050 B.C. The LH period is also divided into several sub-periods, (I, IIA, IIB, IIIA1-2, IIIB and IIIC),(Rutter, 2000).

The Early part of the IA is referred to as the Protogeometric period (PG). The name of this cultural period comes from the geometric decoration common to the pottery of this period (Dickinson, 2006). Like the BA periods before the PG period has several small subdividions of time. These are in their most basic forms Early, Middle, and Late (Johnson, 1999; Rutter, 2000).

Although the samples used in this study originate in periods with several sub-periods this research lacks both the temporal resolution and sample size to operate under this division of time. As a result, each sample's periods will only be reported to their general period (i.e. LH or PG), unless otherwise specified.

The Settlement of Greece and the Origins of Agriculture

Humans have occupied Greece since at least the Middle Palaeolithic (Dickinson, 1994). The majority of these early sites are located in the North of Greece, but there is also some evidence of the colonization of Greece as far south as the northern Peloponnese. Many of these sites are open-air sites located near fresh water, although a few sites are located in caves or rock shelters (Dickinson, 1994). Franchthi Cave is perhaps the most renowned with stratigraphic units dating from the Palaeolithic to Neolithic (Jacobsen, 1981). The first populations of Greece were small groups, likely not more than 25 individuals (Gamble, 1999). The archaeological evidence indicates that these early populations, like Neanderthals before them, were hunter gatherers (Jacobsen, 1981).

These early groups utilized plant species such as pulses and nuts. Wild cereals represented the main plant constituent of the diet. Animal protein consisted of a variety of terrestrial mammals, but mainly deer and wild ass are identified in the archaeological

record. By the beginning of the Neolithic, fish and shell fish appear to have also been an important component of their diet (Dickinson, 1994). It should be noted, that towards the end of the Neolithic in Greece, aquatic resources were no longer common and made up only a small to insignificant portion of the overall diet (Papathanasiou, 2003).

The first evidence for agriculture found on mainland Greece dates to the beginning of the 7th millennium and was found in north Central Greece in the region known as Thessaly (Dickinson, 1994). It appears that these early farming settlements were located on previously unoccupied lands and were situated on optimal agricultural lands. The archaeological record indicates that these early agricultural groups in Greece grew wheat, legumes, and barley (Dickinson, 1994). Isotopic studies of Neolithic samples have demonstrated that the diet of the Neolithic agriculturalist throughout mainland Greece focused mainly on C_3 plants, such as barley and wheat (Papathanasiou, 2003; Papathanasiou et al., 2000; Papathanasiou et al., 2009). C_3 plants are temperate plants that use the C_3 photosynthetic pathway to convert carbon into an organic compound (Katzenberg, 2007). Sheep and goats also played an important role in the subsistence strategy of these people though domesticates also included pig, cattle, and dog (Papathanasiou et al., 2000). Despite the advent of agriculture, the practice of collecting wild resources continued (Dickinson, 1994).

The shift to agriculture allowed the development of more semi-permanent and permanent settlements (Dickinson, 1994). Archaeological evidence indicates that during the late Neolithic, small villages, along with small hamlets and farmsteads, typically spotted the landscape (Bintliff and Farinetti, 2006). The ability to maintain a large population in one settlement is generally seen in later Bronze Age sites, but several Neolithic sites had permanent populations much larger than typical BA settlements. This

suggests that the development of large permanent settlements with a social hierarchy started in the late Neolithic, and not in the BA as originally thought (Manning, 2010).

The Greek Bronze Age and Protogeometric Phase

As stated above, the period known as the Greek BA is a modern temporal and cultural construct used to describe a period from c.a. 3100 B.C. to c.a. 1050 B.C. To describe all of the technological and cultural changes seen during this period is far beyond the scope of this study. The following is a general discussion of topics that are most relevant to the research conducted here (for a more in-depth desscusion see Cline, 2010; Dickinson, 1994; Dickinson, 2006; Shelmerdine, 2008).

The archaeological record shows that in the earliest part of the BA, settlement patterns deviate from those found in the Final Neolithic (FN). An increase in both the number of sites and the size of sites is seen during the EBA. By the EBA, the FN sites located inland and at higher altitudes were abandoned and new previously unsettled areas such as coastal plains were colonized. Sites during the EBA are commonly found close to the coasts and in areas of lower elevations, such as bottomlands (Pullen, 2008; Pullen, 1992). The movement towards the coastline may relate to an increase in trade, while the movement away from higher areas may be due to an increased reliance on rain dependent agriculture and a decrease in the reliance of pastoralism (Pullen, 2008).

It also appears that many of the new EH I sites developed in areas away from running water and closer to deeper fertile soils (Pullen, 2008; Pullen, 1992). The movement away from readily available sources of water for irrigating soils was likely due to new agricultural technologies. For example, a terracotta figure of a bull with a yoke was found at Tsoungiza Hill near Nemea, which indicates that animal traction was used

during this period (Pullen, 2008; Pullen, 1992). The plow allowed EH farmers to reach deeper soils found in lowland areas that were rich and fertile. The figurine is the only evidence of animal traction (Pullen, 1992).

The EH II phase continued to see social and cultural change, while population growth slowed and many earlier settlements were abandoned (Pullen, 2008). Settlements became more nucleated and for the first time there is clear evidence for fortifications (Forsén, 2010; Pullen, 2008). Defensive fortifications, often including towers, have been excavated in the Peloponnese, Attica, Euboea, and Boeotia (Pullen, 2008). Such defensive structures are common during this period on the coast regardless of settlement size. However, Thebes is the only reported fortified settlement in the interior of Greece (Pullen, 2008).

The earliest inhabitants of the Greek mainland do not share the ethnic or linguistic attributes that are seen in later Greek populations (Dickinson, 1994; Pullen, 2008). It is believed by many scholars that the end of EHII is the time when populations considered to be ethnically and linguistically Greek arrived in Greece (Pullen, 2008; Wright, 2008). These arguments are based on destruction levels found at several sites as well as linguistic and stylistic changes seen during this period. Other hypotheses regarding the arrival of the Greeks, see them developing *in situ* during the EH period or arriving at the end of the FN and peacefully integrating into society (Dickinson, 1994)

There is also a large body of evidence for social stratification during the EH period. A lead seal (used for taxation or commerce) found at the site of Tsougiza suggests increased commerce and tribute, which would likely have been controlled by elite individuals (Pullen, 2008). Perhaps the greatest evidence of a differing social hierarchy is the appearance of monumental architecture (Forsén, 2010). Several structures interpreted

as housing and/or storage structures have been found dating to the EH IIA period (Forsén, 2010; Pullen, 2008). These early houses had varied floor plans, but they were generally square in shape with a second floor supported by thick stone walls (Pullen, 2008). For example, House A, found at Tsoungiza in the 1920s, had walls that were approximately one meter thick (Pullen, 2008).

These early houses may be a forerunner to the corridor house type that became popular during the EH IIB period. Corridor houses have been found in a number of different regions of Greece and they all share a similar floor plan (Forsén, 2010; Pullen, 2008). The House of the Tiles at Lerna, so named because of the large number of baked clay roof tiles found with it, is the best-preserved corridor house to date. Many seals have been found inside corridor houses, including as many as 70 from the House of the Tiles alone (Pullen, 2008). Seals found in the context of monumental structures suggest that these buildings where the center of the social and economic system (Dickinson, 1994; Forsén, 2010; Pullen, 2008). The hierarchical system of these societies has often been referred to as similar to Chiefdom-level societies (Pullen, 2008). This insinuates that an elite person or group of elite individuals had some form of control, certainly economic but likely also social and political over a region centered on their settlement (Forsén, 2010; Pullen, 2008).

At the end of the EH (c.a. 2100 B.C.), many sites including smaller sites in the country were either abandoned or suffered a decrease in population (Pullen, 2008; Wright, 2008). During the MH period, it appears that settlements were more nucleated than the dispersed EH settlements (Bintliff and Farinetti, 2006; Dickinson, 1994; Wright, 2008). At the end of the MH period (c.a. 1650 B.C.) during the MH III sub-period, the archaeological record indicates that many settlements expanded in size and a number of

new settlements were founded. It is during the late MH period that evidence for the centralization of political, religious, and economic activities can be found. Several sites, such as Tiryns and Argos, appear to have been planned so that the areas where these activities occurred were separate from other areas of these sites (Wright, 2008).

Social stratification during the MH period is especially visible in the mortuary practices of the era. Towards the end of this period (MH III), the variety of burial forms (pits, cists, shaft graves) and their associated burial goods suggests the existence of well-defined social classes (Dickinson, 1994; Wright, 2008). The excavation of MH cemeteries indicates that an individual's lineage was of great importance to their social status. Evidence for this has been found at a number of cemeteries that include all ages and sexes, with different generations buried together. It is hypothesized that an individual's status was associated with their ability to hunt, conduct trade, and/or an individual's prowess as a warrior. This is supported by burial goods associated with some individuals (Wright, 2008). Excellent examples of this point are the burials found in Grave Circle B at Mycenae.

Sometime during MH III and LH I, a large increase in the population of Greece is indicated by an increase in site size, such as at Pylos. Not only does the archaeological record indicate that villages and cities were growing, but also that warfare and raiding were also more commonplace. This is suggested by the increase in fortifications found at sites across southern and central Greece, as well as an increase in artistic representations of warfare (Wright, 2008).

The developments mentioned above, as well as the political and social changes that occurred during the LH period did not occur at the same time or in the same manner throughout Greece. Central palaces with a central ruler, or *Wanax*, came to power at

many different sites during the LH period (Shelmerdine and Bennet, 2008). These palaces, often called citadels due to their monumental fortifications, were the homes of the ruling elite. These citadels often housed a megaron, or throne room.

From linear B tablets recovered during excavations at such sites, it is apparent that these new Mycenaean centers controlled vast areas of land, goods, and people (Shelmerdine and Bennet, 2008; Wright, 2008). During this period the economy flourished, goods were traded to far corners of the Mediterranean as well as to areas around the Black Sea and the Near East (Cline, 2010; Dickinson, 1994; Mee, 2008). From LH I to LH IIIB2 period, the Mycenaean palatial centers were wealthy, powerful, and in control of large amounts of land (Deger-Jalkotzy, 2008; Dickinson, 1994; Dickinson, 2006; Wright, 2008).

The end of the BA and the beginning of the EIA (LH IIIB2 EPG) is characterized by significant social and political upheaval throughout the Aegean and eastern Mediterranean (Deger-Jalkotzy, 1998; Deger-Jalkotzy, 2008; French, 1998). There are a number of theories which attempt to explain the cause for this turbulent period but as of yet there is no consensus. Theories include invasion, internal social upheaval, climate change, earthquakes, or any combination of the above (Bentancourt, 2000; French, 1998; Stiebing, 2009). Whatever the cause, the palatial centers that once dominated commerce and the associated trade networks collapsed (Iezzi, 2005; Whitley, 2001). Multiple archaeological examples of this collapse have been documented across mainland Greece (Deger-Jalkotzy, 2008; Dickinson, 2006; Whitley, 2001).

Although most large Mycenaean sites were either abandoned or re-occupied by a significantly smaller population, Mitrou is one of few sites exhibiting continued stability and occupation during the transition between the BA and EIA (Fossey, 1990; Van de

Moortel, 2007; Van de Moortel and Zahou, 2005; Van de Moortel and Zahou, n.d.; Whitley, 2001). It is important to note that the collapse we see in Greece is part of a sweeping trend in the eastern Mediterranean where other civilizations, such as the New Kingdom in Egypt, the Minoans on Crete, and the Hittite Empire, also saw great declines in power and in some cases even collapse (Van de Moortel and Zahou, 2005; Whitley, 2001).

Diet

As previous research (Bendall, 2004; Hansen, 2000; Keenleyside et al., 2006; Megaloudi, 2006; Patroutsa et al., 2009; Petroutsa and Manolis, 2010; Richards and Hedges, 2008; Triantaphyllou et al., 2008; Valamoti, 2009) has pointed out, the common diet of prehistoric Greece was rather homogenous consisting of terrestrial mammals and C_3 terrestrial plants. The main ingredients of this diet consisted of a number of cereals, legumes, and fruit sources (See Megaloudi, 2006 for a more detailed discription of food sources). Wheat, barley and emmer appear to have been a major component of the BA/EIA diet (Megaloudi, 2006). Wheat and barley seem to be of great importance to the Mycenaean palatial centers, as the palatial centers acted as storage and redistributive centers (Chadwick, 1976; Shelmerdine and Bennet, 2008). These goods entered the palace as tribute or taxes (Pullen, 1992). Other cereals such as emmer, einkorn, millet, and bread wheat have also been found at a number of Mycenaean sites (Kramer-Hajós, 2008). A number of fruit and berries including grapes, figs, strawberries, pears, as well as olives have been identified at BA and IA sites (Kramer-Hajós, 2008; Megaloudi, 2006). Although the above is not an exhaustive list of ingredients used in the Mycenaean diet, the items mentioned are the most common. It should also be noted that, due to

preservation bias, some food sources my not be accurately represented in the archaeological record and in some cases they may be completely absent. It should be noted that the biases stated above do not directly affect this research. This is because neither DMA nor DMTA directly analyze these materials.

Animal protein was also an important component of the diet. Sheep, goat, pig, and cattle remains are commonly found across mainland Greece. These animals were likely used not only for their meat but also for secondary resources such as dairy products or a source of fibers for textiles (Halstead, 1996; Kramer-Hajós, 2008). The use of animals for resources other than meat can be determined through a number of factors. This can be done by looking at the demographic makeup of available animal populations (Halstead, 1996; Kramer-Hajós, 2008). For example, an increase in the age at death of male cattle is seen during the BA, which suggests that these animals were useful in their adult years. It has been hypothesized that the introduction of the plow increased the importance of older bulls during the BA (Kramer-Hajós, 2008). Using demographic models has also shown that while sheep where being used predominantly for wool on Crete, the demographic makeup of sheep populations in Thessaly located just north of Lokris suggests that they were used for meat (Kramer-Hajós, 2008).

While all foods such as the ones that were part of BA-EIA diet can create dental microwear features when masticated, butchered or processed foods can also include extrinsic material. Particles, such as sand or grit, can become incorporated into food during the grinding, butchering, drying, or smoking process. The texture of the edible substance and any material incorporated into the food will influence how dental microwear manifests on a tooth. Changes in food preparation technology or an increase in

the diversity of food resources exploited can contribute to what foods are consumed and/or the manner in which they are manipulated from harvest to consumption.

The Sites of Mitrou and Tragana Agia Triada

The sites examined in this study are from a region in central Greece called East Lokris. Mitrou is a small tidal island located in the southern part of the Bay of Atalanti. The island is located roughly 1.5 km north of Tragana, a small, modern farming village located on the national road. The site of Tragana Agia Triada is located approximately 1 km southwest of Tragana, and approximately 3 km to the south west of Mitrou. Mitrou is located on the Atalanti plain, a fertile coastal area that is protected by mountains to the east, south, west, and the Northern Euboean Gulf to the north. Tragana Agia Triada is located half way up the slope of the mountain range found to the south west. The plain is located along important sea and land trade routes, both in ancient times, and modern day with the national highway running from Athens through Tragana to Thessaloniki, located near the Macedonian border. Mitrou and Tragana Agia Triada are also located near other important central Greek BA sites such as Orchomenos, Thebes, Kynos, Lefkandi, and Gla.

During the BA and IA, Mitrou was not an island but a small rise, or tell, on the larger Atalanti plain that made up the prehistoric coast line (Kramer-Hajós, 2008). Over the course of millennia sea levels rose and tectonic activity caused the plain to submerge gradually (Kramer-Hajós, 2008). A British admiralty map from 1874 depicts Mitrou as a peninsula. In 1894, there was a series of earthquakes, one of which was associated with a tidal wave, after which Mitrou became an island (Kramer-Hajós, 2008). While it is impossible to know exactly how the coastline appeared in the BA, Kramer-Hajós (2008,

see Figure 3) created a tentative rendering of where the coast may have been located. Her reconstruction shows a deep protected port located just to the north of Mitrou. Based on evidence recovered from an intensive surface survey of the islet, the site of Mitrou has been occupied from the Neolithic to the Classical period (Kramer-Hajos and O'Neill, 2008). That being said, the only evidence for a continuous occupation at the site of Mitrou is from EH IIB to the Late Protogeometric period (see Deger-Jalkotzy, 2008; Dickinson, 1994; Dickinson, 2006).This was also the most intensive occupation at the site. The site's proximity to two major trade routes, one by land and the other by sea, may have added to its attractiveness as a settlement for BA groups. The artifact assemblage recovered from excavations conducted by the Mitrou Archaeology Project (MAP) and the earlier survey undertaken by the Cornell Halai and East Lokris Project suggests that Mitrou was part of a broad trade network covering the Aegean (Kramer-Hajos and O'Neill, 2008; Van de Moortel and Zahou, 2005; Van de Moortel and Zahou, n.d.).

Mitrou is rather unique for several reasons. Due to its uninterrupted occupation, it is the perfect site for studying the development of BA society and the transition from BA to EIA societies. It is neither abandoned nor destroyed at the end of the BA, which is an unusual circumstance, and the reasons for this comparative stability are not yet known. (Van de Moortel and Zahou, n.d.). Roof tiles such as those found associated with corridor houses such as the House of Tiles excavated at Lerna (Pullen, 2008) are found at Mitrou, making Mitrou the most northern site where roof tiles have been recovered (Van de Moortel and Zahou, n.d.). The tiles are important because, as stated above, they are associated with Corridor Houses, which are often interpreted as evidence for political centralization at many sites across mainland Greece (Pullen, 2008; Van de Moortel and Zahou, n.d.). In addition, the discovery of seals is also significant since this type of

artifact is typically associated with administrative and economic activities (Pullen, 2008; Van de Moortel and Zahou, n.d.).

Mitrou also appears to have been subject to a strong central power. Starting at the beginning of the LH I period, Mitrou underwent a major restructuring in respect to city planning and mortuary practices (Van de Moortel and Zahou, n.d.). As Van De Moortel and Zahou (n.d.) point out, this reorganization can be seen during the LH I period when an orthogonal street pattern developed, with the majority of the roads going in NNE-SSW or WNW-ESE direction. During this time, the NE area seems to have been converted from a settlement area to a burial ground. During the MH and for a portion of the LH I period, individuals were interred in cists within residential areas. The creation of a specific area for the dead is not only a departure from the mortuary practices observed in the MH period, but also lends support to the hypotheses of a strong ruling hand directing these changes (Van de Moortel and Zahou, n.d.). No burial from Mitrou has been identified definitively as dating to the time periods between LH IIIA and the end of the LH IIIC period (Van de Moortel and Zahou, n.d.). The burials from Agia Triada date to the LH IIIC period and are only three kilometers from Mitrou (Kramer-Hajós, 2008). The shift in the mortuary practices seen at Mitrou during this period indicates that the dead were buried outside of the settlement. One possible candidate for mortuary activity for at least a portion of the population is Tragana Agia Triada, where multiple tombs are located in close proximity and within view of Mitrou.

DATE	TEMPORAL PERIOD	CULTURAL PHASE	SUB-PHASE
3400 B.C.	Neolithic	Final Neolithic	
3200			
3100	EARLY BRONZE AGE (EBA)	Early Helladic (EH)	EH I
3000			
2900			
2800			
2700			EH II
2600			
2500			
2400			
2300			
2200			EH III
2100			
2000	Middle Bronze Age (MBA)	Middle Helladic (MH)	MH I
1900			MH II
1800			
1700			MH III
1600	Late Bronze Age (LBA)	Late Helladic (LH)	LH I, IIA
1500			
1400			LH IIB, IIIA1,
1300			LH IIIA2, IIIB1, IIIB2
1200			
1100			LH IIIC
1000	Early Iron Age (EIA)	Protogeometric (PG)	Early PG
			Middle PG
900			

Figure 3 Chronology of Central Greece (adapted from Dickinson, 1994; Dickinson, 2006; Manning, 1995; Rutter, 2000; Rutter, 2010).

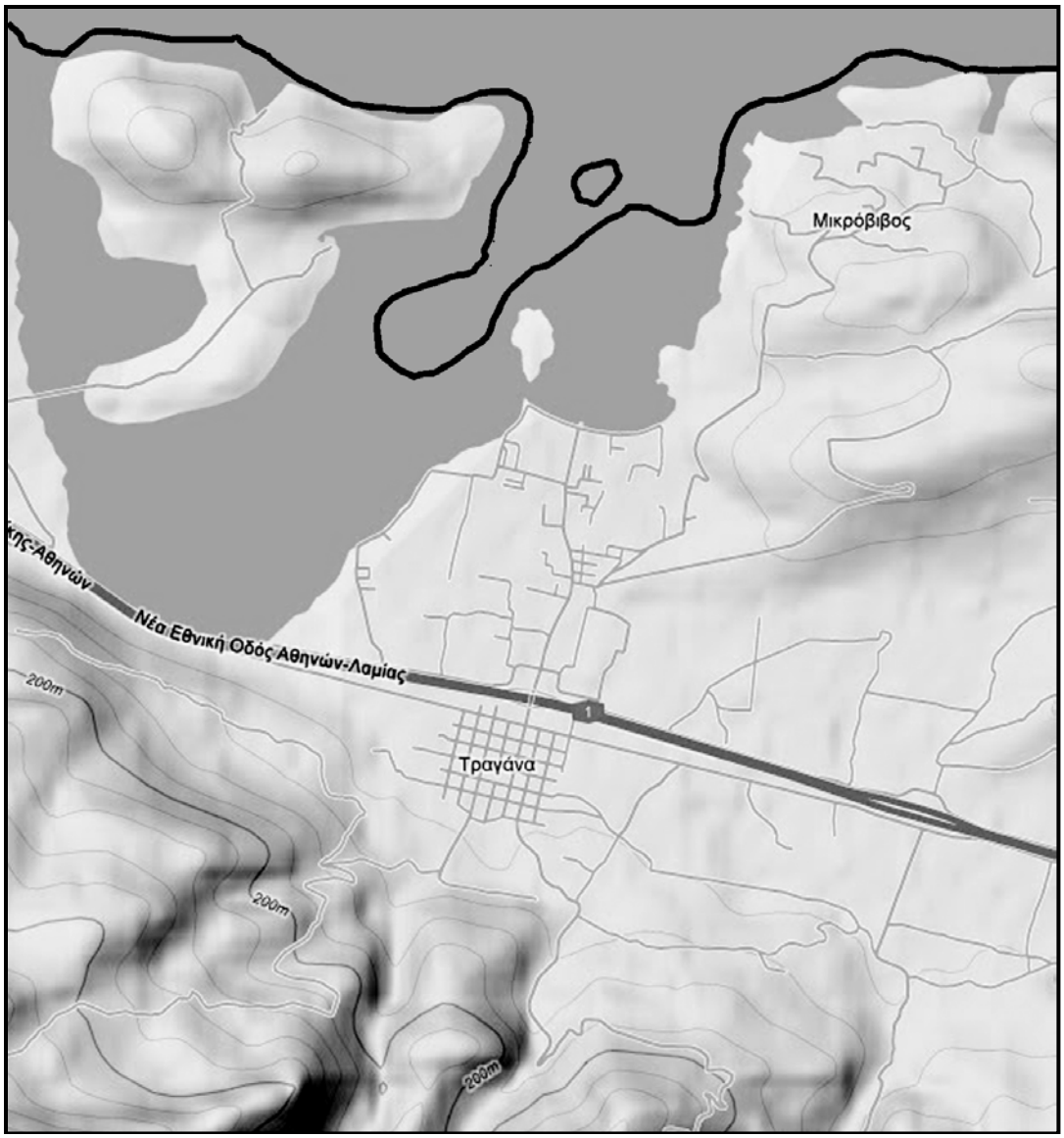

Figure 4 Depiction of coastline during the BA and IA. Black arrow indicates Mitrou. Adapted from Kramer-Hajós (2008)

CHAPTER IV

METHODS

The methods used in this study to replicate the dental samples are presented in this chapter. This is followed by detailed descriptions of how the samples are analyzed using both DMA and DMTA. This study of dental microwear is just one portion of a much larger project currently under way designed to assess the burials recovered during excavations of Mitrou. As stated in chapter 1, diet is a very important part of human culture. The relationship of diet to all other aspects of human culture and health is extremely complex and multidimensional. The methods outlined in this chapter were selected to obtain the information from the available data.

Sample Selection

The samples used in this study are lower second molars (18, 31) or lower third molars (17, 32) (Figure. 5). These were collected during the summer study seasons of 2009 and 2010, and a complete list can be found in Appendix I Due to the fragmentary and incomplete condition of the skeletal collections from Mitrou and Agia Triada, several steps were taken to increase sample size.

First, third molars were used if the second molars were not available. While it is preferable to use only one type of tooth, third molars are acceptable substitutes as no significant difference has been found between second and third molar microwear signatures (Mahoney, 2006b). The second step taken to increase sample was to use both left and right molars; no side preference was given. While there is some evidence that

microwear signatures differ between antimeres, these differences are not significant (Mahoney, 2006b). Crown condition and the developmental stage of the individual were also used to assess the viability the of sample. Finally, the samples had to have relatively clean occlusal surfaces, minimal taphonomic damage, a wear score of three or greater as outlined by Scott (1979), and represent adult dentition.

Of the samples selected, only phase II facets (the grinding facet) were observed during analysis. Phase II facets have been shown to better distinguish differences in diet between primate species in DMA analysis (1979). Phase II facets also tend to show stronger microwear signatures which gives a better representation of diet (Krueger et al., 2008).

Preparation Protocol

The importance of having a clean occlusal surface cannot be overstated. Both the SEM and Confocal microscope view the surface of a sample. If a sample is dirty or coated with an inorganic compound, the occlusal surface will not be observable.

Typical cleaning procedures for DMA samples consist of soaking or swabbing the samples with acetone, allowing them to air dry, swabbing with ethanol, and allowing them to air dry again prior to creating a negative mold (Teaford, 1991). A mild detergent and water may also be used (Bullington, 1991; Galbany et al., 2006; Rose, 1983; Ungar et al., 2006). If an ultrasonic cleaner is not available, it is common practice for researchers to gently swab the samples with cotton or soft fiber (sable) brushes (Rose, 1983).

The samples used in this study were cleaned in a similar manner to those used in other studies, with slight procedural modifications. First, samples were gently swabbed

with cotton soaked in ethanol or acetone. They were then allowed to air dry, at which time a small amount of the impression material was applied to the occlusal surface of the sample.

Coltène-Whaledent President Jet Vinyl Polysiloxane Impression Material (light body) was used in all molding procedures. This coating was allowed to set for 15 minutes. Once the material set, it was removed. The swabbing, drying, and coating of the occlusal surface was then repeated. Ideally, the extra step used in the process outlined above would loosen any remaining debris that the solvents did not remove (Organ et al., 2005; Ungar et al., 2006).

Molding Procedure

After all samples were cleaned and allowed to air dry, they were then molded. If a sample was still in occlusion, the occlusal surfaces of the sample, and any adjacent teeth, were impressed. For loose teeth, the molding material was placed in a small tray and the tooth was gently pushed into the material.

All impressions were allowed to set for an hour. Once the impressions were set, they were then removed from the sample. These molds were subsequently placed in small plastic artifact bags and allowed to de-gas. Two molds were created for each sample. All sample information was recorded in a Microsoft Excel spreadsheet. Each pair of samples was also assigned a random number in order to remove any bias that may occur due to previous knowledge of the sites or burials.

While the impression material is durable and can survive for a number of years only three replicas are made from each impression. Each time an impression is used to create a replica, a small amount of detail is lost. As Galbany and colleagues (2006; for

more information see Teaford et al., 2001; Teaford and Oyen, 1989; Ungar et al., 2006) have shown, there is no significant loss of resolution on the first three replicas made from a mold. The fourth replica, however, has experienced a slight loss of resolution though it is still usable. The fourth replica were not used in this study as any loss of resolution greater than that found on the third replica may bias the results of this research.

Replication Protocol

Replicas were created using Epotek 301 (Epoxy Technologies Corp.). Epotek 301 is a two-component epoxy that is mixed at a four to one ratio of base to hardener, respectively. This epoxy begins to set 45 to 60 minutes after mixing the two components. Regardless of the type of epoxy used to create dental replicas, air bubbles are always an issue that researchers need to anticipate. A number of researchers (Galbany et al., 2006) have outlined a variety of methods for the removal of air bubbles prior to the time the epoxy sets. This study utilized a low vacuum to remove air bubbles from epoxy.

Due to a lack of access to much of the equipment described in other studies, procedures for creating replicas were modified to utilize the equipment available to the author. Component A and component B were mixed at a 4:1 ratio by weight. These two components were stirred briskly for three minutes. The epoxy was then placed in a vacuum between 10 and 15 psi for five minutes. The epoxy was then removed and stirred for another three minutes. At the end of this mixing, the epoxy was then returned to the vacuum for another five minutes. The reason for placing the mixture in the vacuum prior to pouring is because distortion of dental replicas can occur if they are allowed to set for extended periods of time under pressure in a vacuum, and the repeated vacuuming removes air bubbles from the epoxy. At this point, the impressions were filled with the

epoxy using a pipette. The replicas were then allowed to set for 24 hours in a ventilation hood.

The procedures used in this research have been developed through trial and error, and have been used by the author to consistently create accurate dental replicas. Each step in the above procedure is intended to remove much of the air trapped in the epoxy while maintaining the actual dimensions of the sample.

Replicas for both traditional DMA analysis and DMTA were created in the same manner. Each sample will have one replica selected for observation under the SEM and a second replica for observation under the confocal microscope. While neither method is destructive, the preparation (see below) needed for use in each instrument is different.

Scanning Electron Microscopy Preparation and Imaging

All replicas selected for DMA were mounted on aluminum stubs with conductive carbon tape. This is done to ensure the conductivity of the sample. All samples were then sputter coated with ~20 Å of gold palladium (Au/Pd). This is done to decrease charging while the samples are being observed as well as to increase image resolution.

The appropriate cusp of each sample was scanned at a magnification between 100-200x. This allowed for the determination of wear facets that were acceptable for analysis. It is important to select areas that are relatively flat and that do not contain any defects. Defects can include natural mineral deposits, taphonomic wear, or air bubbles that may remain from the mixing procedure. Unfortunately, it is impossible to see with the naked eye all defects that a tooth or replica's surface may contain. If defects were presented in a sample, they only became apparent when the sample was observed under the microscope. Any replica that was found to contain a defect that could not be

overcome was culled from the sample population. Mineral deposits were by far the greatest complicating factor regarding sample selection. An example of this is presented in Figure 6.

Once areas of interest were identified, they were delineated on a scout photomicrograph. The scout photomicrograph was taken at a magnification of 36x and the resulting digital image was saved. This magnification does not allow for great detail, but can capture an image of almost the complete occlusal surface. Each area of interest was delineated with a square and labeled (a1, a2, etc.) using available image editing software.

Once each area had been marked they were then examined at 500x, which is the level of magnification commonly used in DMA research (Bullington, 1991; Homes and Melsheimer, 2008; Ma and Teaford, 2009; Schmidt, 2001). Each area was imaged at this magnification with a resolution of 200 dpi. Multiple photomicrographs were taken of each area. All images were then converted from tiff files to bmp files for use in *Microware* 4.02 (El Zaatari, 2008; Nystrom et al., 2004; Rivals and Deniaux, 2005; Strait, 1993; Teaford et al., 2001; Ungar et al., 2006).

Confocal Microscopy Preparation and Imaging

All confocal imaging was carried out at the University of Indianapolis, using a Sensofar Plμ Confocal Imaging Profiler (Sensofar LLC. Carefree AZ). All samples were mounted on small trays using dental clay. Each sample's facet 9 (phase II grinding facet) was examined at a magnification of 10x to determine if the surface was usable. If a usable surface was identified then the sample was scanned at a magnification of 100x. The Sensofar software automatically scans four adjacent areas and stiches the surfacees

together creating one surface that is 204 x 279 μm. Samples were then leveled using Solarmap Universal software. Each leveled surface was then checked for defects (i.e. dirt, taphonomic damage, or bubbles). If surface defects were observed, they were erased. Optimally, 10% or less of a sample's surface can be modified, but up to 15% of a surface area could be erased and the surface would still be acceptable for study.

DMA Analysis

Once all samples were imaged under the SEM, image files were then converted into a useable format and each image was quantified using Microwear 4.2. The quantification process can be time consuming. The researcher starts by selecting the start point of a feature along the feature's major axis. A mouse is used to select these points. The end point of this axis is then selected, followed by the start and end point of a line across the minor axis. This continues for every feature on a sample's surface. Microwear 4.0 tallies all features and of the feature's metrics and distinguishes between pit and scratch feature. The program considers any feature with a ration of less than 4:1 major to minor axis as a pit and all features with a ratio greater than this to be scratches. This is the default setting for Microwear 4.0.As mentioned above, this method of quantification is very subjective, although it is the standard in the literature. Five variables were used in the DMA analysis: number of features, pit width, scratch width, scratch orientation and the percentage of pits. Definitions can be found in table 2. These are the variables traditionally used in DMA. After each sample was quantified, its random ID was reassociated with its site and demographic information.

At this point I would like to reiterate the hypothesis that were tested. The first hypothesis tested all samples to determine if there is any diachronic variation from the

Late Helladic (LH) to the Protogeometric (PG) period. The second hypothesis to be tested used only LH samples from each site in order to determine if any variation existed between the two sites. The third hypothesis tested all palatial samples against all Post-palatial samples to determine if a difference exists. The final hypothesis grouped all samples by site regardless of period and tested them against each other to ascertain if the microwear signature between the two sites differ significantly. All samples were tested for normality (Shapiro and Wilk, 1965), to determine if they could be tested using basic parametric forms of analysis. For hypothesis one, a one-way ANOVA test was used. ANOVA was utilized because of its ability to examine variation in multiple groups that are normally distributed. Hypothesis two and three were tested using simple t-tests. A t-test was selected due to its ability to work well with small samples (n=19). Intra-observer error was checked for using the protocol outlined in Buikstra and Ubelaker (1994), and no significant error was found. More specifically, samples were quantified, and then one month later 20% of these samples were selected at random and recoded. These samples were recoded again two weeks later. An ANOVA was then used to test these samples to determine if any significant difference existed between the original scoring of each sample, and the subsequent scores. The results of the ANOVA test indicated that no significant difference or error was found.

DMTA Analysis

For all samples observed with the confocal, there was no need to manually quantify them as described for DMA because *ToothFrax* and *SFrax* automatically quantifies all parameters. The quantification is done using scale sensitive fractal analysis (SSFA). SSFA functions on the basic principle that a feature's metrics (length, depth,

width) vary based on scale (Krueger, 2011; Scott et al., 2006; Scott et al., 2005). These changes in scale can be a change at which the sample is observed, or the scale of the fractals. DMTA also quantifies different variables than DMA, such as scale of maximum complexity. These are described below. For this analysis, six variables (see Table 2) were observed per sample and each variable is discussed in detail in the following section.

DMTA Variables

Exact proportion Length-scale anisotropy of relief (epLsar)

Exact proportion Length-scale anisotropy of relief (epLsar) referred to in this document as anisotropy or epLsar is a measurement of surface direction (El Zaatari, 2007; Krueger, 2011; Scott et al., 2006; Scott et al., 2005). This variable was calculated in *ToothFrax*, using a length-scale rotational algorithm (Scott, 2010). In the most basic of forms epLsar is calculated by taking the relative length of microwear features at different orientations in 5° intervals from 0° to 180°. Each of these 36 lengths are vectors which are normalized by dividing them by the sum of all lengths (El Zaatari, 2007). In general terms, epLsar is the mean vector length at a chosen scale. In this study, the chosen scale is 1.8 μm, as this is a scale commonly used in other studies (El Zaatari, 2007; Scott, 2010; Scott et al., 2006; Scott et al., 2005). A sample with a high epLsar would have a high number of parallel linear features (Scott et al., 2009). The variable epLsar has been used to distinguish between diet that contain tough materials and those that contained hard material (Scott et al., 2012).

Textural fill volume (Tfv)

Textural fill volume (Tfv) was quantified using the Rob – Volume Scale plug in found in *SFrax* (Scott, 2010; Scott et al., 2006). This parameter is a derivative of a sample's volume. *SFrax* calculates this variable by filling all surface depressions with rectangular cuboids (square or rectangular) of a known size. Tfv is estimated by finding the difference between the structural fill volume and Ctfv, which is a finer scale of fill (Scott, 2010). For this analysis, Sfv was set to 10, Ctfv to 2, and Ftfv was set to 0.2. The values for Sfv and Ftfv are also the default setting for these variables (Scott, 2010). A surface with deep pits would have a larger Tfv than a surface with fewer pits or a surface with shallow pits (Scott et al., 2009).

Complexity (Asfc)

The variable Complexity (Asfc) or area scale fractal complexity is a measure of surface variability at differing scales of observation (Scott et al., 2006; Scott et al., 2005). This variable was calculated in *ToothFrax* using the scale-tiling algorithm. This algorithm uses different sized triangular fractals, larger at increased scales and smaller at finer scales. The total area of these triangles is summed and then the quotient of the area and the planimetric area is found. This value is the relative area of the sample. A log-log plot of the relative area for the scale range is then plotted and multiplied by -1000. The steepest slope of this line is the value for the variable Asfc (El Zaatari, 2007; Krueger, 2011; Scott et al., 2006; Scott et al., 2005). The scale used in this study to determine Asfc ranges between 7200 μm^2 and 0.02 μm^2, as these are common values used (El Zaatari, 2007; Krueger, 2011; Scott, 2010; Scott et al., 2006; Scott et al., 2005). A sample with overlying microwear features would have an increased complexity (Scott et al., 2009). As suggested by Scott et al. (2005) and Scott et al. (2009) this parameter is useful

for distinguishing primates that eat hard brittle material and those that consume though material. This variable has been found to distinguish between diets containing hard brittle materials (Scott et al., 2012)

Scale of maximum complexity (Smc)

Scale of maximum complexity (Smc) is the value for the scale of observation where the surface has the greatest degree of complexity (El Zaatari, 2007; Scott et al., 2009; Scott et al., 2006) This parameter is calculated in *ToothFrax*, and is listed as start of line in the results output file (Scott, 2010).

Heterogeneity (HAsfc)

The parameter heterogeneity or HAsfc is a measure of variability across a sample's surface (El Zaatari, 2007; Scott et al., 2009; Scott et al., 2006; Scott et al., 2005). The algorithm used to determine this variable is found in *ToothFrax*. It is initiated by selecting the Auto-split function. By selecting this option each surface is divided into an even number of rows and columns starting at 2 x 2 all the way to 11 x 11 (Scott et al., 2009). For example, a 3 x 3 would have a total of nine surfaces, hence HAsfc9. HAsfc9 and HAsfc81 are commonly used variations of this variable, and both are used in this study (Krueger, 2011; Scott et al., 2009). I calculated this variable using simple arithmetic in Microsoft Excel. This variable is found by determining the quotient of the median absolute deviation of the parameter Asfc for each surface and the median Asfc of a sample (El Zaatari, 2007; Scott, 2010). HAsfc is used to determine variation of microwear across a sample's surface. HAsfc is potentially related to the size and variability of a samples diet (Scott et al., 2012)

To address the issue of diachronic variation stated in hypothesis one, the variables Tfv, HAfsc81, epLsar, and Asfc were tested using a One-way ANOVA test to determine significance. ANOVA was selected due to its ability to test for variation within and between more than two groups. For the non-normality distributed variables Smc and HAsfc9 were tested using a Kruskal–Wallis test. This test was selected because an assumption of normality is not needed and for the test's ability to test for statistical differences in more than two groups. All other hypotheses were tested using independent sample t-tests, and Mann-Whitney U tests. These forms of statistical testing were utilized due to their ability to work well with small samples (n=19), and, in the case of Mann-Whitney U, its ability to work with data that does not conform to a normal distribution.

Table 1 DMA variables.

Variable	Definition	Calculation
Number of features	The total number of quantified pits and scratches.	Tallied by Microwear.
Pit width	The mean width of all pit features quantified on a sample.	Calculated by Microwear.
Scratch width	The mean width of all scratch features quantified on a sample.	Calculated by Microwear.
Scratch orientation	Mean orientation of major axis of all quantified scratch feature .	Calculated by Microwear.
Percent of pit features	The percent of total features that are quantified by Microwear to be pit features.	Calculated in Microsoft Excel.

Table 2 Explanation of DMTA variables.

Variable	Definition	Calculation
Anisotropy (epLsar)	Anisotropy is used a measure of concentration of parallel features (Ungar et al. 2008b).	Anisotropy is determined by measuring the difference in the length of depth profiles of microwear features. The surface is sampled across 180° at 5°intervals at a chosen scale (Scott et al. 2006; Ungar et al. 2008b). These measurements are then normalized as vectors and a mean vector length is then calculated (Ungar et al. 2008b).epLsar is calculated in *ToothFrax* using a length-scale rotational algorithm (Krueger, 2011) .
Complexity (Asfc)	Complexity is measuring roughness at a specific scale. Asfc is used to distinguish between hard, brittle food sources and tough food sources (Scott et al. 2005; Ungar et al. 2003a).	This variable is calculated in *ToothFrax* using the area-scale tiling algorithm (Krueger, 2011).
Texture fill volume (Tfv)	Texture fill volume is a variable that has been used to determine the volume of enamel removed by microwear, as well as the texture of the ingested material (El Zaatari 2007).	Texture fill volume is calculated by summing the number of cubes that can fill a samples surface (Ungar et al. 2008b). Tfv is calculated using the Rob – Volume Scale plug in found in *SFrax* (Scott, 2010)
Heterogeneity (HAsfc)	HAsfc describes how variable a samples surface is.	HAsfc is found by dividing the median absolute deviation of Asfc by the median of a sample (El Zaatari, 2007).Parameter was calculated using *ToothFrax* and Microsoft Excel (Scott, 2010)
Scale of maximum complexity (Smc)	Scale of maximum complexity is the scale when the samples surface is observed to be most complex (El Zaatari 2007). This variable has been used to infer the size of food and abrasive material creating microwear features (El Zaatari et al. 2010) .	Scale of maximum complexity is the scale when the samples surface is observed to be most complex (El Zaatari 2007). Scale of maximum, complexity was calculated using *ToothFrax* (Scott, 2010)

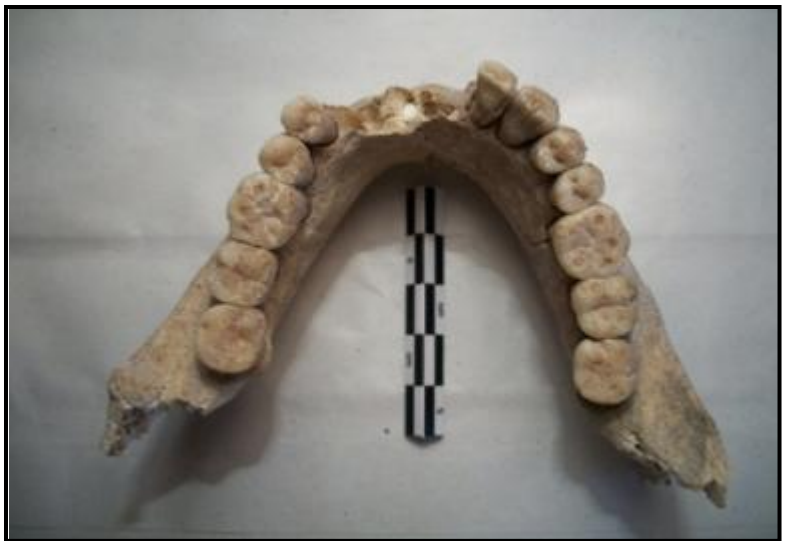

Figure 5 Mandible from LN783-577-011B (Mitrou). Black Arrows indicate anatomical position of samples.

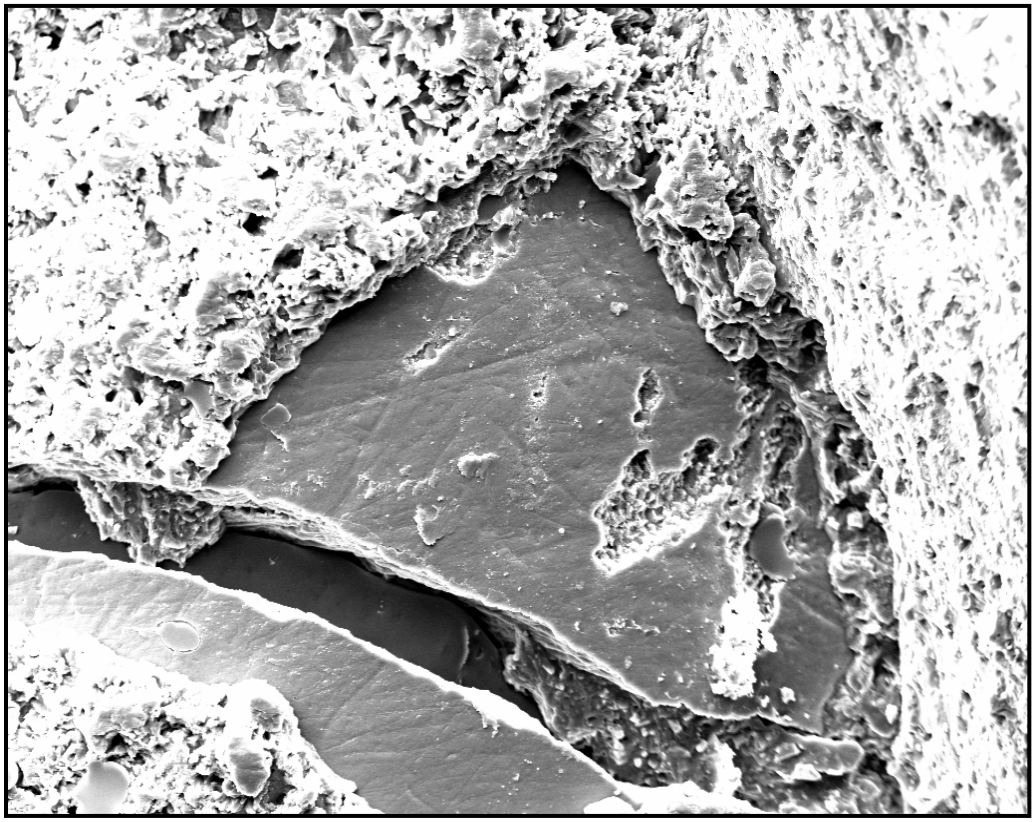

Figure 6 Example of mineral deposits adhering to a sample. Black arrow points to mineral deposits and red arrow points to tooth surface

Figure 7 Micrograph of a sample taken at a magnification of 500x with an SEM. Black arrows indicate pit features. Red arrows indicate scratch features.

Figure 8 Sample 158. Example of a sample's surface captured with Sensofar Plµ Confocal Imaging Profiler.

CHAPTER V

RESULTS

In this chapter, the results of all analyses are presented in detail. The results of the four hypotheses testing DMA are presented first, followed by the results from the DMTA analyses. Each section presents the summary statistics, the statistical test used, and the test results. In this research, the level of significance is $p = .1$. The author made this decision because of the total sample size is small (not greater than 19 for any analysis) and because the variable nature of the parameters used in DMA and DMTA. All DMA and DMTA variables were checked for normality using a Shapiro-Wilk test (Shapiro and Wilk, 1965). None of the DMA variables exhibited a significant deviation from a normal distribution. Two DMTA variables, Smc and HAsfc9, deviate significantly from a normal distribution. These variables were examined using non-parametric statistical tests.

DMA Results

The first hypothesis was tested by dividing the samples into three groups according to period, as shown in table 3. The results of a one-way ANOVA are presented in table 4. When the samples are aggregated into their respective periods, no significant difference was found between any of the groups. These findings suggest that there is no significant difference in the microwear signature of samples belonging to the three chronological periods in this study. This may reflect the homogenous nature of BA and IA diets found in isotope studies based on samples from other contemporaneous mainland

Greek sites (Heaton et al., 2009; Ingvarsson-Sundström et al., 2009; Papathanasiou, 2003; Patroutsa et al., 2009; Petroutsa and Manolis, 2010).

Hypothesis two was tested to determine if there was any significant variation in the LH samples from both sites. Sample size is presented in table 5 and the results of this t-test are show in table 6. Only two variables, number of pits and percent of pits, were significantly different between the two samples. As table 5 shows, the *p* value for both percent and number of pits is below .1, which is the significance level used in this analysis. As is demonstrated by table 6 there are some noticeable differences. The LH IIIC samples from Agia Triada have a higher mean number of features and pits, while the Late Helladic samples from Mitrou have a higher number of scratches.

The third hypothesis examined all samples (see table 7), segregated by site, with no regard for chronological period. The results from a simple t-test (see Table 8) indicate that all variables, with the exception of percentage and number of pits, are not significant. This is displayed visually in Figure 11, a box plot that shows a higher mean and a tighter plotting for the Agia Triada samples.

Like hypotheses two and three, hypothesis four was tested using an independent sample t-test. All samples prior to LH IIIC were classified as palatial and all those from LH IIIC or PG were considered post-palatial (see table 9). The results are presented in table 10. As indicated, the only variable that is significant is pit width.

DMTA Results

Prior to analysis, DMTA variables were tested to determine if they conformed to a normal distribution (Shapiro and Wilk, 1965). Two variables, Smc and Asfc9 (table 11)

were not normally distributed and these variables were evaluated using non-parametric forms of testing.

It is important to note that the results for Tfv are extremely high compared to results published in other studies (e.g. El Zaatari, 2007; Krueger, 2011; Scott et al., 2009). A direct cause of this was not determined, but it is possible that taphonomic factors are, potentially influencing the results.

The first hypothesis was tested using a one-way ANOVA for normally distributed variables and a Kruskal-Wallis test for those that were not. All samples were segregated into their respective period (i.e. LH, LH IIIC and PG), and compared against each other. The results of the statistical test are shown in Table 12 and table 13. The results of this analysis shows no significant difference between any variable for each period. Sample size and summary statistics are provided in Table 14.

Hypothesis two was tested using an independent sample *t-test* for all normally distributed variables and a Mann-Whitney U test for those that were found not to conform. As indicated by table 15 and table 16, no significant difference was found between the LH samples from Mitrou and the LH IIIC samples from Agia Triada. Although no statistically significant difference was found, it is interesting to note that the mean value for Tfv for the LH IIIC samples (40067.44) is nearly double that found for the LH samples (21380.79). All summary statistics are presented in table 17. This indicates that while a significant difference does not exist; the general trend of a coarsening of the texture of the diet is also found in this analysis.

An independent sample *t-test* and a Mann-Whitney U test were also used to test hypothesis three. As stated in chapter 1 this hypothesis was tested to determine if there was any significant difference between the Agia Triada samples and the Mitrou samples,

regardless of chronological period. When these samples were tested, no significant difference was found between the two samples (tables 18 and 19). Descriptive statistics are presented in table 20.

As with hypotheses two and three, the fourth hypothesis was tested using an independent sample *t-test* and a Mann-Whitney U test (table 21). The results of the Mann-Whitney U test indicate that the only variable, that is significantly different between third palatial samples and post-palatial samples, is the variable Tfv (table 22). As mentioned above, all results for this variable must be viewed with a degree of caution. As is shown in table 23 and graphically in Figure 14, the mean value for Tfv is substantially higher for the Post-palatial samples. These results indicate that the palatial samples have a more planar surface than the post-palatial samples. This suggests that the dietary texture of the post-palatial samples was more coarse then earlier palatial samples.

Table 3 Summary statistics for samples by chronological periods.

Period (n)	Statistic	Number of features	Number of pits	Pit width	Scratch width	Percent of pit features
LH (11)	Mean	221.00	94.13	3.26	1.60	0.37
	Std. Deviation	95.34	71.16	0.77	0.20	0.19
	Median	210.00	74.50	3.42	1.59	0.38
	Std error	33.71	25.16	0.27	0.07	0.07
LH IIIC (5)	Mean	291.40	182.60	2.62	1.57	0.59
	Std. Deviation	118.38	103.46	0.66	0.20	0.15
	Median	234.00	154.00	2.54	1.62	0.62
	Std error	52.94	46.27	0.30	0.09	0.07
PG (3)	Mean	241.00	102.67	2.67	1.57	0.40
	Std. Deviation	81.18	64.45	0.52	0.06	0.12
	Median	222.00	77.00	2.87	1.58	0.35
	Std error	46.87	37.21	0.30	0.03	0.07

Table 4 Results of one-way ANOVA test for significance between periods.

Variable	Sum of Squares	d.f.	Mean of Square	F	Significance
Number of features	15371.80	2	7685.90	0.75	0.491
Number of pits	25669.01	2	12834.50	1.92	0.185
Pit width	1.54	2	0.77	1.56	0.247
Scratch Length	55.38	2	27.69	0.70	0.512
Percent of pits	0.15	2	0.08	2.66	0.107

Table 5 Summary statistics for all Late Helladic samples, grouped by site.

Date General	Statistic	Number of features	Number of pits	Pit width	Scratch width	Percent of pit features
LH (11)	Mean	221.00	94.13	3.26	1.60	0.37
	Std. Dev.	95.34	71.16	0.77	0.20	0.19
	Median	210.00	74.50	3.42	1.59	0.38
	Std error	33.71	25.16	0.27	0.07	0.07
LH IIIC (5)	Mean	291.40	182.60	2.62	1.57	0.59
	Std. Dev.	118.38	103.46	0.66	0.20	0.15
	Median	234.00	154.00	2.54	1.62	0.62
	Std error	52.94	46.27	0.30	0.09	0.07

Table 6 Results of t-test of Mitrou LH samples against Agia Triada LH IIIC samples.

Variables	T	d.f.	Sig. (2-tailed)
Number of features	-1.18	11	0.261
Number of pits	-1.84	11	**0.093**
Pit width	1.538	11	0.152
Scratch width	0.309	11	0.763
Percent of pits	-2.14	11	**0.055**

Table 7 Summary statistics for all samples grouped by site.

Site	Statistic	Number of features	Number of pits	Pit Width	Scratch width	Frequency of pit features
Agia Triada (5)	Mean	291.40	182.60	2.62	1.57	0.59
	Std. Dev.	118.38	103.46	0.66	0.20	0.15
	Median	234.00	154.00	2.54	1.62	0.62
	Std error	52.94	46.27	0.30	0.09	0.07
Mitrou (13)	Mean	226.45	96.45	3.10	1.59	0.38
	Std. Dev.	88.14	66.27	0.74	0.17	0.17
	Median	214.00	77.00	3.07	1.58	0.35
	Std error	26.57	19.98	0.22	0.05	0.05

Table 8 Results of t-test testing all samples from each site.

Variable	t	d.f.	Sig. (2-tailed)
Number of features	-1.23	14	0.238
Number of pits	-2.03	14	**0.062**
Pit width	1.25	14	0.232
Scratch width	0.28	14	0.786
Percentage of pit features	-2.38	14	**0.032**

Table 9 Summary statistics for all samples grouped into palatial and post-palatial.

Period (n)	Statistic	Number of features	Number of pits	Pit width	Scratch With	Percent Pits
Palatial (10)	Mean	221.00	94.13	3.26	1.60	0.37
	Std. Dev	95.34	71.16	0.77	0.20	0.19
	Median	210.00	74.50	3.42	1.59	0.38
	Std error	33.71	25.16	0.27	0.07	0.07
Post-palatial (8)	Mean	272.50	152.63	2.64	1.57	0.52
	Std. Dev.	102.82	94.95	0.57	0.16	0.16
	Median	228.00	133.00	2.61	1.60	0.52
	Std error	36.35	33.57	0.20	0.06	0.06

Table 10 Results of t-test for palatial and post-palatial samples

Variable	t	d.f.	Sig. (2-tailed)
Number of features	-1.039	14	.316
Number of pits	-1.394	14	.185
Pit width	1.828	14	**.089**
Scratch width	.378	14	.711
Percent of pit features	-1.634	14	.125

Table 11 Results of Shapiro-Wilk test of normality for DMTA variables.

	Shapiro-Wilk		
Variable	Statistic	d.f.	Sig.
Asfc	.940	18	.285
epLsar	.962	18	.650
Tfv	.964	18	.679
Smc	.825	18	.004
HAsfc9	.879	18	.025
HAsfc81	.956	18	.527

Table 12 Results of ANOVA test.

Variables	F	Sig.
Asfc	.583	.571
epLsar	1.088	.362
Tfv	1.888	.186
HAsfc	.717	.504
Ranked Smc	.083	.921

Table 13 Results of Kruskal-Wallis test for non-normally distributed variables.

Variable	Sig.
Smc	0.911
HAsfc9	0.919

Table 14 Summary Statistics for DMTA variables grouped by chronological period.

Period (n)	Statistic	Asfc	Smc	epLsar	Tfv	HAsfc9	HAsfc81
LH (3)	Mean	1.136	1.409	0.0044	21380.79	0.394	0.833
	Std. Dev.	0.322	0.550	0.0014	5586.64	0.165	0.239
	Median	1.122	1.373	0.0052	21887.96	0.397	0.868
	Std error	0.186	0.317	0.0008	3225.45	0.095	0.138
LH IIIC (11)	Mean	1.139	1.412	0.0037	40067.44	0.374	0.743
	Std. Dev.	0.417	0.053	0.0018	18692.92	0.126	0.130
	Median	1.166	1.373	0.0039	45511.94	0.361	0.796
	Std error	0.126	0.160	0.0005	5636.13	0.0381	0.039
PG (4)	Mean	1.369	1.400	0.0027	43504.94	0.476	0.682
	Std. Dev.	0.237	0.449	0.0007	11511.84	0.339	0.204
	Median	1.369	1.372	0.0027	46787.39	0.397	0.775
	Std error	0.118	0.224	0.0004	5755.92	0.169	0.102

Table 15 Independent sample t-test results for Late Helladic samples.

Variable	t	d.f.	Sig. (2-tailed)
Asfc	-0.01	12	.989
epLsar	0.68	12	.512
Tfv	-1.67	12	.121
HAsfc81	0.90	12	.385

Table 16 Results of Mann-Whitney U test for Late Helladic samples.

Variable	Sig.
Smc	0.875
HAsfc9	0.815

Table 17 Descriptive Statistics for LH samples and LH IIIC samples.

Site (n)	Statistic	Asfc	Smc	epLsar	Tfv	HAsfc9	HAsfc 81
Mitrou LH (3)	Mean	1.136	1.409	0.0044	21380.79	0.394	0.833
	Std. Dev.	0.322	0.550	0.0014	5586.64	0.165	0.239
	Median	1.122	1.373	0.0052	21887.96	0.397	0.868
	Std error	0.186	0.317	0.0008	3225.45	0.095	0.138
Agia Triada LH IIIC (11)	Mean	1.139	1.412	0.0037	40067.44	0.374	0.743
	Std. Dev.	0.417	0.053	0.0018	18692.92	0.126	0.130
	Median	1.166	1.373	0.0039	45511.94	0.361	0.796
	Std error	0.126	0.160	0.0005	5636.13	0.0381	0.039

Table 18 Results of independent sample t-test for hypothesis three

Varibles	t	d.f.	Sig. (2-tailed)
Asfc1om	.720	16	.482
epLsar	-.297	16	.770
Tfv	-.722	16	.481
HAsfc81	.052	16	.959

Table 19 Results of Mann-Whitney testing samples by site.

Variable	Sig.
Smc	0.765
HAsfc9	0.859

Table 20 Descriptive statistics for all samples grouped by site.

Site(n)	Statistic	Asfc	Smc	epLsar	Tfv	HAsfc9	HAsfc 81
Mitrou (7)	Mean	1.269	1.404	0.0035	34023.16	0.441	0.747
	Std. Dev.	0.280	0.449	0.0013	14714.47	0.261	0.215
	Median	1.227	1.372	0.0028	27007.08	0.397	0.798
	Std error	0.106	0.170	0.0005	5561.55	0.100	0.081
Tragana Agia Triada (11)	Mean	1.139	1.412	0.0037	40067.44	0.374	0.743
	Std. Dev.	0.417	0.053	0.0018	18692.92	0.126	0.130
	Median	1.166	1.373	0.0039	45511.94	0.361	0.796
	Std error	0.126	0.160	0.0005	5636.13	0.0381	0.039

Table 21 Results of Mann-Whitney U test for all samples grouped by site.

Variable	Sig.
Smc	0.927
HAsfc9	0.684

Table 22 Results of independent sample t-test four hypotheses four.

Variables	t	d.f.	Sig. (2-tailed)
Asfc	-.271	16	.790
epLsar	1.018	16	.324
Tfv	-1.963	16	**.067**
HAsfc81	1.040	16	.314

Table 23 Descriptive statistics for samples grouped by palatial period.

Period(n)	Statistic	Asfc	Smc	epLsar	Tfv	HAsfc9	HAsfc81
Palatial (3)	Mean	1.136	1.409	0.0044	21380.79	0.394	0.833
	Std. Dev.	0.322	0.550	0.0014	5586.64	0.165	0.239
	Median	1.122	1.373	0.0052	21887.96	0.397	0.868
	Std error	0.186	0.317	0.0008	3225.45	0.095	0.138
Post-palatial (15)	Mean	1.201	1.409	0.0034	40984.10	0.402	0.727
	Std. Dev.	0.384	0.494	0.0016	16747.03	0.195	0.148
	Median	1.227	1.372	0.0036	45511.94	0.366	0.796
	Std. error	0.099	0.127	0.0004	4324.06	0.050	0.038

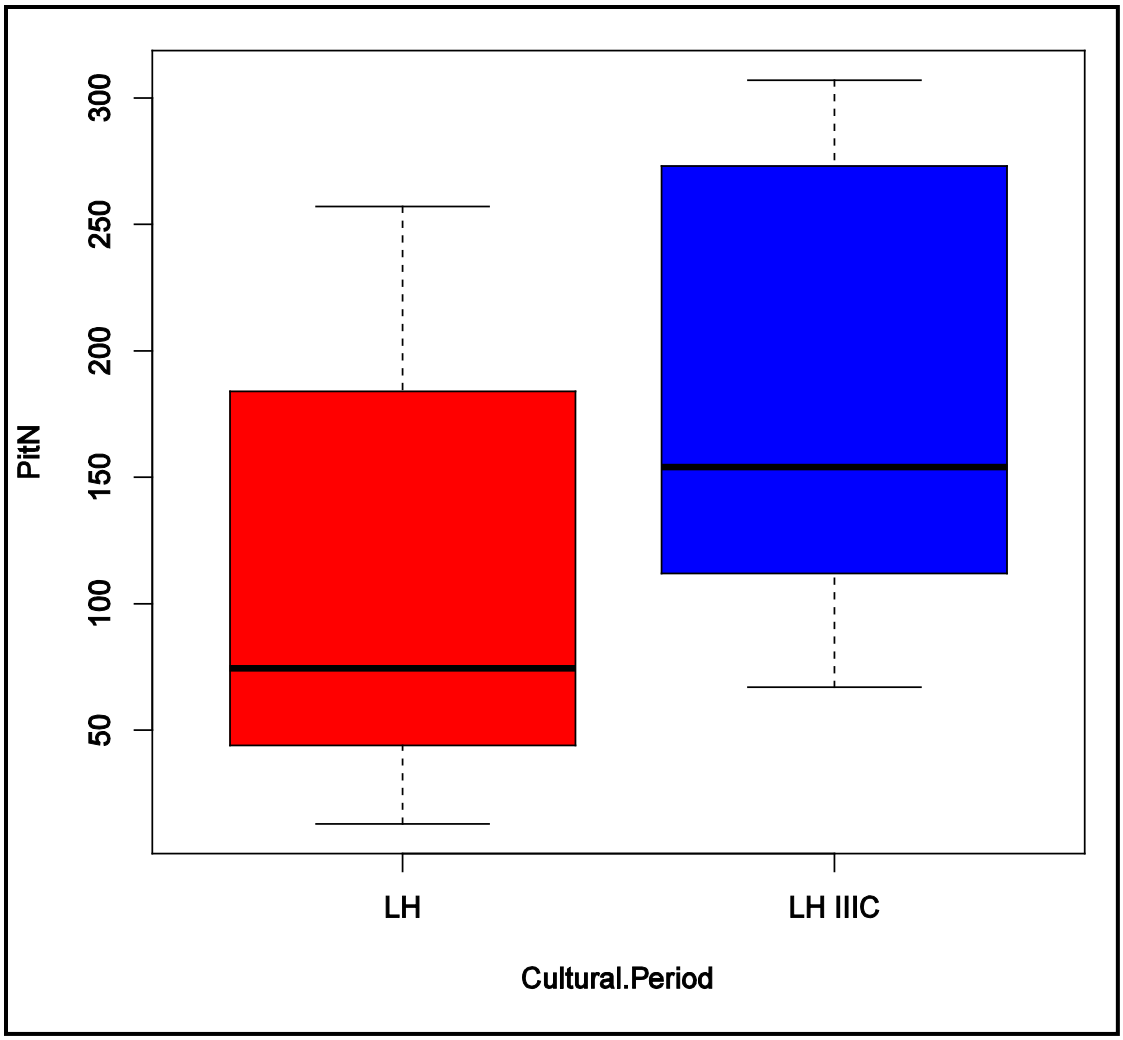

Figure 9 Mean number of pit features for LH samples

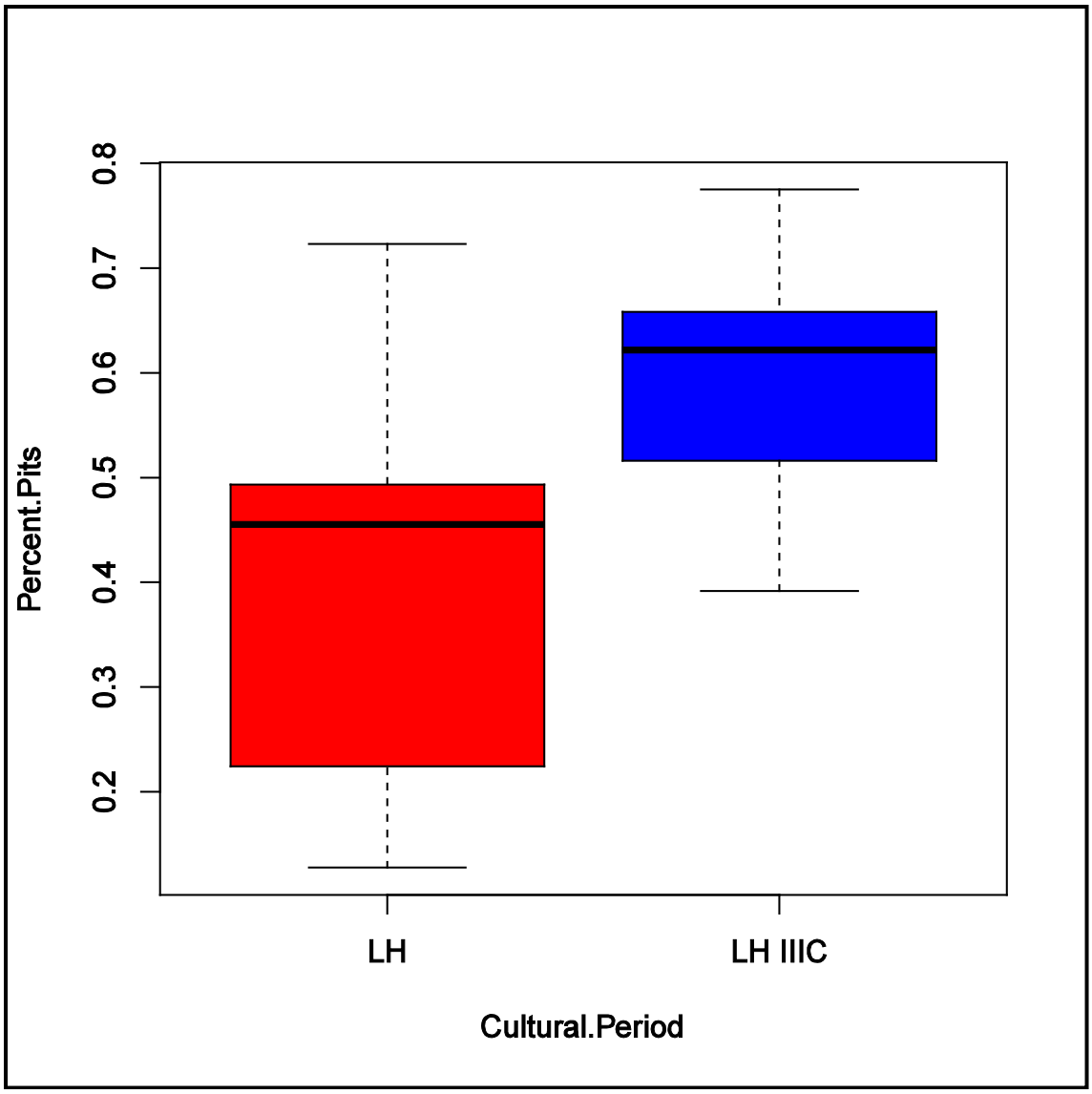

Figure 10 Mean percent of pit features for LH samples.

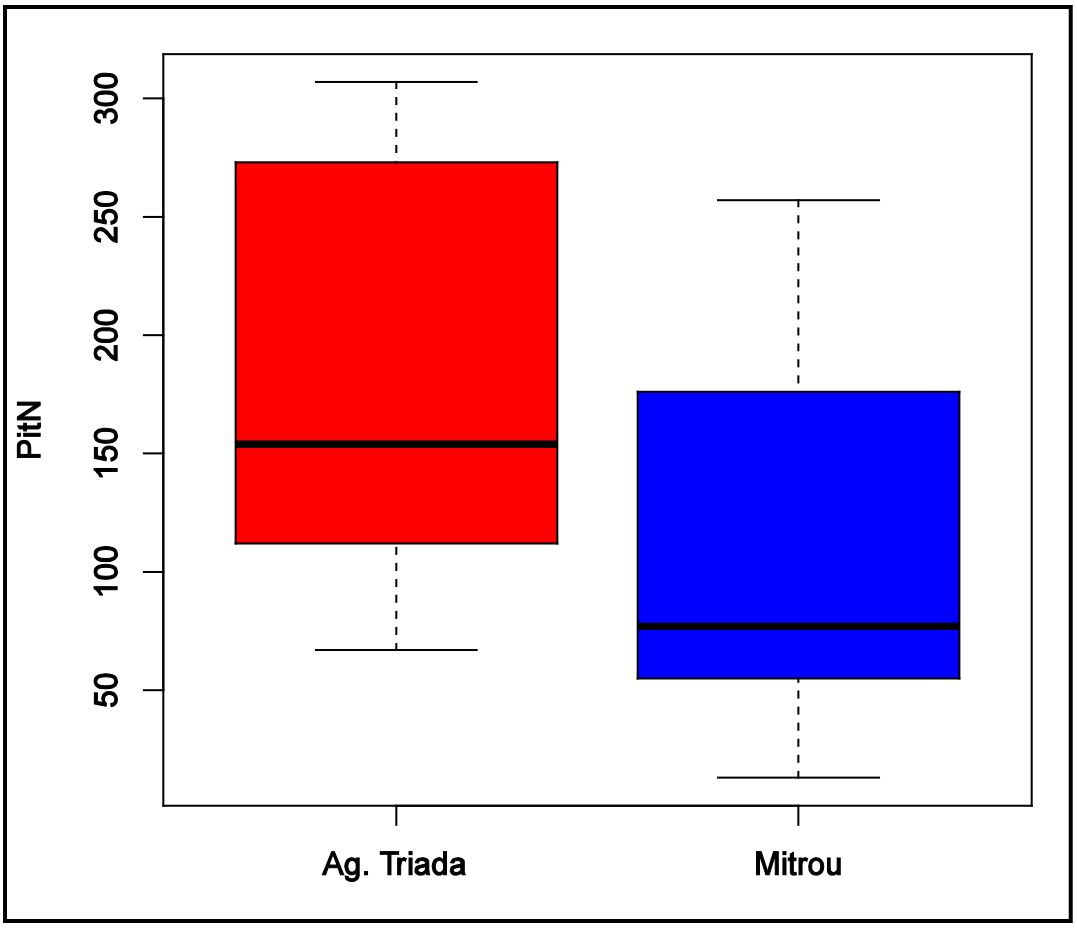

Figure 11 Mean number of pit features for each site.

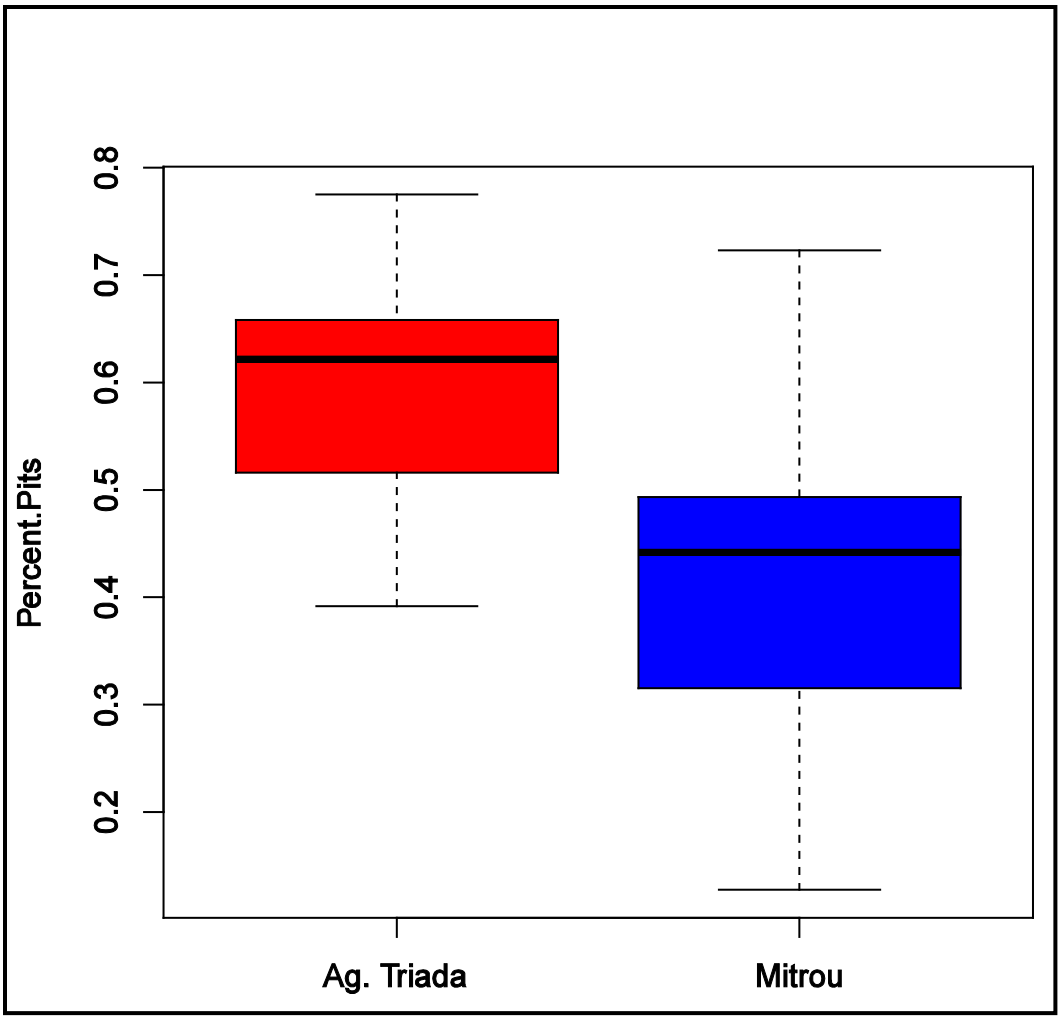

Figure 12 Mean percentage of pit features for each site.

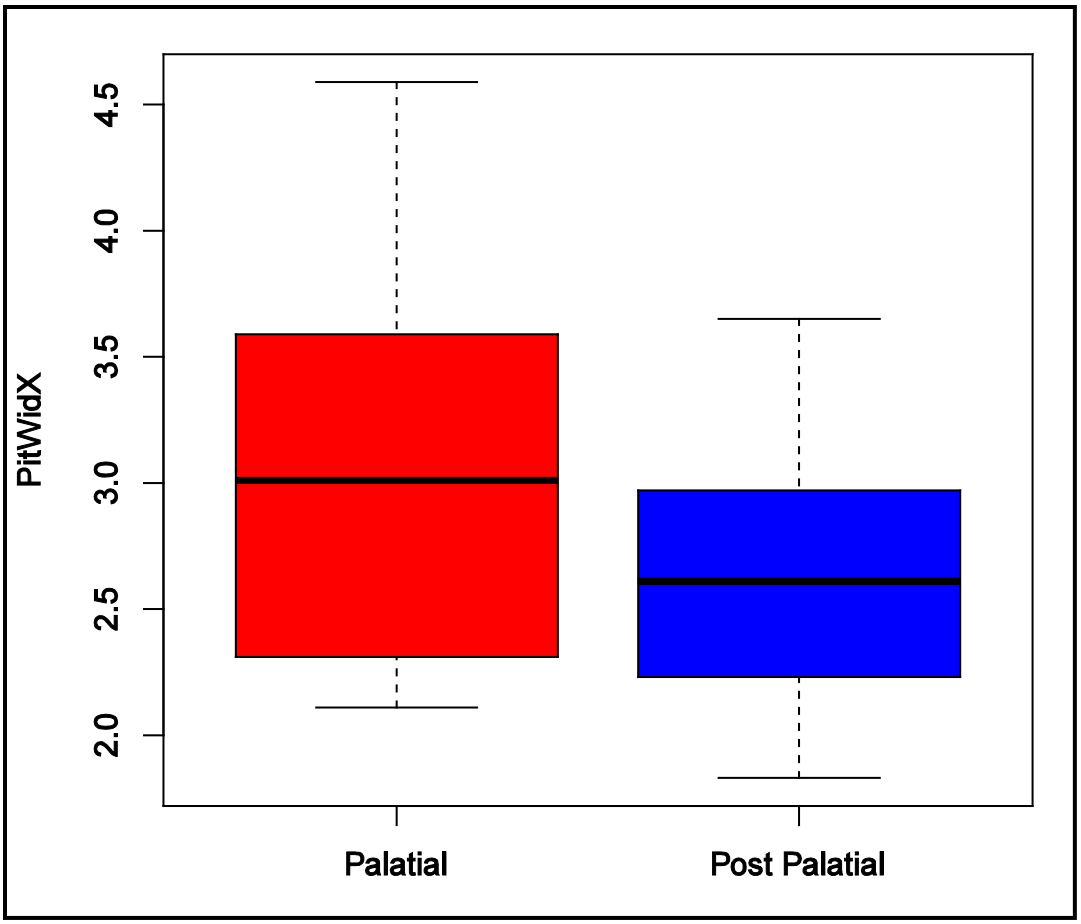

Figure 13 Mean pit width by palatial period.

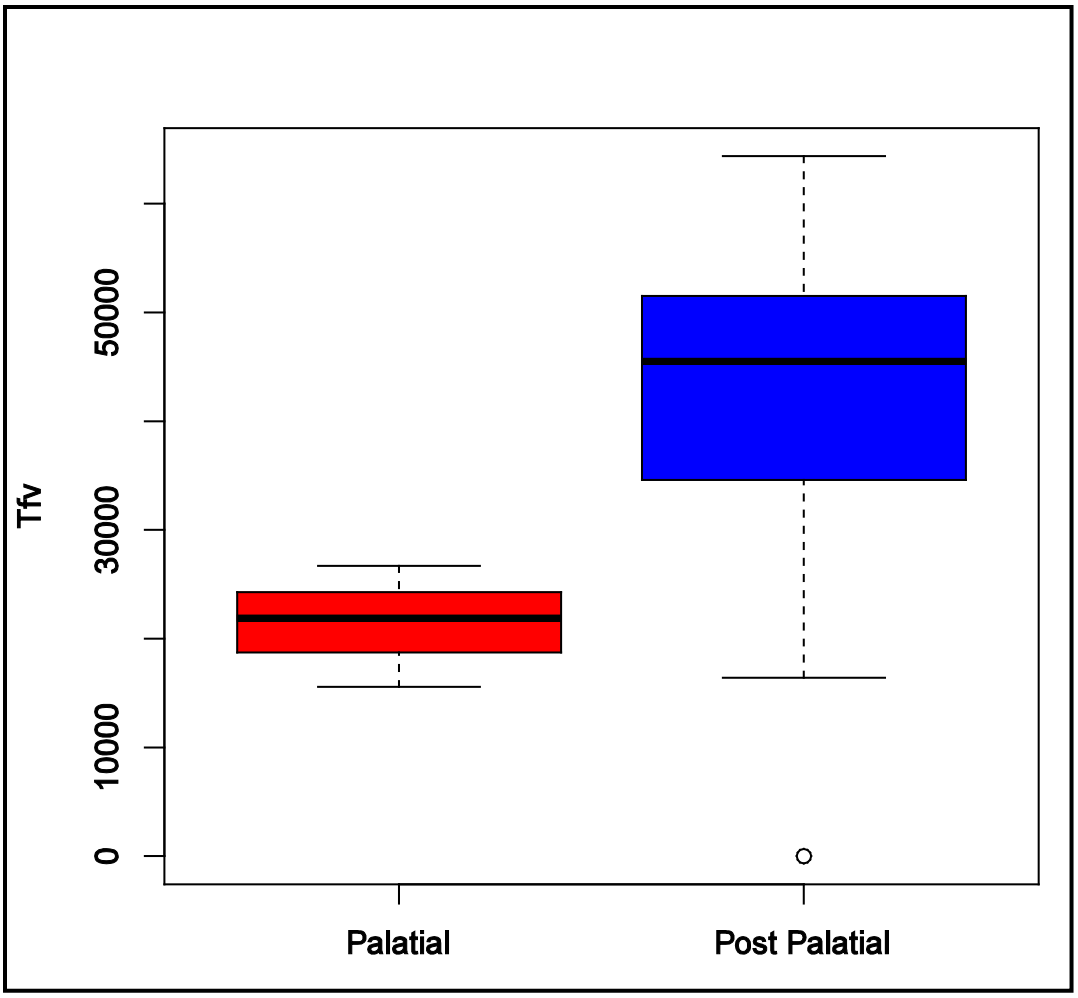

Figure 14 Mean Tfv values for samples by palatial period.

CHAPTER VI

DISCUSSION

This chapter is presented in three parts. The first and second sections address the results of the DMA and DMTA analyses, respectively. The third section discuses patterns found in both analytical methods.

Dental Microware Analysis

The results of the DMA analyses suggest two general trends. The first indicates that there is a general coarsening in the texture of the diet. The direct cause of this increase in coarseness is due to a greater proportion of hard brittle particles in the diet. This is seen from the LH period into the LH IIIC period. An increase in coarseness, in the form of an increase in number of pit features and percent of pit features is also seen from the palatial period (all Mitrou samples prior to the LH IIIC period) into the post-palatial period (LH IIIC and PG samples).

The second general trend deals with the overall size of the particles that cause the formation of pits. As the overall coarseness of the diet increased, the overall pit width decreased. The variable pit width is associated with the size of the hard brittle constituents of the diet.

Generally, two different phenomena can cause the trends mentioned above. The first, and most obvious, is a change in what types of food resources are included in the diet. If a food is added to or removed from the dietary menu, it can modify the intrinsic

particles included in the diet. This can change the texture of a sample's diet and thus potentially alter the associated microwear signature.

The second potential cause is a change in food preparation. Food preparation is understood here as all forms of washing, processing and cooking that a specific food item goes through when obtained and prepared by a human with the intent of consumption. This includes, but is not limited to grinding, drying, smoking, butchering, cleaning, picking, broiling, baking, and roasting of a food item once procured. All food preparation has the potential to add extrinsic material into the diet and alter dietary textures and microwear signatures.

While DMA does not have the ability to determine the cause or causes for any changes indicated by the analysis, with the aid of the samples' context it can allow inferences to be made about the diet of the individuals from which the samples were derived. Both archaeological and chemical evidence will be used to investigate the most likely cause of the trends identified above.

Although the ethnobotanical studies have suggested that the EBA saw an increase in the number of plant species found at sites, a number of chemical studies indicate that the diet during the BA and EIA on mainland Greece remained rather homogenous. (Heaton et al., 2009; Ingvarsson-Sundström et al., 2009; Patroutsa et al., 2009; Petroutsa and Manolis, 2010; Triantaphyllou et al., 2008). It is therefore unlikely that differences revealed in this study can be explained by a change in the types of food consumed.

The LH phase witnessed both the rise and fall of Mycenaean socio-political centers. As the major palatial center collapsed, the trade networks associated with them shrank (Deger-Jalkotzy, 2008; Dickinson, 2006). There is ample archaeological evidence for a decrease in imported goods (Deger-Jalkotzy, 2008; Dickinson, 2006) and, for the

reduction of Greek trade, can also be found outside of Greece. For example, in Macedonia, but also as far as Syria and Palestine, where the production of locally made Mycenaean style pottery suggests a decline in the availability of pottery produced on the Greek mainland (Deger-Jalkotzy, 2008; Killebrew, 2000; Mee, 2008).

Local trade routes also appear to have been impacted by the palatial collapse. There are a number of archaeological indicators of increased conflict such as additional defensive fortifications being built directly before this collapse. At Mycenae and Tiryns, for example, fortifications were built and/or reinforced to protect water sources (Deger-Jalkotzy, 2008; Dickinson, 2006). The development of fortifications is commonly believed to be evidence for conflict or some other form of aggression. If there was an increase in conflict this could potentially be the cause for the reduction in trade seen in the archaeological record, as an increase in conflict may have made movements along trade route more dangerous.

This is relevant to this study for several reasons. During the LH IIIC period the decline in trade causes pottery production to become more regionally based, where before it appears to be mass produced from specific regions (Dickinson, 2006). From the end of LH IIIB period the pottery is generally produced on a local scale (Dickinson, 2006; Mee, 2008). The overall range of shapes and the method of manufacture do not change drastically, but the fabric generally becomes coarser, containing more inclusions than earlier palatial fabrics. Coarse wares are also found in greater proportion then fine wares in the post-palatial period (Dickinson, 2006). Another point of potential significance for this study is that post-palatial pottery from mainland Greece was not as well-fired. According to Dickinson (2006) post-palatial pottery was not fired to the same hardness as earlier ceramics, and it was often fired unevenly. Poorly fired ceramics could potentially

cause the pottery to become more friable. A poorly fired cooking pot would likely introduce more extrinsic material to the diet than one that was appropriately fired, and less friable. Friable materials easily break apart into small particles. This would allow for small particles of the matrix as well as any inclusions or temper to become incorporated into whatever substance is contained in the vessel. As the results of this analysis indicate the textural changes of these samples' diet coincide with changes in the quality of pottery. This suggest that the pottery itself, namely the cooking and storage vessels may be the potential cause for the changes in the microwear signature of these samples.

Dental Microwear Texture Analysis

Although not statistically significant, the results for DMTA discussed above suggest the same general trends as the DMA results. Instead of an increase in the number of pits over time as was shown in the DMA results, we have an increase in Tfv over time. As is shown in Figure 17, there is a marked increase in Tfv. This variable is indicative of surfaces with large, deep features. As is stated by Scott et al. (2009), a surface with larger, deeper features would have a higher Tfv than surfaces with smaller, shallower features. A general decrease in the overall complexity (HAsfc) of the samples' surfaces are seen across palatial periods. This data is presented in Tables 8 and 9 below. This study used two variations of the parameter HAsfc. HAsfc9 and HAsfc81 are measures of surface complexity at different scales. While these variables do not significantly differ, a decrease was seen from the palatial period into the post-palatial period. Tfv was also found to differ significantly between palatial and post-palatial samples. This suggests that the texture of the diet became coarser over time; the size of the material being masticated also appears to become more similarly sized. A diet that contained a high

number of hard brittle materials would have a higher Tfv, whereas a sample that has a variety of different textures would have a higher HAsfc at comparable scales. As stated in the previous section the changes we are seeing are likely due to changes in cooking technologies, most likely the cooking pots.

Combined Results

When the results from both methods are considered together, changes in the texture of the diet of these two sites become apparent. The diet of those individuals interred at Mitrou during the LH period contained less coarse material than those LH IIIC burials at Agia Triada and during the PG period at Mitrou. A number of variables could be causing these changes. Taphonomic factors, cooking technologies and/or changes in substance patterns could all be the sole cause or a contributing factor.

Nevertheless, it is the opinion of the author that the most likely factor is a change in the fabric quality of the cooking and storage vessels. Further research is needed to definitively say that the potter is the cause of the change seen in dental texture. The general trend in pottery manufacture over the course of the LH period is one of decreasing quality, a trend which is well established in other areas of Mycenaean culture (Dickinson, 2006). An increase in local production throughout mainland Greece is very relevant in that the disappearance of centralized industries such as pottery manufacture would have resulted in increased pressure placed on local producers, which, in turn, would have caused a decrease in quality as potentially less skilled, or inexperienced ceramicists tried to meet the market demands. (Dickinson, 2006; Mee, 2008). Another factor that could also have affected the quality of pottery is the disappearance of elite individuals who would have had the finances and power to obtain the finest quality

pottery. As these individuals disappeared, the demand for these goods would have disappeared as well.

CHAPTER VII

CONCLUSION

The main and most obvious goal of this research was to document the microwear signatures of these samples. A secondary goal focused on assessing any discernible differences in these samples when aggregated into different geographic and temporal groups. As a final goal, the research attempted to determine if the two different methods would produce results indicating the same general patterns. All of these goals were successfully achieved through the methods and analyses presented.

Documentation of Dental Microwear

The methods stated in this document allowed for successful documentation of the dental microwear signature of the available samples from Mitrou and Agia Triada. While the results from DMA may not be comparable to samples coded by other researchers due to the fundamental interobserver biases (Galbany, 2005) inherent in DMA research, the DMTA samples can be used by other researchers for future studies. This is important because DMTA is still a relatively young analytical method in biological anthropology, and, as methods are refined, the digital surfaces will still be available.

Dental Microwear and Diet

This research successfully demonstrated that there is a discernible change in the texture of the diet at Mitrou over time and between the sites of Mitrou and Agia Triada. The results from DMA and DMTA clearly show similar trends for each hypothesis. This

includes significant difference in the coarseness of the diet consumed by these individuals between sites and between palatial periods. This suggests that both techniques are capable of detecting difference in dietary textures.

Dental Microwear Analysis and Dental Microwear Texture Analysis

While the findings presented for each method are statistically dissimilar, the general trends discussed above are visible in both analytical methods. These results indicate that the diet of these samples experienced some degree of textural change between sites and palatial periods. While DMA and DMTA are proven techniques for determining the presence or absence of dietary textural differences these methods lack the ability to pinpoint a direct cause of these differences in prehistoric human samples.

This should not be seen as a failure of the methods, nor should these methods be seen as lacking usefulness in today's technologically advanced world of isotope studies and trace element analysis. Instead, studies such as this can be used as a steppingstone for directing further research and analyses. For example, the results presented in this document identify a general change towards a coarser diet, but do not indicate the direct cause of this change. Further analysis using skeletal health markers, ceramic petrography, faunal, paleoethnobotanical or chemical analyses in combination with the results presented here could aid in the identification of the causal factors. Currently, these forms of analysis have not been conducted, or are in the process of being completed.

Concluding Remarks and Future Research

Dental microwear analysis and Dental Microwear texture analysis both have a place in bioarchaeological studies. Both methods can be used as a precursor to isotope

analyses, attempting to determine dietary differences. As the methods presented here are non-destructive and potentially cheaper than chemical analysis, their usefulness should not be underestimated.

While this study provides answers to certain questions, it also raises many more and highlights the need for isotopic analysis, petrographic analysis, and ethnobotanical studies at both Mitrou and Agia Triada. Prior to this analysis any statements made regarding the diet at these sites had little empirical evidence to support those statements. DMTA and DMA have now provided evidence that the textures of the BA and IA diet was changing at these sites. It also indicates that future research is needed to determine the cause of this change. As other dietary and health studies are completed these results should be interpreted in conjunction with the results presented in this document. These future research projects may facilitate the re-evaluation of the DMA and DMTA results. The data presented here, when combined with other research from Mitrou and Agia Triada. will have amplified explanatory power and will provide a better understanding of the Mitrou and Agia Triada communities.

It is the hope of this author that future research using DMA and DMTA focuses on three objectives. The first and perhaps the most important, is to gain a better understanding of what DMTA variables are, and in turn what they can tell us. One-step towards this may be studies such as the one presented here, which compare DMA to DMTA. Secondly, I believe that researchers must start investigating both Phase I and Phase II facets together. Finally, future studies examining diet need to incorporate multiple methods. For example, studies using only DMTA, residue analysis, or stable isotopes employ one line of evidence to investigate diet, an extremely complex component of human behavior. The combination of all three methods would provide a

multifaceted and complementary approach and would likely produce a clearer picture of diet. The author realizes that due to a number of reasons this may not always be possible, but this is a goal that we, as scholars, should strive to achieve.

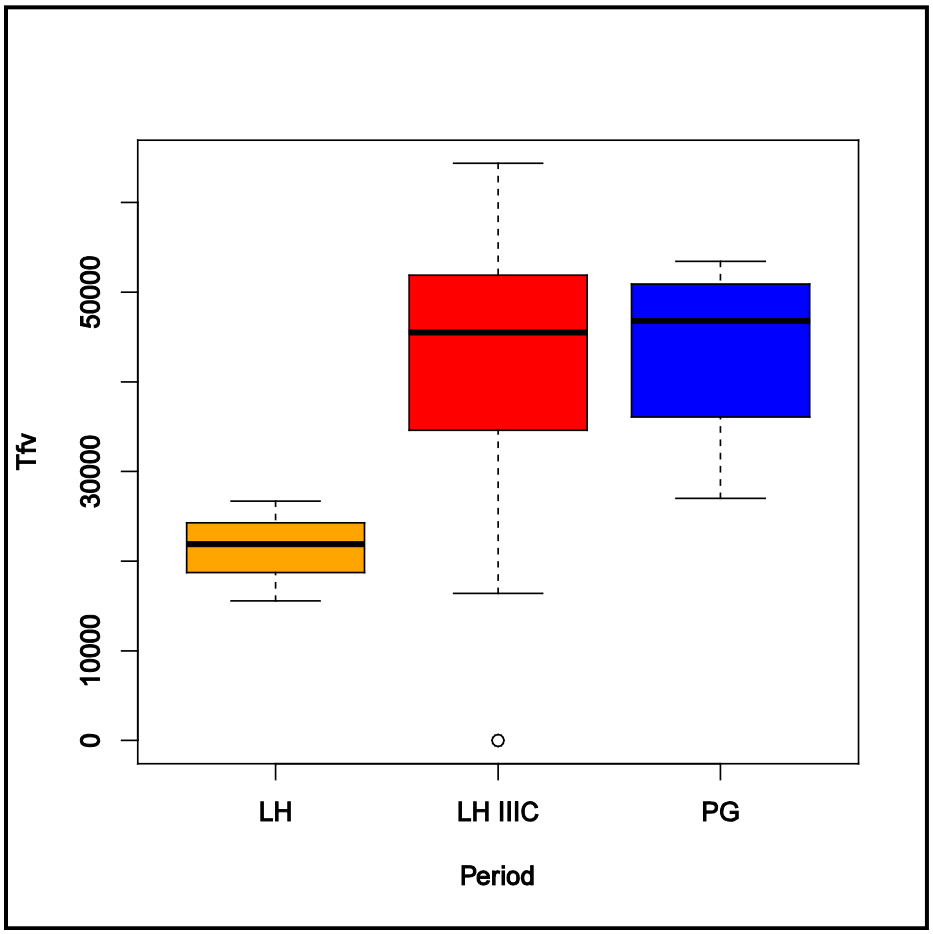

Figure 15 Mean Tfv for chronological periods.

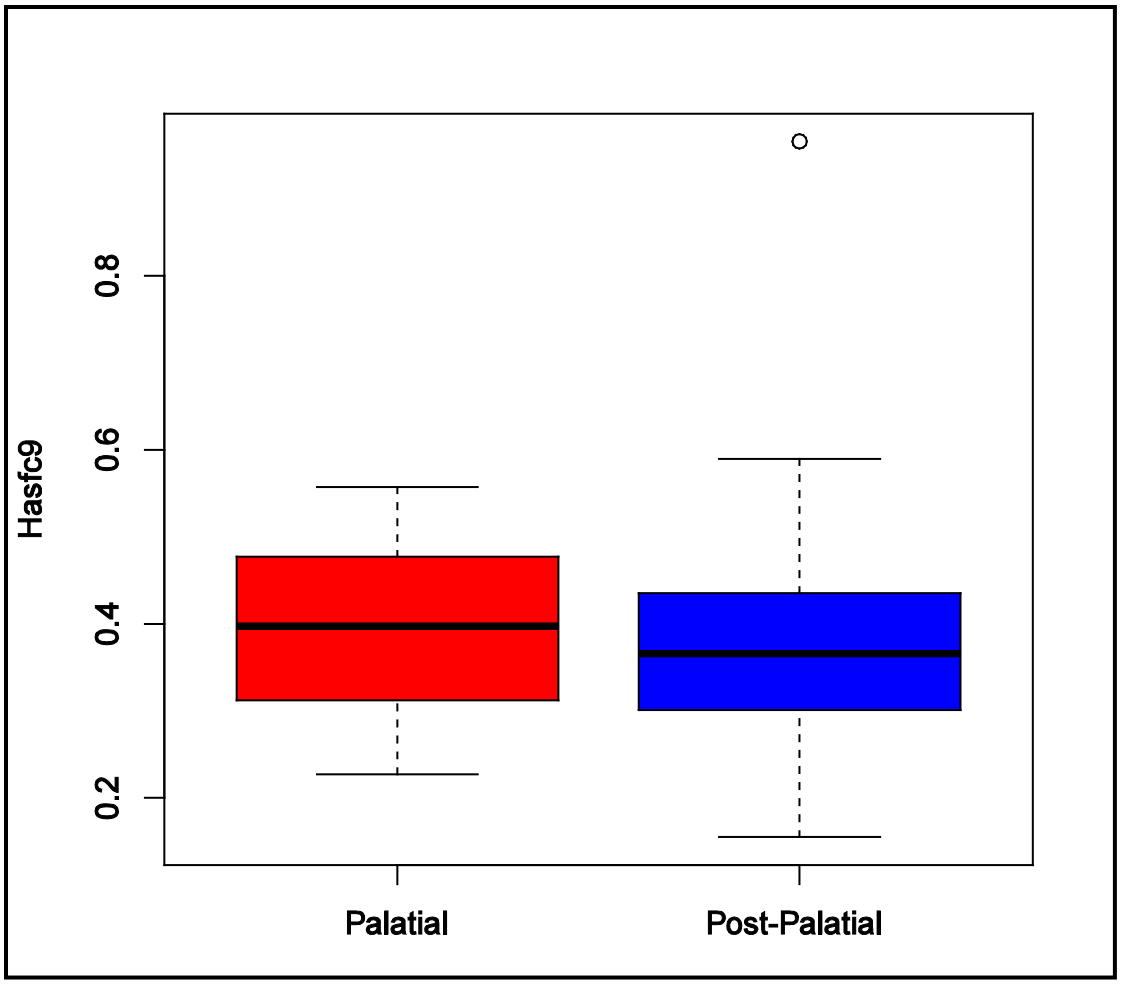

Figure 16 Mean ranked HAsfc9 for palatial and post-palatial sample.

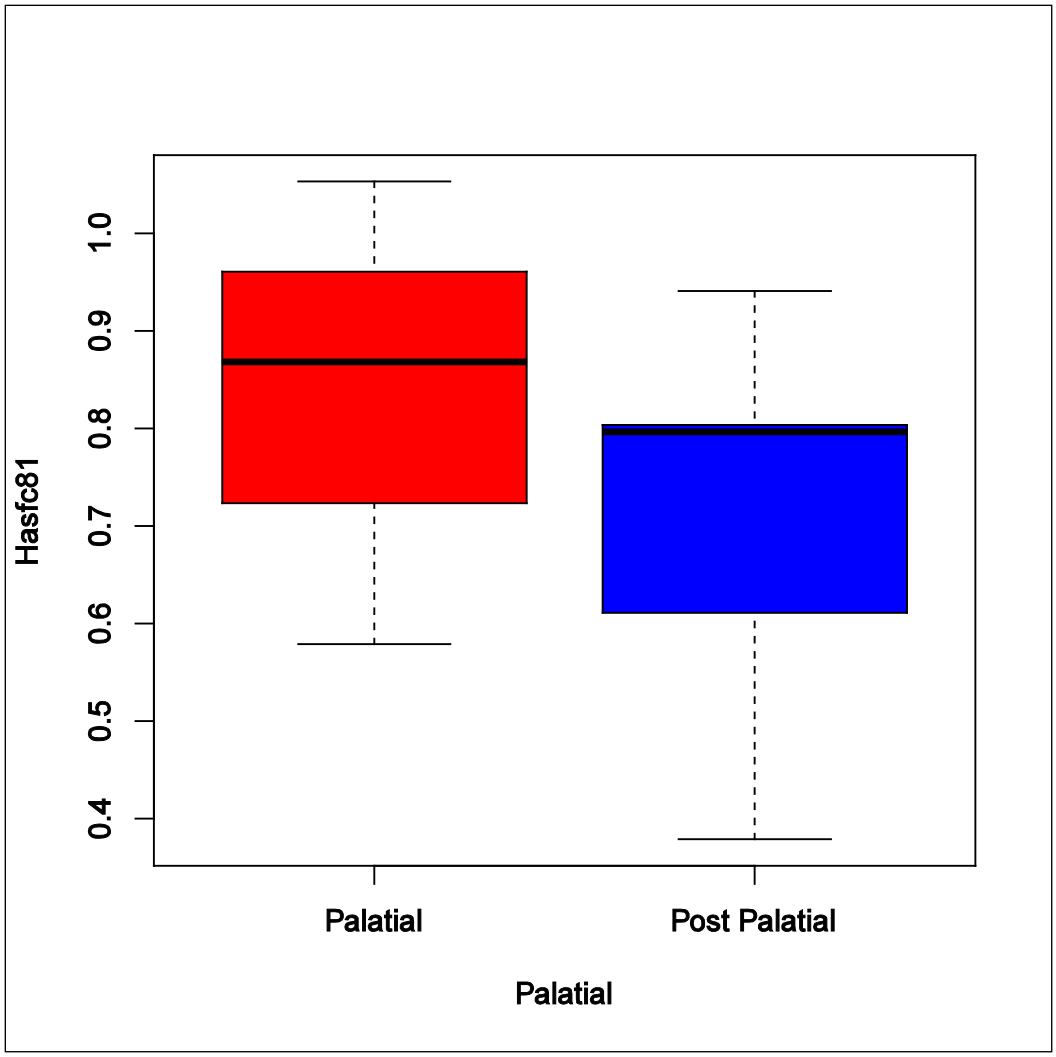

Figure 17 Mean HAsfc81 for palatial and post-palatial samples.

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APPENDIX A

SAMPLE INFORMATION

Table 24 DMA sample information.

Period	TR-SU	Tomb/grave	Teph./Burial	OM.	Tooth
Mitrou					
LH	Mitrou		52		31
LH	LO784-859	73	74		18
LH	LR797-011	50	53		32
LH	LR797-057	66	66		18
LH	LE793-013	34	32		31
LH	LO784-859	73	74		30
LH	LR797-057	66	66		18
LH	LR797-011	50	53		18
LH	LF190-20	10	13		18
LH	LE795-092	25	30		18
PG	LP785-79	42	49		31
PG	LN786-027	6	9		18
PG	LP785-79	42	49		32
Agia Triada					
LH IIIC		V	α	4	18
LH IIIC		I	η	2	19
LH IIIC		I	η	2	19
LH IIIC		V			31
LH IIIC		VIII	Γ	Γ	18

Table 25 DMTA sample information

Period	Sample ID	TR-SU	Tomb/grave	Teph./Burial	OM.	Tooth
Mitrou						
LH	100	LE793-013	34	32		31
LH	189	LR797-011	50	53		18
LH	122	LR797-057	66	66		31
PG	129	LN786-028	6	9		18
PG	133	LP785-019	33	34		17
PG	198	LN783-577A	74	75		31
PG	156	LN783-577B	74	76		18
Agia Triada						
LH III C	103		I		2η	31
LH III C	105		VIII	10	10	18
LH III C	112		V	β	4α	31
LH III C	184		I		2η	18
LH III C	116		V	?	?	18
LH III C	187		V	β	4α	31
LH III C	115		I	2α	2α	18
LH III C	167		VIII	Γ	6	32
LH III C	135		I		2η	31
LH III C	125		V	β	4α	18
LH III C	190		1		2η	18

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APPENDIX B

DMTA SAMPLE SURFACs

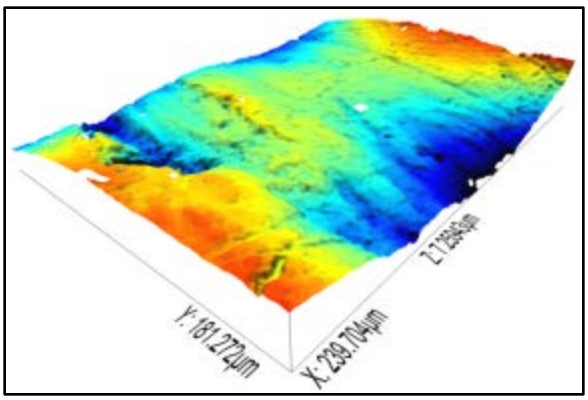


Figure 18 Surface of sample 101

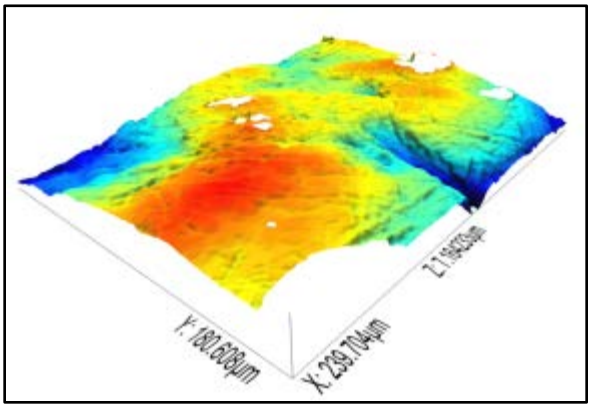
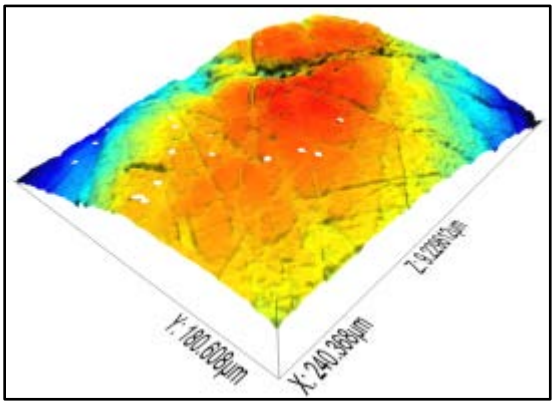


Figure 19 Surface of sample 103



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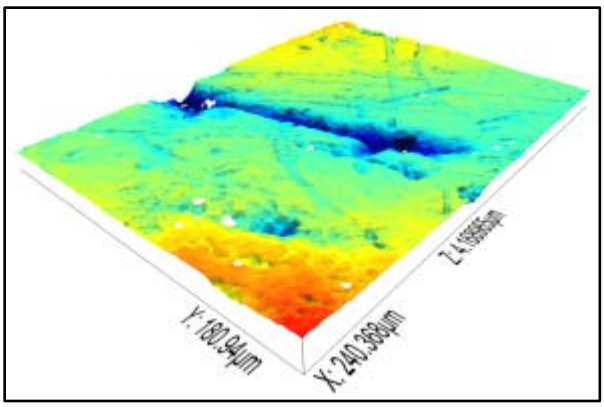

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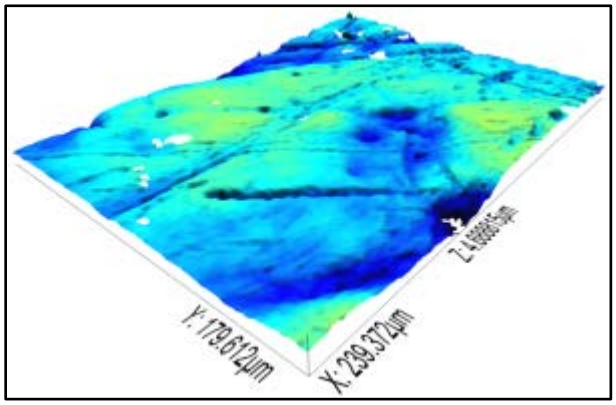


Figure 22 Surface of sample 112

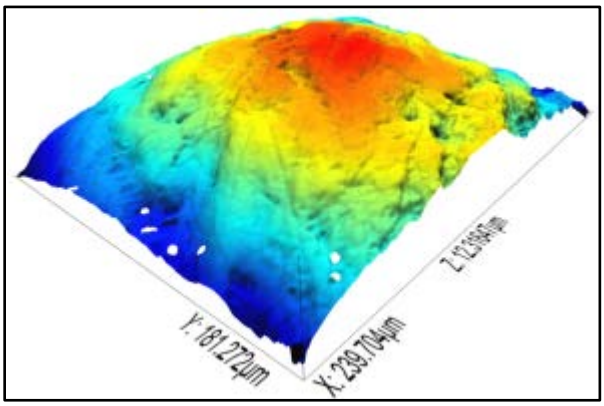


Figure 23 Surface of sample 115

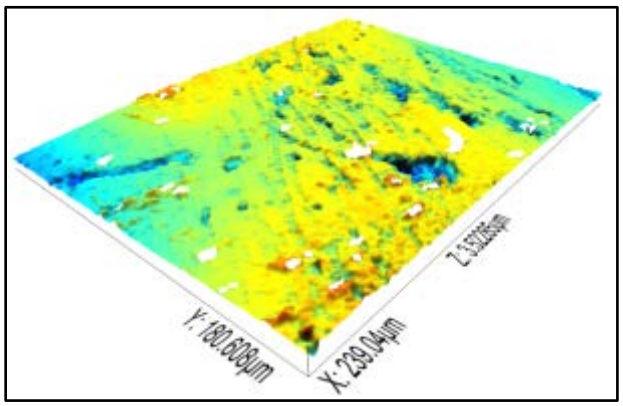


Figure 24 Surface of sample 116

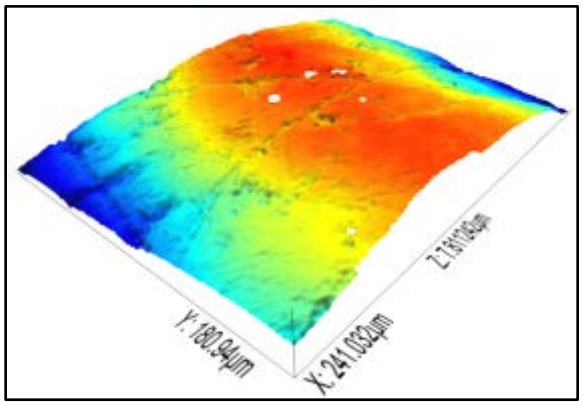
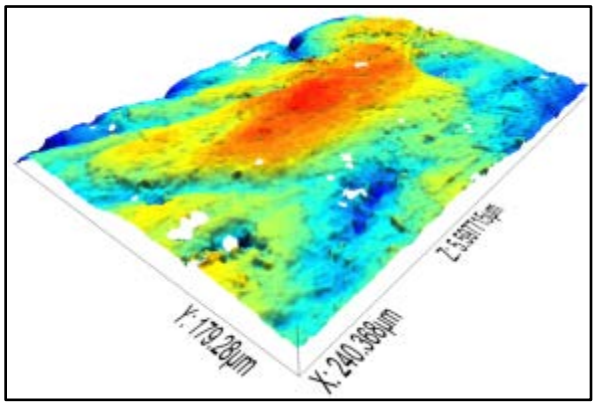


Figure 25 Surface of sample 125



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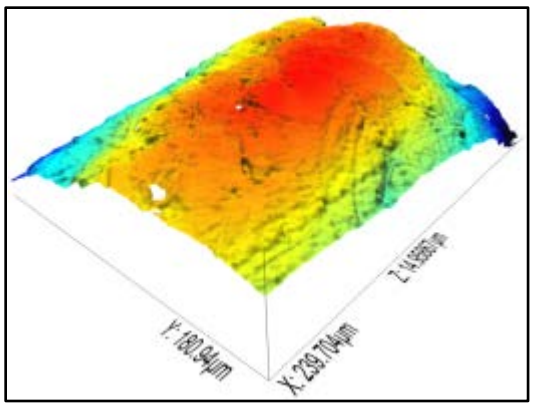


Figure 27 Surface of sample 135

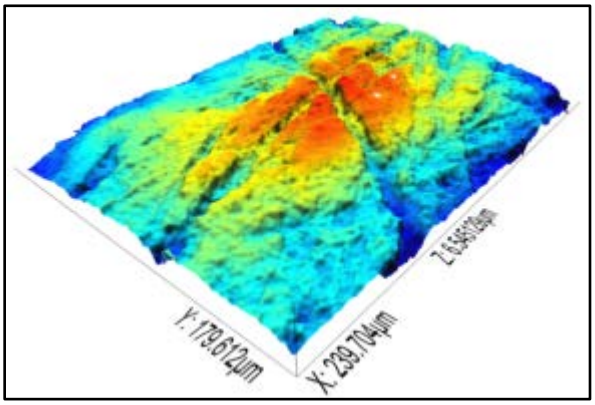


Figure 28 Surface of sample 156

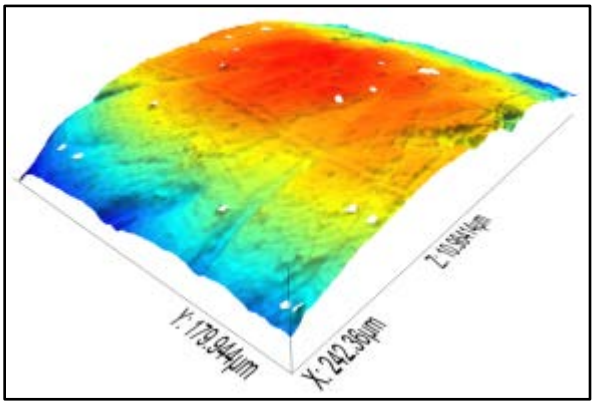
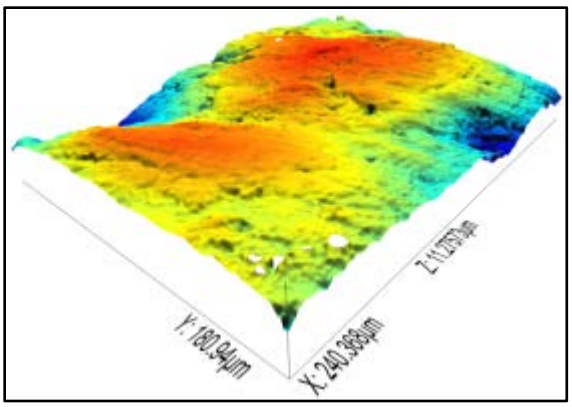


Figure 29 Surface of sample 167



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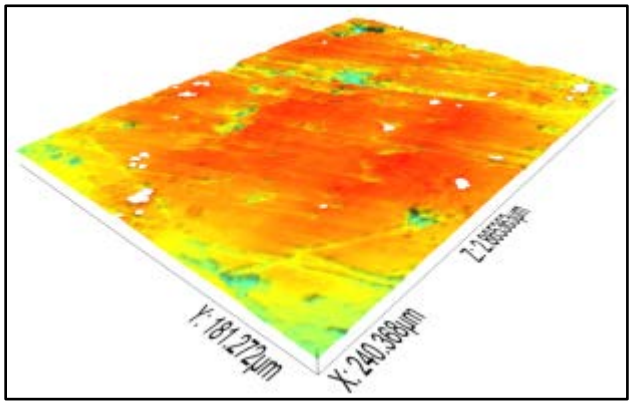
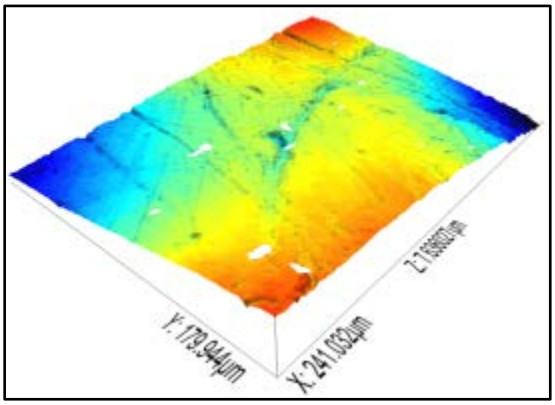


Figure 31 Surface of sample 184



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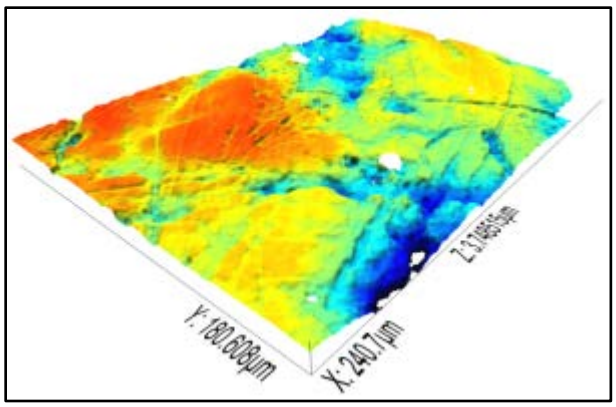

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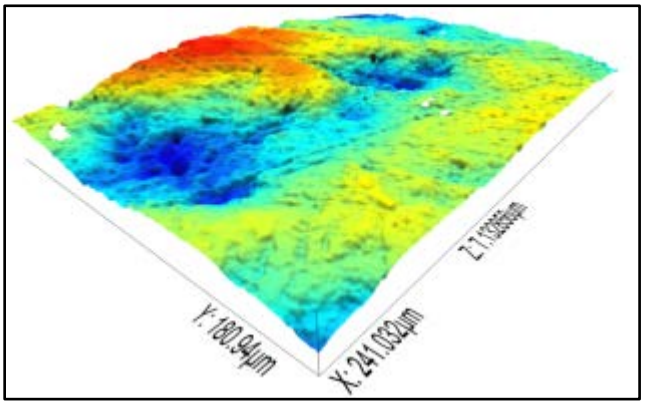

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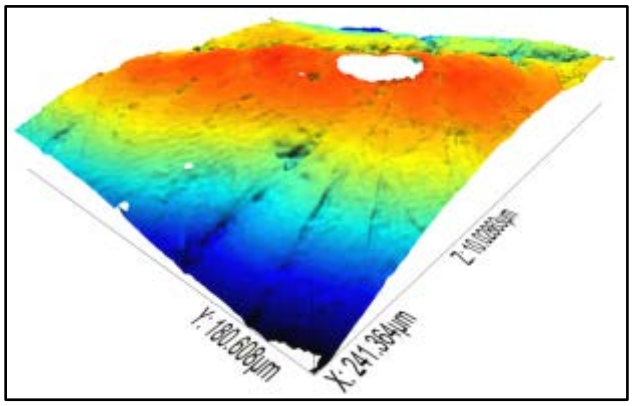

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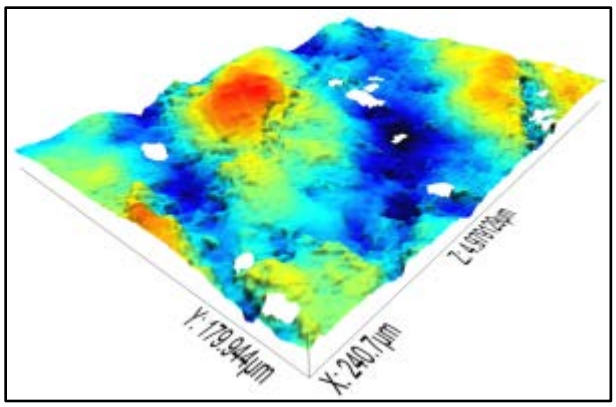

Figure 36 Surface of sample 133