Phosphate Analysis and Evidence for Industry at Iklaina:

Implications for Mycenaean Economies and State Formation

by

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Abstract

The intent of this thesis is to gain a better understanding of the settlement organization, site function, and extent of industrial activity at Iklaina, a late Bronze Age Mycenaean site located in southwest Greece, through phosphate analysis carried out on samples collected from both the excavated and unexcavated areas of the site. I conducted phosphate analysis on a total of 52 samples from the center of the site and the surrounding area to determine the scope of economic activity and clarify the organization of the site by examining the distribution and concentration of phosphate across the site. The phosphate results were compared to the results from the archaeological excavations to identify evidence for particular economic activities and understand how spaces for certain activities were potentially segregated at Iklaina. Determining the extent of the site's economic activity is necessary to clarify Iklaina's role in the regional settlement hierarchy and its relationship to Pylos, the state capital, over time. This is significant for understanding processes of Mycenaean state formation since the extent of Iklaina's economic activity depends somewhat on the degree of Pylian state centralization, along with the structure of local social systems and regional interactions. This would affect the way that the site was organized and how it functioned in the settlement hierarchy, which may reflect competition between the two sites or centralized control exerted by Pylos. My analysis of the distribution and concentrations of phosphate at Iklaina suggest that it was a fairly well-developed industrial center that appears to have been an economically specialized site with differentiated administrative, residential, and industrial spaces. This degree of complexity seems to support Iklaina's higher position in the settlement hierarchy, where it may have been in competition with Pylos before the unification of the Pylian state after Iklaina's destruction; however, the exact nature of Iklaina and its relationship to Pylos is still uncertain. Overall, these results provide a

greater context for understanding the nature of Mycenaean economies and the development of the Pylian state in Messenia.

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Chapter 1: Introduction

The aim of this thesis is to better understand the settlement organization and site function of Iklaina, a Mycenaean site in the region of Messenia, through phosphate analysis conducted on soil samples from both excavated and unexcavated areas of the site. Patterns of phosphate concentration and distribution were analyzed to determine the extent of economic and industrial activities at Iklaina, which has implications for the site's role in the regional settlement hierarchy. Iklaina's relationship to the regional center at Pylos based on this hierarchy is important for understanding the rise and development of the Pylian state, and for Mycenaean state formation processes more generally (Cosmopoulos 2006; Cosmopoulos and Shelmerdine 2016). The excavations at Iklaina are currently directed by Dr. Michael Cosmopoulos, who has permitted me to work with the soil samples collected by Dr. Michael Galaty. Dr. Catherine Scott had previously completed chemical analyses for the site on a range of elements, excluding phosphate, which provided a foundation for considering the range of economic activities performed at the site while revealing the need for phosphate analysis to clarify the degree of industry at Iklaina (Scott et al. 2016). Analysis of the phosphate concentrations produced from the samples suggests that Iklaina was a fairly well-developed industrial center that appears to have been an economically specialized site with differentiated administrative, residential, and industrial spaces. This raises broader questions about Iklaina's development in relation to Pylos and the degree of economic control exerted on it by the palace, which is significant for a better understanding of Mycenaean state formation.

The purpose of completing phosphate analysis on samples from Iklaina was to determine if the patterns of phosphate for excavated and unexcavated areas of the site could clarify the degree of economic activity and organization of the site. The extent of Iklaina's economic

activity depends somewhat on the degree of state centralization, along with the structure of local social systems and regional interactions. A better understanding of Iklaina's economic importance over time in relation to Pylos is necessary for understanding how Mycenaean states formed. Iklaina's relationship to Pylos would affect the way the site was organized and how it functioned in the settlement hierarchy, which can indicate the extent of competition between sites or centralized control from the palace (Cosmopoulos 2019).

Pylos may have had different degrees of control over Iklaina, depending on the level of industry in addition to site organization and function at Iklaina. The extent of industrial activity at Iklaina would likely vary based on whether Iklaina was relatively independent or if Pylos had centralized control, and this affects the distribution of phosphate that would be expected. The presence of industrial workshops is one way to distinguish between a palatial capital and a town or locational redistribution center (Cosmopoulos 2006). If phosphate analysis indicates the presence of industrial activities such as metalworking, it could be evidence suggestive of Iklaina's greater importance in the settlement hierarchy. Linear B tablets have recorded the importance of bronze-working activity in Mycenaean economies, particularly around Pylos, and this would deposit a high concentration of phosphorus into the soil (Galaty and Parkinson 2007). Palatial centers like Pylos may have functioned as administrative and redistributive centers, mobilizing sites such as Iklaina to produce raw materials into goods that were exchanged with and utilized by Pylos. Iklaina may have had control of perfumed oil for production and distribution and there may also be some evidence for metalworking, pottery production, and linen production that would leave a chemical trace for phosphate analysis (Galaty and Parkinson 2007). If higher phosphate concentrations are found near open basins or drains, then this chemical trace may be evidence for these industries since a lot of water is required for processing

flax or smelting (Figures 1 and 2). If there is a large area that is low in phosphate, then this may indicate the presence of a plaza, domestic space, or other "clean" area because the main source of anthropogenic phosphate is organic debris, which is generally removed from domestic contexts (Middleton and Price 1996). If phosphate patterning reveals a clear separation of space between administrative, residential, and industrial areas at Iklaina, then this complexity would suggest that Iklaina is higher in the settlement hierarchy, potentially in competition with Pylos. High levels of pattern variation are marked by differing levels of high and low phosphate across the site, while low levels of pattern variation are recognized through relatively similar phosphate levels across the sampled area. If there is less variation in the phosphate patterns and similar concentrations throughout the site, then this may indicate less industry and a lack of highly defined areas for particular activities. This could suggest that Iklaina was subordinate to Pylos and that it held a lower position in the regional hierarchy. Soil chemistry has had limited application in the Mediterranean region so far, so research on phosphate analysis at Iklaina is useful for contributing to the growth of soil chemistry in this region.

Figure 1: *Aerial view of the built drains associated with the North Sector (Cosmopoulos 2019).*

Figure 2: *Photograph of a clay water supply pipe for the houses of the North Sector (Cosmopoulos 2019).*

To determine the extent of industrial activity at Iklaina, and therefore its relationship to Pylos based on the distribution of phosphate, I developed a set of hypotheses to interpret the results from phosphate analysis and understand how patterns in phosphate variation are associated with the organization of the site and potential industrial activities. First, 1) if Iklaina is thought to be a subordinate settlement to Pylos with less industry and complex organization, then little variation in the phosphate distribution throughout the site can be expected. 2) If Iklaina held a higher position in the settlement hierarchy, potentially in competition with Pylos, then greater variation in phosphate distribution should show a clear separation of administrative, industrial, and domestic space at the site. Next, 3) if there are defined areas of high phosphate, then this may indicate the presence of industrial activities, middens, or human and animal waste; if these high phosphate concentrations are located near drains, then this may be evidence for smelting or other industrial activities that use water for processing. 4) If there is a large area with overall low phosphate concentration, then this space may represent a "clean" area such as a plaza or household area (Middleton and Price 1996). Finally, 5) if higher phosphate concentrations are found on the site periphery with lower concentrations around the site center, then this suggests that high phosphate producing activities were conducted away from the center of the site. It can be expected that industrial activities could have been located on the edges of Iklaina away from the site center where the administrative unit was; this is significant because if this is occurring at Iklaina, then it would be more similar to Pylos, which would be further evidence that the two sites are connected in some way, perhaps with Iklaina under the control of Pylos at some point. Around this time, industrial activities were being drawn into the palace at Pylos, so if this is occurring at both the palace and at Iklaina, this would seem to suggest that they are following similar processes of development. Utilizing these hypotheses, the evidence suggests a significant

level of variability and complexity at Iklaina, which implies a higher position in the regional settlement hierarchy.

Chapter 2: Literature Review

This chapter will address the current evidence for Iklaina's role in the regional settlement hierarchy, which has implications for the scale and extent of economic activities and the organization of space within the site. Iklaina's relationship to the palatial capital at Pylos over time provides a greater context for understanding the function of the site, which affects the distribution and quantity of chemical residues depending on the activities performed. This literature review also discusses possible sources of anthropogenic phosphate at Iklaina as well as the advantages and effectiveness of conducting phosphate analysis at the site.

Iklaina

Iklaina is located on an extensive plateau in Messenia, in the southwestern part of the Peloponnese region in Greece (Figure 3), where there is evidence for habitation from approximately 1800 BCE to 1200 BCE based on recent radiocarbon dates from the site (Cosmopoulos et al. 2019). Iklaina was most likely a district capital within the four-tier settlement hierarchy of Mycenaean settlements in Messenia. In this region, sites are matched up to the levels of site hierarchy mentioned in the Linear B tablets from Pylos. In this context, hierarchy is defined as settlement structure based on its political and economic status within the settlement network of the Pylian state (Cosmopoulos 2006). Understanding the structure of these settlements is necessary to make comparisons between them and to reconstruct their organizational structures. Settlements are generally ranked according to their economic standing, which is based on the range of activities the settlement engages in and its level of productivity (Cosmopoulos and Shelmerdine 2016). At the top of this hierarchy was the palatial capital at

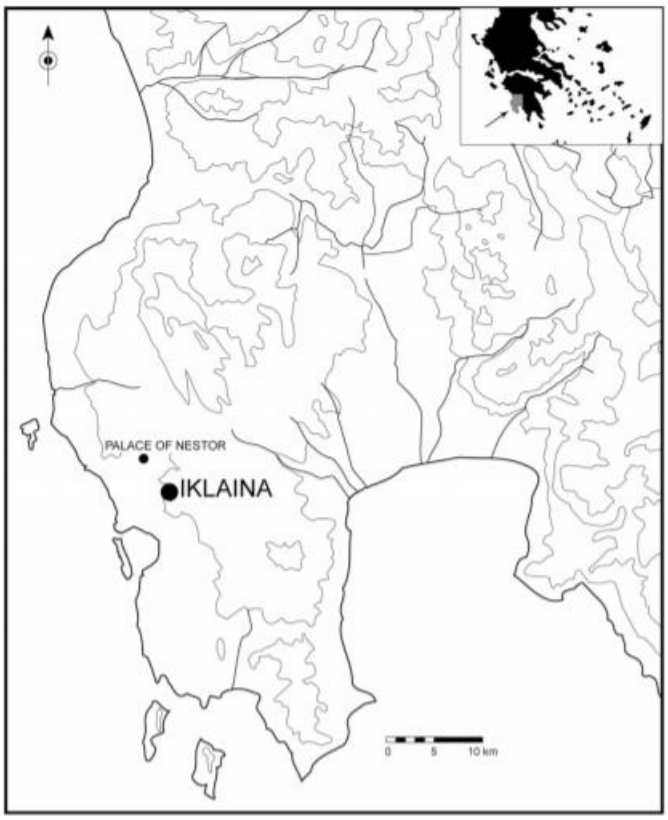

Figure 3: *Map of Messenia showing the location of Iklaina and the Palace of Nestor at Pylos (Cosmopoulos et al. 2019).*

Pylos, which operated as the political and economic center of the state. Following this were the district capitals that had some administrative, economic, and political functions. The third tier consisted of villages that performed specialized economic activities that may have been of special interest to the palace. Finally, there were small villages and settlements that had a lesser economic importance and were not of direct interest to the palace (Cosmopoulos and Shelmerdine 2016). Cosmopoulos has recently argued that Iklaina and Pylos were of the same hierarchical rank and that they were independent and competing chiefdoms at the top of this hierarchy (Cosmopoulos 2019). Iklaina may represent a settlement that grew and flourished in proximity to Pylos, since architecture revealed by the excavations shows a considerable labor and resource investment (Figure 4). In LH I-II the site covered an area of about 8 ha, eventually reaching a size of 12 ha in LH IIIA-IIIB (Cosmopoulos 2019). While Iklaina may have been a subordinate site, this investment suggests that it had a greater importance. Currently soil chemistry has confirmed the excavation results that show a clear separation of space at the site (Scott et al. 2016). Unlike Nichoria, a smaller and less economically specialized site, administrative, residential, and industrial spaces appear to be differentiated. Based on the evidence so far, Iklaina seems to have been an industrial center

involving metallurgical activity on-site and possibly at a smaller settlement nearby at Katsimigas (Cosmopoulos and Shelmerdine 2016).

Katsimigas, a smaller site between 1-2 ha in size near Iklaina, may have had a specialized function. Dense concentrations of slag suggest the site's role as a metallurgical center where bronzeworking could have occurred (Cosmopoulos 2019). This site along the exposed ridgetop near Iklaina could be the location of the metalworking processes referenced in the Linear B tablets; however, further excavation is needed to better establish its function (Cosmopoulos 2006). Similarly, Koukounara is another smaller nearby site that has an unclear economic role. While it remains unexcavated, it is associated with tholos tombs and may have had a religious function, which would imply lower phosphate levels (Galaty et al. 2012). One sample has been collected from each of these sites in an attempt to better understand and compare the role of these smaller settlements in relation to Iklaina.

Figure 4: *Aerial photograph of Iklaina and the surrounding area (Cosmopoulos 2018).*

The tablets mention that the palace recorded and controlled the resources of some villages directly, rather than indirectly through towns. This suggests that some villages had a special importance to the palace because of their economic activities (Galaty and Parkinson 2007). Second level hierarchy sites are characterized by their administrative, economic, and

political functions while still being dependent on the palace (Cosmopoulos 2006). Therefore, it seems that Iklaina may have operated somewhat independently while Pylos exerted control over industrial activities that were of interest to the palace. Iklaina is unusual because it is a major settlement that developed close to Pylos, about 10 kilometers away, raising questions about the site's relationship to the palace and the degree of economic control exerted by the palace. The results from phosphate analysis could reveal the range and degree of economic activities at the site, which would be useful for understanding and clarifying Iklaina's place in the regional hierarchy.

The results from the excavations clarify the developmental trajectory of the site along with the socio-political and economic organization of the site. The excavations show that monumental building projects were undertaken at Iklaina based on the presence of the Cyclopean Terrace Complex, the paved piazza, and the entrance gate. Ashlar blocks were used on the Cyclopean Terrace building, which indicates formal construction. The excavation also provided insight into the functional organization of the site (Figure 5), since the entrance gate to the administrative center and a residential quarter indicate a clear separation of space and activity areas at the site (Cosmopoulos 2018). The monumental building program and clear separation of activity areas at Iklaina is interesting because Iklaina was thought to be secondary to Pylos,

Figure 5: *Photograph of Iklaina showing the three excavated sectors of the site (Cosmopoulos 2019).*

Figure 6: *Fallen ashlar blocks in the destruction level in front of the north facade of the Cyclopean Platform (Cosmopoulos 2019).*

so state formation processes in this region need to be reconsidered with this additional evidence (Cosmopoulos 2016). Iklaina and Pylos are relatively close, so it would be difficult for both to be independent city-states for a long period of time. Cosmopoulos has argued that Iklaina and Pylos followed similar trajectories until Iklaina was annexed, perhaps violently (Cosmopoulos 2019). There is some evidence for a hostile takeover from an outside force, since there was destruction and later rebuilding and integration after Iklaina was destroyed (Figure 6). Based on radiocarbon dates associated with LH IIIB pottery from the rubble of Building X, there is evidence that the latest end date for this destruction layer dates to the 13th century BCE (Cosmopoulos et al. 2019). Perhaps Pylos attacked Iklaina, then rebuilt the administrative part of the site according to their plans and symbolic of their new authority. The destruction of Iklaina may suggest that this site was competing with the palace in some way, but more evidence about the site's function and organization is needed to clarify this. The continuous evolution of Iklaina indicates a gradual, uninterrupted process of internal growth, eventually leading to the emergence of monumental architecture (Figure 7). Annexation seems to have occurred when the monumental buildings were destroyed and the formal area of the site was abandoned (Cosmopoulos 2019). This destruction was followed by a phase indicating the use of industrial and storage buildings with final IIIB-Early IIIC pottery (Cosmopoulos et al. 2019). Iklaina may have lost its administrative role but the industrial areas remained because they were useful to the palace. This suggests a violent takeover by a new political authority since the monumental

buildings representing the previous authority were destroyed and Iklaina was demoted to a dependent industrial center. The post-destruction phase at Iklaina is contemporaneous with the final stages of Pylos. The destruction at Iklaina may represent the unification of the Pylian state, suggesting a short lifespan for the formation of this state whose destruction is traditionally dated to 1200 BCE (Cosmopoulos et al. 2019). Additional radiocarbon dates from material at Iklaina will help to further refine this chronological sequence and reconstruct the development and evolution of the site. On a broader scale, this is important for understanding the decline of Mycenaean control on a regional level.

Figure 7: *Aerial view of the Cyclopean Platform from the north (Cosmopoulos 2019).*

Economies of Mycenaean States

In the traditional chronological view, the LH IIIB period showed the slow integration and unification of Iklaina with Pylos, over the course of about 150 years. However, the latest radiocarbon dates show that this was taking place over approximately 50 years, a much shorter time span that supports the proposed High Chronology for the early Mycenaean period (Cosmopoulos et al. 2019). The site may have started out small, then it experienced rapid expansion in the rebuilding phase after its destruction. If this rapid chronology is correct, then phosphate from industrial and other activities may not have accumulated as quickly if industry was only conducted for a short period of time (Cosmopoulos 2019). Based on the differing

chronological views for Iklaina and the unification of the Pylian state, Iklaina's development would have followed a different trajectory, as compared to other regional sites, which would have affected the site's soil chemistry. Perhaps a more simple, random variation of phosphate could be indicative of less structure and formalized industry at Iklaina, which may signal less control from Pylos.

Palatial centers in the Aegean used their position to mobilize raw materials used in the production of goods by the palatial labor force for elite exchange. Palatial centers operated as administrative and production centers, with industries for the production of perfumed oil, wine, and bronze (Bennet and Galaty 1997). Based on the need for the production of goods for elite exchange, this suggests that some production activities may have been occurring near the palace at Iklaina. Depending on the organization and function of Iklaina, along with the degree of industry, Pylos may have exerted different levels of control. The extent of industrial activity at Iklaina may be different if Pylos has centralized control compared to a more individualizing Iklaina, and this has implications for the distribution of phosphate (Bennet and Galaty 1997). The presence of industrial workshops is one way to distinguish between a palatial capital and a town or locational redistribution center. If phosphate analysis reveals the presence of these industrial activities, it could be evidence suggestive of Iklaina's greater importance in the settlement hierarchy.

The Linear B tablets mention bronzeworking in connection to Iklaina, which is one industry that may have left a chemical trace at the site. Katsimigas may be one of the smaller sites near Iklaina that had a greater importance to the palace because of its bronze-working industry (Cosmopoulos 2006). The Linear B tablets also mention that bronzesmiths here received allocations of bronze from the palace. Bronzeworking would deposit a high concentration of

phosphorus into the soil (Cosmopoulos and Shelmerdine 2016). At Iklaina, flax production and textile manufacture seem to have been some of the most important economic activities in addition to bronzeworking. The perfume and textile industries could also be detectable through phosphate analysis, since these would leave a significant chemical trace. The range and extent of industrial activities such as these at Iklaina are necessary for understanding the spatial organization and function of the site, which can better explain Iklaina's place in the settlement hierarchy and its relationship to Pylos.

Phosphate Analysis

Soil chemistry has previously had limited application in the Mediterranean region, but studies in other regions have shown its use in distinguishing activity areas and site organization (Sarris et al. 2004; Save et al. 2020). However, chemical analysis, particularly phosphate, has the potential to help archaeologists identify and better understand the scale of industrial activities, which can clarify the development and function of Iklaina in relation to Pylos. Crowther (1997) has noted the importance of undertaking phosphate analysis to understand patterns of activity across a site better, especially in areas that have been excavated. Contour maps created for the sample results can be compared with the excavation results to consider broader questions of settlement hierarchy. Integrating these results can strengthen the analysis of site organization and function, and if these correlations can be tested across many sites, then soil chemistry can be used more accurately as a site prospecting method.

Phosphate is a common element that has many natural and cultural sources, and it can enter soils through a variety of direct and indirect processes (Holliday and Gartner 2007).

Phosphorus is an element that leaches from bones and organic tissues and concentrates where these materials were left to decay (Sarris et al. 2004). Soils have been defined by Middleton and Price (1996) as sediments that have undergone processes of weathering and incorporation of new materials such as organic matter. Phosphate patterns in archaeological soils are distinguishable from natural soils, so sampled residues can be considered accurate indicators of human activity (Middleton and Price 1996). The purpose of conducting phosphate analysis is to use the residues remaining from human activities or occupation as chemical traces that are preserved even when the artifacts associated with these activities are removed (Sarris et al. 2004).

There are many potential factors that can affect phosphate analysis results, including leaching and diffusion (Crowther 1997). Phosphorus in its phosphate form tends to be less susceptible than other elements to leaching. When phosphorus is added to the soil organically, it bonds with other elements to form relatively stable phosphate compounds; some forms of the compounds are highly resistant to leaching. Phosphate tends to accumulate at the site of deposition and the anthropogenic phosphate can be much greater than the natural phosphate in the soil (Holliday and Gartner 2007). In addition, Iklaina's environment is relatively dry, so the soils are not being affected by frequent precipitation. Therefore, it is unlikely that soluble phosphate is leaching lower through the profile due to rainwater. Additionally, because the soil levels in the area are fairly shallow, soluble phosphate has low mobility to travel through the profile. The site is built on bedrock with a little dry soil over it, making it difficult for phosphate to travel. Some of the samples were taken in the vicinity of olive groves and it is unclear how much fertilizer was put in the soil. However, it likely is not a substantial amount that would affect the phosphate results, especially because it would have to move through 30-50 cm of soil

to reach the archaeological levels. Based on this, leaching from fertilizer and phosphate movement from rain suggests that significant contamination is unlikely.

Hearths, cooking features, and middens that have elevated levels of phosphate are some features that may represent industrial activity at Iklaina since these correlations have been observed at other sites (Price and Middleton 1996). Sources of anthropogenic phosphate include human refuse and waste, burials, livestock, and fertilizer. Pre-industrial societies have phosphate coming primarily from human waste and refuse, especially from organic discard, along with burials and ash from fires. Phosphate from livestock can be added to fields as well as from accumulation in barns or pens. There is a lot of evidence for burning at Iklaina, which could be indicative of industry or places where something was burnt down. Meanwhile, some ritual activities can actually deplete phosphate levels because of extensive cleaning of sacred surfaces (Holliday and Gartner 2007).

To measure phosphate levels, colorimetry reduces compounds in an acid to create a blue-colored solution. The shade of blue is proportional to the phosphate content of the sample, providing an indirect measure of phosphate concentration. Phosphate levels can be used to prospect for sites and to map activity areas. Measuring the total phosphate content produces quantitative, comparable results and is a good indicator of human inputs when compared to the results from natural soils (Holliday and Gartner 2007). The phosphate analysis for Iklaina was conducted using a weak acid method that measures organic unbound phosphate. The colorimeter converts the shade of blue to ppm as a fairly accurate estimate of phosphate levels and it allows for dilution of the sample. At Iklaina the samples were not taken on a set grid and were more "random" because they were taken based on the areas around the excavation. These results can be compared to the results from Scott's article to understand better the greater questions and

broader importance of settlement hierarchy (Scott et al. 2016). The weak acid method will consistently pull out the same amount of phosphorus at the same rate, so these results can be used to understand the various indicators of human activity and the patterns that certain behaviors will leave as chemical residues.

Chapter 3: Methods

I conducted phosphate analysis on a total of 52 samples that were collected by Dr. Michael Galaty from the center of the site, the area around the site, and smaller settlements near Iklaina. Nine of these samples were collected from the area west of Iklaina. In addition, I analyzed one sample from Katsimigas and one from Koukounara to determine if phosphate analysis indicates the presence of specialized activities at these smaller settlements near Iklaina.

Collection

A 10 m grid was laid out across the site for the collection of soil samples, and all of the samples were collected using an Oakfield corer. Many of the samples were taken on a 10 m grid, while some were sampled from areas that were under excavation so that these excavation results could be compared with the results from phosphate analysis. As a result, some of the samples are more concentrated around the excavated Monumental Building Sector and the North Sector. The collection of these samples was more "random" in the sense that the areas under excavation determined where the samples could be taken when possible. Each sample was taken from the archaeological level, but the actual depth varied from sample to sample. The on-site samples were collected from the archaeological levels that lie just above the bedrock, which ranged from 20-50 cm depending on what part of the site the sample was taken from. The archaeological level was clearly defined as a black layer of soil that was enriched with organic matter, which differed from the red oxidized soil of the upper layers. The dry environment and relatively shallow soil levels at Iklaina make leaching and the movement of phosphate from rain and other processes unlikely, so there is not a significant risk of contamination from modern inputs of phosphate.

Extraction

All 52 samples were analyzed at the Research Museums Center at the University of Michigan in the Museum of Anthropological Archaeology wet lab using a weak acid method that measures organic unbound phosphate. Phosphate analysis was carried out under laboratory conditions. For each sample, the soil was ground using a ceramic mortar and pestle, then rocks and modern plant remains were removed from the sample. A spatula was used to transfer the soil to a weighing dish where 1.5 g of soil was weighed out with a portable balance. The balance was zeroed before the soil was added to the weighing dish and the exact soil mass was recorded. Next, the 1.5 g soil sample was placed in a vial containing 15 ml of a pre-mixed commercial extracting solution and was then shaken for 10 minutes. A funnel with a paper filter was placed in a Hach vial and the mixture was poured into it after 10 minutes. This filtered out the non-soluble material from the mixture in the vial so that 10 ml of the clear extractant remained in the Hach vial that was placed in the colorimeter.

Developing

A HI713 Checker HC (Handheld Colorimeter) was used to develop the extractant. The colorimeter was turned on and the unreacted sample was placed inside to zero the meter. The Hach vial was then removed from the colorimeter and one packet of HI713-0 reagent was added. The vial was then shaken for 2 minutes until the powder was completely dissolved. Next the vial was placed back in the colorimeter for 3 minutes until it displayed the concentration of phosphate in ppm. The maximum range of the colorimeter is 2.50 ppm, so if a flashing value of this maximum concentration appeared for a sample this indicated that the reading was over range

and that dilution was necessary. If the reading was too concentrated, a graduated cylinder was used to measure out 10 ml of water. The water was poured into an empty tall vial with the developed Hach solution and shaken to mix it well. This mixture was used to refill the Hach vial to the 10 ml mark and it was placed inside the colorimeter for 3 minutes to get a new reading in ppm. If the reading was still too concentrated the dilution process was repeated. The exact concentration in ppm was recorded for each sample along with the dilution factor, if applicable. The vials and other equipment were thoroughly cleaned after each experiment to prevent the contamination of the other samples.

This method is useful because colorimetry uses an acid to reduce compounds that produce a blue shade that is proportional to a sample's total phosphate content. The reaction between phosphate and the reagent produces the blue tint in the sample that is based on an internal calibration curve within the colorimeter. Using a weak acid method is beneficial because it consistently pulls out the same amount of phosphorus to produce quantitative, comparable results. It is difficult to directly compare the ppm measurements to other sites in the area because of a lack of phosphate analysis for Late Bronze Age sites in the region and because there is no standardized methodology for measuring phosphate; therefore, comparison is complicated because different techniques measure phosphate differently. However, further phosphate analysis in this area should help to establish phosphate patterns at Mycenaean sites to better define the functions of the sites and their relationships to each other.

The results from this phosphate analysis were then mapped using a Surfer software program with the excavation results to determine if phosphate concentrations vary throughout the site or according to known structures. Contour maps were created showing the phosphate levels from low to high across the site at 0.25 ppm intervals using the Kriging algorithm. This is one of

the most flexible methods and is useful for interpolation with almost any type of data. This analysis was conducted at such a small scale that the slight differences produced by other algorithm methods are not significant. The contour maps cover parts of the site where samples were not taken, so the program extrapolates phosphate levels for these areas based on the surrounding points. As a result, the map becomes more accurate when there are more points. This places limitations on the extent of the interpretations that can be made for the results from the areas that were not based on samples, but this method allows the results from the samples themselves to be accurately mapped.

Chapter 4: Results

Once the phosphate analysis was complete, it became clear that there was a relatively high degree of variability present among the samples. Table 1 at the end of this chapter displays the phosphate concentration for each sample in ppm after accounting for the dilution factor. Figure 9 shows a contour map with the results of the soil chemistry overlaid with a site plan of the excavated areas (Figure 8), while Figure 10 depicts the results of the samples taken from the area west of Iklaina. High levels of phosphate concentration variations are apparent across the site from these figures, with differing concentrations of high and low phosphate indicating that space was organized according to site function in some way.

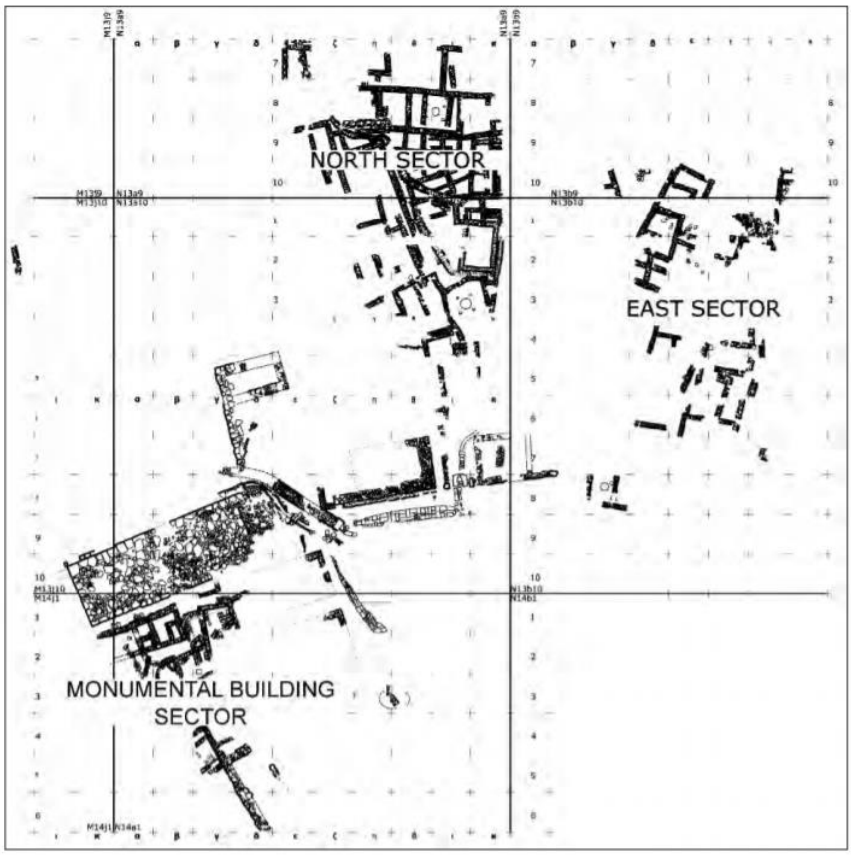

Figure 8: *Plan of Iklaina showing the excavated areas at the end of the 2016 season (by Michael Nelson) (Cosmopoulos 2018).*

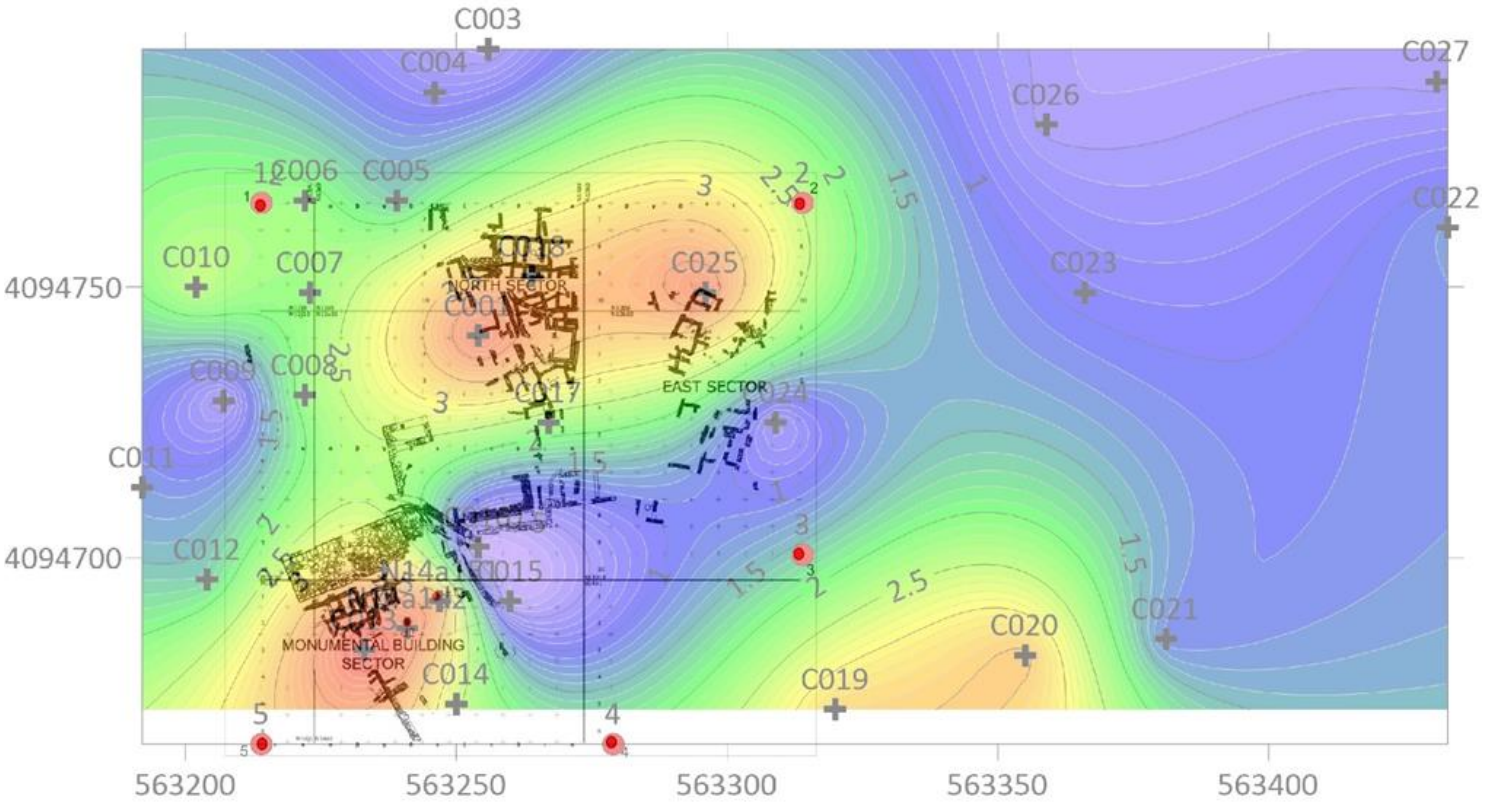

Figure 9: *Contour map of Iklaina with the plan of the excavated areas of the site displaying the sample phosphate concentrations in ppm.*

Figure 9 displays high levels of variation in phosphate concentration across the sampled area of the site. In the site, phosphate levels peak with samples C013, C018, and C025, implying the occurrence of high phosphate producing activities. A zone of medium phosphate levels is visible towards the western edge of the site around samples C006, C007, and C010. This may reflect a domestic space or a midden rather than an area of industrial activity. This could indicate the presence of an area where a midden would accumulate because of the slope towards the west, so houses may be less likely here because of the topography.

As seen in Figure 9, the areas of highest phosphate concentration are found around the North Sector and the Monumental Building Sector, as well as the northern area of the East Sector. Sample C018 in the North Sector has a value of 3.68 ppm while sample C025 to the east of this has an even higher concentration of 4.36 ppm. One of the highest concentrations of 4.84 ppm throughout the entire sampled area is sample C013 from the Monumental Building Sector.

In addition, elevated phosphate levels are present across three samples taken from a recently excavated, modern water line trench, WL001, WL002, and WL003. Sample WL001 has a phosphate concentration of 6.92 ppm, the highest concentration found out of all the samples. These samples were collected from the eastern edge of the site, taken from a trench dug for irrigation in an olive grove. This gave access to a deep profile so that different points could be sampled from along the stratigraphic column, which tested if there were differences in phosphate concentration through the deeper column of the soil and whether there were differences between the red oxidized soil and the enriched darker soil of the site. Instead of using a corer to take samples at an approximate depth, samples were taken directly out of the stratigraphic profile, so they were collected at precise depths to determine if there were significant differences in the quantities of phosphate. The significantly high phosphate concentrations from the water line trench suggests that it was related to industrial activities that require a lot of water for processing, such as textile production or metalworking. The samples from the North Sector have similarly high phosphate concentrations and are associated with the drains, which indicates that this area may have had an industrial rather than domestic function. Scott et al.'s (2016) soil chemical analysis conducted on various elements, excluding phosphate, also indicated high concentrations of elements associated with particular activity areas in this eastern area of the site that suggests some type of activity, whether it was domestic occupation or industry. The phosphate samples

analyzed from this same general area seem to reinforce this idea because of the similarly high phosphate concentrations that support Scott et al.'s (2016) interpretation of activity along the eastern edge of the site; however, no excavation has been carried out in this area, so it is difficult to further interpret the organization and use of space here.

Interestingly, to the west of the excavated areas is a relatively large area of moderate phosphate concentration. These levels are noticeably lower than those of the excavated areas, but this region has significantly higher phosphate levels than the areas to the north and south that exhibit little to no phosphate. Samples C006, C007, and C010 have values of 2.2, 2.16, and 2.52 ppm respectively, indicating the presence of phosphate-producing activity in a large space away from the center of the site. These values seem to be too low to represent the presence of industrial activities such as bronzeworking, but instead may reflect middens or the use of this space as a domestic area. The westward sloping topography also suggests the potential presence of a midden here. The phosphate concentrations in this area appear to be too high to indicate the function of this space as a plaza or "clean" area.

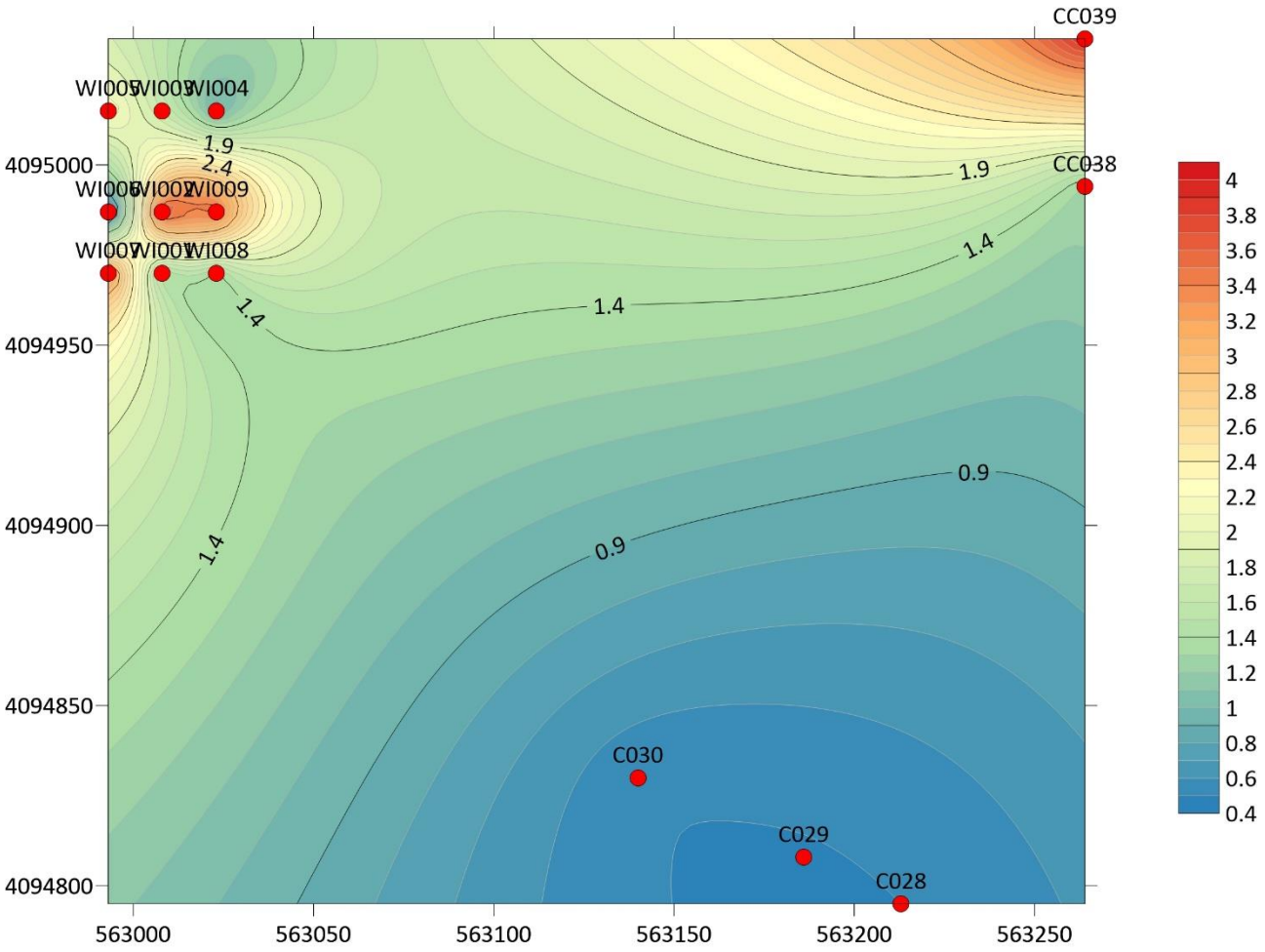

Figure 10: *Contour map of the westernmost area of Iklaina displaying the sample phosphate concentrations in ppm.*

Three of the samples collected from the westernmost area of Iklaina (C028, C029, and C030) have very low phosphate concentrations, suggesting that this space was not used for domestic occupation or industry (Figure 10). The samples taken on the grid (WI001-WI009) in west Iklaina are not particularly important for understanding the central area of the site (Figure 11), but they are significant for understanding how phosphate can enter the soil through modern processes. The samples from this grid are associated with a modern house, so the spike in phosphate observed here is likely the result of modern processes rather than phosphate patterning resulting from activities at Iklaina. Similarly, samples CC038 and CC039 (Figure 10) are

associated with a modern water reservoir for animals. The high concentration of phosphate here can likely be explained as a result of the presence of animals in this area. While not directly useful for understanding the organization of space and the extent of industrial activities at Iklaina, these samples provide direct evidence that demonstrates the need for cautious analysis because there are many ways that modern phosphate can enter and accumulate in the soil.

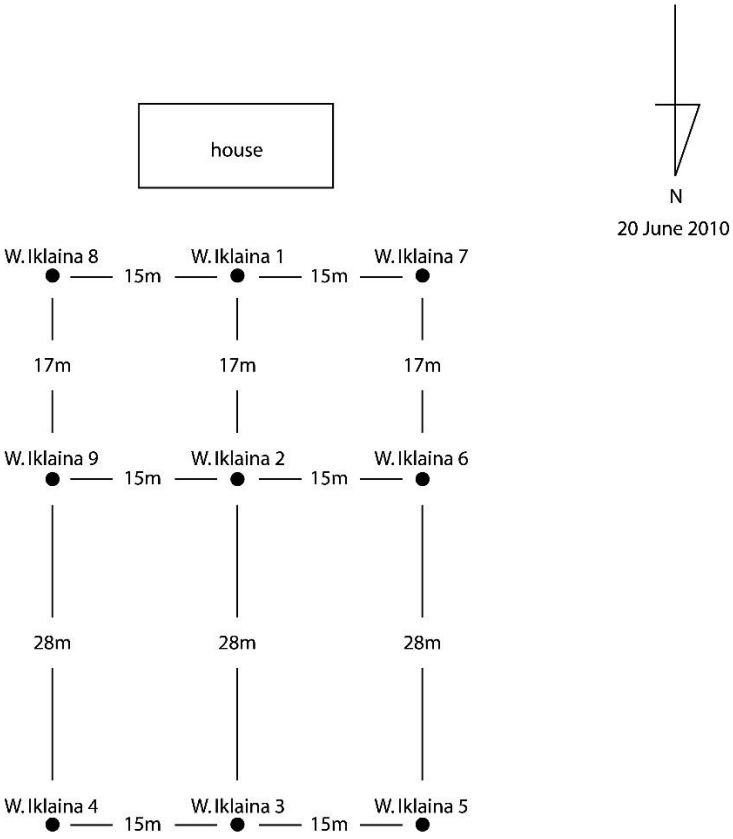

Figure 11: *A grid plan of the nine samples collected near the modern house in the westernmost area of Iklaina.*

Directly to the east of the Monumental Building Sector is an area of low phosphate that extends to the southern part of the East Sector. Samples C015 and C016 have concentrations of 0.2 and 0 ppm, and this extremely low concentration is similar to sample C024 at 0.5 ppm. This section seems to be an area of little specialized economic activity.

At the southwest edge of the site, samples C019 and C020 have relatively high phosphate concentrations. These samples were collected close to a surface feature that may be the remains of a pottery kiln. Further excavation in this area of the site is needed to confirm if this is a kiln,

but the evidence from the surface remains and the phosphate levels suggests that certain industrial activities were segregated in particular spaces away from the center of the site.

The sample taken from Katsimigas (KATS031) has a somewhat low phosphate concentration of 1.26 ppm, so this result is not a clear indicator that significant industry was taking place at this smaller settlement. This is interesting because high quantities of slag were found at this site and interpreted as the result of industrial activities. However, it is difficult to conclude this entirely since the data is limited to one sample. Similarly, the sample from Koukounara (KOU032) has a concentration of 1.03 ppm, making it difficult to determine the extent of economic activities here. This low phosphate concentration might be expected from Koukounara because there were no indications for industry here and it has instead been interpreted as having a possible religious significance related to the presence of tholos tombs. As only one sample has been analyzed from this site, conclusive results about the function of Koukounara cannot be made without further sampling or excavation.

Overall, Iklaina appears to be a complicated site based on the high degree of variation in phosphate levels across the sampled area with a clear separation of space between administrative, industrial, and domestic spaces. This seems to agree with Cosmopoulos' interpretation of the site that places Iklaina in a relatively equal relationship with Pylos based on the complexity of the site and the scale of specialized activities (Cosmopoulos 2019).

Table 1*: IKAP soil sample data.*

Sample Number	Date Collected	Description	Colorimeter	Notes	Dilution	Colorimeter with Dilution Factor
WI001	20-Jun-10	West Iklaina	1.36	c. 25 cm below surface		1.36
WI002	20-Jun-10	West Iklaina	1.84		x2	3.68
WI003	20-Jun-10	West Iklaina	1.69			1.69
WI004	20-Jun-10	West Iklaina	0.93			0.93
WI005	20-Jun-10	West Iklaina	2.21			2.21
WI006	20-Jun-10	West Iklaina	0.24			0.24
WI007	20-Jun-10	West Iklaina	1.68		x2	3.36
WI008	20-Jun-10	West Iklaina	0.68		x2	1.36
WI009	20-Jun-10	West Iklaina	1.75		x2	3.5
WL001	20-Jun-10	water line trench	1.73	tan soil, 0-30 cm	x4	6.92
WL002	20-Jun-10	water line trench	0.68	red soil, 30-40 cm, adjacent to black soil	x4	2.72
WL003	20-Jun-10	water line trench	1.25	black soil, 30-40 cm, adjacent to red soil	x4	5
OS001	1-Jun-08	on site	1.13	near 2006 excavation; 34S 0563254, 4094741	x4	4.52
OS002	20-Jun-10	on site	1.07	N14a1d2	x4	4.28
OS003	20-Jun-10	on site	1.94	N14a1E1	x2	3.88
CC033	19-Jun-10	East Iklaina	0.85			0.85

CC034	19-Jun-10	East Iklaina	0.21		x4	0.84
CC035	19-Jun-10	East Iklaina	0.17		x4	0.68
CC036	19-Jun-10	East Iklaina	0.18			0.18
CC037	19-Jun-10	East Iklaina	0.64			0.64
CC038	19-Jun-10	North Iklaina	1.28			1.28
CC039	19-Jun-10	North Iklaina	1.97		x2	3.94
KATS031	2-Jun-08	Katsimigas	1.26			1.26
KOU032	2-Jun-08	Koukounara	1.03			1.03
C003	1-Jun-08	near excavations	0.33			0.33
C004	1-Jun-08	near excavations	0.75			0.75
C005	1-Jun-08	near excavations	0.4		x4	1.6
C006	1-Jun-08	near excavations	0.55		x4	2.2
C007	1-Jun-08	near excavations	0.54		x4	2.16
C008	1-Jun-08	near excavations	0.55		x4	2.2
C009	1-Jun-08	near excavations	0.34			0.34
C010	1-Jun-08	near excavations	0.63		x4	2.52
C011	1-Jun-08	near excavations	1.22			1.22
C012	1-Jun-08	near excavations	1.62			1.62
C013	1-Jun-08	near excavations	2.42		x2	4.84
C014	1-Jun-08	near excavations	0.64		x4	2.56
C015	1-Jun-08	near excavations	0.05		x4	0.2
C016	1-Jun-08	near excavations	0			0
C017	1-Jun-08	near excavations	0.57		x4	2.28

C018	1-Jun-08	near excavations	1.84		x2	3.68
C019	2-Jun-08	near excavations	0.85		x4	3.4
C020	2-Jun-08	near excavations	1.81		x2	3.62
C021	2-Jun-08	near excavations	0.28	near possible kiln	x4	1.12
C022	2-Jun-08	near excavations	1.23			1.23
C023	2-Jun-08	near excavations	0.93	deep plow		0.93
C024	2-Jun-08	near excavations	0.5			0.5
C025	2-Jun-08	near excavations	1.09		x4	4.36
C026	2-Jun-08	near excavations	0.44	deep plow		0.44
C027	2-Jun-08	near excavations	0.45			0.45
C028	2-Jun-08	near excavations	0.5			0.5
C029	2-Jun-08	near excavations	0.49			0.49
C030	2-Jun-08	near excavations	0.52			0.52

Chapter 5: Interpretation

The results from the phosphate analysis conducted for the site seem to support the idea that Iklaina was a relatively complex site with possible specialized economic activities. The data suggest that Iklaina was an industrial center with a clear separation of space between administrative, industrial, and domestic spaces. This degree of complexity would indicate Iklaina's higher position in the settlement hierarchy where it seems to have been in competition with Pylos before the unification of the Pylian state following the destruction of Iklaina. The same kinds of centralization processes that were taking place at Pylos also seem to have taken place at Iklaina at the same time late in the LH IIIB period, right before the destruction. This further reinforces the idea that Iklaina appears to be relatively similar, rather than different, to Pylos based on the results from the phosphate analysis and the archaeological excavations.

Based on the results of the phosphate concentrations and their distributions across the site, the first hypothesis does not seem to be supported. The first hypothesis states that if Iklaina is thought to be a subordinate settlement to Pylos with less industry and complex organization, then little variation in the phosphate distribution throughout the site can be expected. There is clearly some level of complex organization occurring at Iklaina, with high variability throughout the site corresponding with the evidence for the excavated areas. Since there are not patterns of low variation at Iklaina, then it is unlikely that there is little industry or organizational complexity. Both the phosphate analysis and excavation results seem to suggest that Iklaina was not a subordinate settlement to Pylos and that they may have been equal in the regional settlement hierarchy until the destruction of Iklaina in the 13th century BCE. This interpretation suggests that the two sites are similarly complex, so therefore they were equals or rivals in some sense. This raises the question of whether the evidence from the first destruction phase and

reorganization of the site is part of the rebuilding process initiated by Pylos after subordinating Iklaina. This also brings up the issue of chronology, because based on the radiocarbon dates this entire process of destruction and reorganization occurred over a 50 year period, which may not be enough time to complete this process; however, even if the destruction and rebuilding of Iklaina initiated by Pylos did take place, the degree of complexity demonstrated through the results from phosphate analysis and the excavations suggests that Iklaina and Pylos still seemed to be relatively equal in some way. A second interpretation proposes that Iklaina became similarly complex as compared to Pylos because Pylos controlled and imposed this site organization on Iklaina. As a result, there are multiple ways that the data can be interpreted. While Iklaina's role in the regional hierarchy and its relationship to Pylos are still somewhat unclear, further evidence may be useful to clarify interpretations of the data.

These results appear to better support the second hypothesis, which states that high variation in phosphate concentrations should be indicative of a clear separation of administrative, industrial, and domestic areas at the site; Iklaina may have held a higher position in the settlement hierarchy, potentially in competition with Pylos. Figures 9 and 10 display this variation between the high phosphate zones of the Monumental Building Sector and North Sector, the mid-phosphate zones along the western edge of the site center, and the low phosphate zones extending to the east of the site. The phosphate concentration variations suggest that industry was occurring in the areas of high phosphate concentration, while possible domestic areas or low phosphate producing activities were located to the west leading away from the site center. This complex organization of the site suggests that Iklaina belonged to a higher position in the regional settlement hierarchy where it was competing with Pylos for most of its development; in the last 50-100 years of its existence, it may have been integrated by the palace

or maintained some degree of independence. Given what is known of other sites in the region such as Nichoria, Iklaina differs greatly and seems to share a greater similarity with Pylos. Nichoria does not demonstrate the same level of monumental building and there is no evidence for a strict segregation of space or industrial activity like that found at Iklaina (Rapp and Aschenbrenner 1974). While complexity in site organization seems to indicate a higher position in the settlement hierarchy, the comparison is limited to these sites, so it may be possible that other sites in the region have greater similarities with Iklaina. However, when Iklaina is compared to Nichoria, the only other excavated regional center, they are vastly different, so it can be suggested that soil phosphate analysis at both sites would produce very different results. The phosphate results from Iklaina along with the excavations seem to indicate that this site may have had a different function and organization of space than Nichoria, supporting the idea that Iklaina was equal to Pylos in some way.

According to the third hypothesis, industrial activities or middens may be indicated by defined areas of high phosphate. If the areas of high phosphate are associated with drains, then this could be evidence for industrial activities that use water for processing. There are three distinct areas of high phosphate concentration in the Monumental Building Sector, North Sector, and East Sector. These areas of elevated phosphate concentration seem to indicate that some sort of industrial activity, like bronzeworking or textile production, was occurring in specific areas of the site. The areas of high phosphate at the southeastern extent of the site may reflect a space used for pottery production away from the site center. They may also represent middens or organic waste that was deposited rather than industrial production. In the North Sector where the high phosphate concentrations are also associated with drains, there is evidence to suggest that the drains may have been used in this area for smelting or flax processing that required water,

supporting the third hypothesis. In the eastern part of the site where the phosphate levels increase near the water line trench, both the phosphate analysis and Scott et al.'s (2016) soil chemical analysis indicates the presence of some form of potential industrial activity. Since the area remains unexcavated it is still unclear what the nature and extent of this activity is.

If there is a large area with overall low phosphate concentration, then this space may represent a "clean" area such as a plaza or household area, according to the fourth hypothesis. The area of medium phosphate concentrations extending to the western edge of the site appears to support the fourth hypothesis, since this large area of relatively low phosphate may have been used as a domestic space. This area was not likely to have been used for industrial purposes since the phosphate levels are lower, but a somewhat "clean" domestic area separate from the industrial and administrative areas may have been designated here. It is interesting that there are medium phosphate levels here since this area has not been excavated, so it is possible that the presence of houses is indicated by the phosphate results. If the phosphate levels were all low in this area, it could be assumed that there is no evidence for activity associated with Iklaina, but since there are medium levels, it implies that there are structures or activities here that may differ from what is found at the site center.

Finally, the fifth hypothesis states that if higher phosphate concentrations are found on the site periphery with lower concentrations around the site center, then this suggests that high phosphate producing activities were conducted away from the center of the site. Based on the distribution of the phosphate concentrations, industry seems to have taken place both in the center of the site and towards the site periphery; however, industrial activity near the site center appears to have occurred in a segregated space for industry. The North Sector may have been one of these segregated industrial spaces, since the high phosphate concentrations from the

samples here are associated with the drains. According to Cosmopoulos' (2018) interpretation of the drains, they were likely used for industry rather than as sewers. Some form of industry may have also taken place at the southeastern extent of the site, where there are relatively high phosphate concentrations that may be the result of a kiln used for pottery production. Based on these variations, certain high phosphate producing activities were conducted away from the center of the site while others may have been carried out at the site center in particular industrial areas. It could be expected that certain industrial activities were located on the edges of Iklaina away from the site center or in segregated spaces, which is significant because it indicates that Iklaina is relatively similar to Pylos. This could be further evidence that the two sites are connected in some way, either as competitors or perhaps with Iklaina under the control of Pylos at some point.

Chapter 6: Conclusion

According to my interpretation of the phosphate results compared with the archaeological excavations, Iklaina appears to have been a relatively complex site in terms of potential economic activities and through the clear separation of space for administrative, residential, and industrial spaces. This has significant implications for understanding Iklaina's role in the regional settlement hierarchy and its relationship to Pylos over time within this hierarchy.

The first hypothesis was not supported by the available evidence, suggesting that Iklaina may have been independent from Pylos based on the high variability in phosphate concentration and distribution across the site. Likewise, this high variability supports the second hypothesis and the idea that Iklaina held a higher position in the settlement hierarchy, perhaps to the extent that it was in competition with Pylos before its destruction. This is reinforced by the evidence for the fifth hypothesis, which demonstrates the separation of space at the site for high phosphate producing activities that are likely the result of industry such as bronzeworking. Some form of industrial activity seems to have taken place in particular areas of the site center, such as the North Sector and the Monumental Building Sector, and potentially at the eastern extent of the site along the water line trench. In addition, the area of medium phosphate levels off to the western edge of the site may represent a separate residential area, which supports the fourth hypothesis because it demonstrates the division between residential and industrial spaces that is designated by overall lower phosphate concentrations.

In the literature review, I proposed the idea that Iklaina could be either independent from Pylos, with control over industrial workshops in differentiated spaces, or subordinate to it, with little specialized industry in clearly defined areas. Based on my interpretation of the data and hypotheses, it appears that Iklaina may actually have maintained a certain degree of

independence from Pylos, even though it was destroyed around 1300 BCE. The two sites seem to be similarly complex, with comparable industrial specialization. There are distinct areas of high phosphate at Iklaina, which may be related to industries such as bronzeworking or linen production. The North Sector is one of these high phosphate zones that is also associated with drains for potential processing activities, so this is a possible industrial area at the site that was separated from the administrative and domestic spaces. While the exact activities and their extent are still unclear, both the phosphate and excavation results support the third hypothesis and the proposal that Iklaina demonstrates site complexity through the presence of industrial activity in particular sectors of the site. Overall, the results from the phosphate analysis and the archaeological excavations do not seem to fully support the idea that Pylos had a high degree of control over Iklaina, at least before its destruction and subsequent rebuilding.

The purpose of conducting phosphate analysis at Iklaina was to determine if phosphate patterning could clarify the scale of industry and site organization, particularly when used in conjunction with the results from the excavation. These results have shown that Iklaina is complex, with similar degrees of industrial specialization to Pylos, so this idea that Pylos conquered Iklaina and controlled it may not be fully supported by the results from the phosphate analysis and the archaeological excavations. This means that if the two sites were relative equals or rivals in some sense, it is possible that the first destruction of Iklaina and its subsequent reorganization may be part of a rebuilding process initiated by Pylos after establishing more centralized control over Iklaina. Based on the radiocarbon dates obtained for Iklaina, if this is the case, the process of reorganization and the centralization of Pylos occurred somewhat rapidly over a 50-year period. Another possible interpretation is that Pylos had control over Iklaina before its destruction and that Iklaina is seemingly complex because of a site organization

imposed by the palace. Further evidence is needed to clarify these interpretations, but it is clear that Iklaina was a complex site that was more similar to Pylos than other regional centers such as Nichoria, which does not have evidence for extensive industrial activity or monumental building.

Understanding the relationship between sites in the regional settlement hierarchy is integral for considering how Mycenaean states formed because the extent of economic activity at non-palatial centers is somewhat dependent on the extent of state centralization. Clarifying Iklaina's economic importance and relationship to Pylos over time provides insight into its role in the Messenian settlement hierarchy, which can be used to understand the extent of centralized control exerted by Pylos on other sites. The degree of centralization would likely affect the scale of industry at sites like Iklaina (Galaty and Parkinson 2007), so phosphate analysis can be used to determine the extent of industry, and therefore can be used to understand better a site's function and the degree of centralized state control. In terms of Mycenaean economies, these results show that palatial centers like Pylos may have functioned as administrative and redistributive centers that mobilized sites such as Iklaina to produce raw materials into goods that were exchanged with and utilized by Pylos.

This has implications for the chronology of the region and for Mycenaean state formation processes more generally. These results also raise further questions about Iklaina's role in the regional hierarchy and the development of the Pylian state. The exact function of Iklaina and its relationship to Pylos over time is still somewhat unclear, and it remains difficult to interpret when and why the site was destroyed, rebuilt, and potentially integrated by the palace. Future work in this area is needed to clarify these issues, but the results of this analysis demonstrate that phosphate analysis is a meaningful method for understanding site organization and industrial activity in the Mediterranean region, particularly when used with archaeological excavation. If

used more regularly in future research, patterns can be established to better define the functions of Mycenaean sites and their relationships to each other through phosphate analysis, which would contribute to a better understanding of Mycenaean economies and state formation processes more generally.

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