May 2018

Investigating Land Use by the Inhabitants of Western Cyprus During the Early Neolithic

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Repository Citation

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INVESTIGATING LAND USE BY THE INHABITANTS OF WESTERN CYPRUS DURING THE EARLY NEOLITHIC

By

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A dissertation submitted in partial fulfillment
of the requirements for the

Doctor of Philosophy – Anthropology

Department of Anthropology
College of Liberal Arts
The Graduate College

University of Nevada Las Vegas
May 2018

UNLV | GRADUATE COLLEGE

Dissertation Approval

The Graduate College
The University of Nevada, Las Vegas

May 7, 2018

This dissertation prepared by

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entitled

Investigating Land Use by the Inhabitants of Western Cyprus During the Early Neolithic

is approved in partial fulfillment of the requirements for the degree of

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ABSTRACT

This study presents the first of its kind in Cyprus that combines the use of ancient crop (two-grained einkorn wheat, hulled barley, and lentils) and animal (domestic sheep, goat, cattle, pig, and wild deer) stable isotopes (carbon, nitrogen, and oxygen) for reconstructing land use by the Kritou Marottou *Ais Giorkis* (Cypro-PPNB, 7956-7058 cal BC) inhabitants in western Cyprus. Current definitions of this time period employ the strict forager/farmer dichotomy, even though archaeological evidence suggests otherwise. In addition, it is still assumed that Cyprus was a barren landscape whose inhabitants were isolated from one another and the mainland. An integrated stable isotope approach provides the opportunity to examine plant (crop water management and soil nitrogen composition) and animal (diet and seasonal movement) management strategies, allowing us to then infer land use. The isotopic data also provide information on the environment, which appears to be wetter than today.

The results of this study do not support seasonal movement of herd animals between the lowlands and uplands. Pig were consuming a primarily herbivorous diet, raising the possibility that these animals were actually feral/wild or part of a free-range husbandry regime. Both the two-grained einkorn and hulled barley fall within the ‘moderately watered category.’ The barley samples also had an enriched nitrogen signal. The plant data suggest that barely was possibly given preferential treatment towards its growth. The isotopic data, in combination with the macrobotanical and zooarchaeological analyses, indicate that the inhabitants were not focusing resources and labor on agricultural practices. I argue that they were instead focused on craft production, which was also embedded in hunting activities, for inter-island and perhaps island-mainland exchange. This study helps to reframe our understanding of the Cypro-PPNB by providing new evidence of human activity during this important period in human history.

ACKNOWLEDGEMENTS

Six years ago, I drove out to Las Vegas with my parents from New York. While the drive itself was an adventure, I never could have imagined in my wildest dreams the journey that I would make to reach this point. Along the way I have been fortunate to be mentored by individuals both in and outside of the field of Anthropology, received a number of grants and fellowships that made this journey possible, and met incredible friends and colleagues.

I would first like to thank my committee chair, Dr. Alan Simmons, for his constant support, encouragement, and mentorship. He helped me to grow to be the scholar and researcher that I am today (and put up with my quirks in the field and slightly anxious personality!). In addition, he was always patient when life intervened, which it inevitably does as you go through a graduate program. My committee members, Drs. Barbara Roth, Pierre Lienard, and Stephen Rowland, provided helpful feedback on this beast of a dissertation, which made it a stronger and more digestible scholarly work. They also all contributed to my growth as a scholar, whether it was through classes that were not in my sub-discipline, reading groups, and working in areas outside of Cyprus. I would next like to express my thanks to my undergraduate adviser Dr. Stuart Swiny and his incredible wife, Helena Wylde-Swiny. Stuart's classes at UAlbany, especially the one on Cyprus, started me on my path to getting a Ph.D. Both of you continue to serve as mentors and sources of inspiration.

Through Stuart and Alan, I have been fortunate to meet a wonderfully supportive community on Cyprus, including: Vathoulla Moustokki (who is one of the kindest individuals I have ever met), Dr. Laura Swantek, Dr. Walter Crist, Bill Weir, Dr. Zuzana Chovanec, Dr. Lindy Crew, Dr. Bernard Knapp, Dr. Sturt Manning (who encouraged me to look into isotopes), Dr. Paul Croft, Dr. Leilani Lucas, Dr. Andrew McCarthy, Dr. Carole McCartney, Dr. Pamela Gaber (the PI of my first archaeological excavation on Cyprus), Dr. Tom Davis and his crew at the Kourion Urban Space Project, Jonathan White, Demet Karşılı, Sarah Douglas, Dr. Michelle Gamble, and Frank Garrod.

Funding from the award made by the National Science Foundation to Dr. Alan Simmons (Grant No. BCS-1220351) covered the costs of all lab analyses in this study. In addition, I would like to express my thanks to Cyprus' Department of Antiquities, and in particular Director Marina Solomidou-Ieronymidou and Popi Chrysostomou, and the Committee of Export of Cultural Goods who gave me permission to conduct stable isotope studies on the faunal remains from *Ais Giorkis*. A number of different scholarships/fellowships and funding from particular departments also helped me conduct research, travel overseas, and write my dissertation, including: the Department of Anthropology, College of Liberal Arts Summer Research Award, Summer Doctoral Research Fellowship, UNLV Graduate College Top Tier Graduate Fellowship, Graduate and Professional Student Association Sponsorships, Phi Kappa Phi Love of Learning Award, University of Nevada Las Vegas International Programs Scholarships for Summer Study Abroad, Platt Fellowship (American Schools of Oriental Research), and the Helena Wylde Swiny and Stuart Swiny Fellowship (Cyprus American Archaeological Research Institute).

Throughout this journey, I have met wonderful friends and colleagues. Although you all know who you are, I would like to give several shout-outs. I have been fortunate to work with a wonderful and supportive team at the Graduate College, and I am particularly grateful for mentorship from Dean Kate Korgan and Valarie Burke. Dr. Levi Keach, you have been a wonderful colleague and friend in the field. I have enjoyed our discussions over the last six years and I am happy we are finishing together (since we did start together). Greg Alliger, I appreciate all of your help with ArcGIS and our chats about Cypriot archaeology over the last few years.

Finally, Matt, thanks for your constant support and encouragement, especially the last few months of the dissertation writing phase. I would also like to thank the best cat that has been a part of my life, Rambo. Not only did you crack me up during periods of incredible stress with your huge and funny personality, but you were also always a source of comfort and joy.

Finally, this dissertation never would have been written without the support of my family. Mom and dad, you instilled in us at a young age the importance of education. You taught us to be independent and critical thinkers. Through thick and thin you always have had my back. Thank you for everything. Megan and Emily, you two are the best sisters any one could ask for. I am proud of both of your accomplishments and look forward to the crazy adventures that we will share together in the coming years.

DEDICATION

To my parents,

who have always been my biggest supporters, encouraged me to pursue my dreams, and who instilled in me at a young age a love for education, research, and reading.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

For the Mediterranean island of Cyprus, “the importance of land and water tenure is exceeded only by the availability of those two elements” (Christodoulou 1959:70). This quote by Demetris Christodolou, who wrote an indispensable volume on rural land use patterns on the island, emphasizes that water and land are finite resources. Cyprus has a semi-arid climate, and as a result, it has a number of physical and environmental constraints including access to fresh water. This is largely due to the unpredictability of rainfall and the high rate of evaporation. In turn, this impacts access to grazing land and the extent of fertile agriculture soil.

These constraints, however, do not present absolute limitations for people. Rather, human resourcefulness in the form of management strategies was used to overcome these constraints. For example, based on ethnographic evidence from Cypriot rural farmers in the 19th and 20th centuries, we know that they alleviated risk through particular agricultural practices, including: multiple cropping, dispersal of field plots, crop rotation, and herding mobility (Marks 1999; Stewart 2016). Access to these finite resources has likely always been challenging for the island’s inhabitants, and particularly when human groups began permanently settling Cyprus around 12,000 years ago and brought with them a variety of plant and animal species.

This study seeks to understand land use strategies by people in a challenging semi-arid environment. To do this, I utilize data from an archaeological site in western Cyprus during the early Neolithic, specifically the Cypro-Pre-Pottery Neolithic B (Cypro-PPNB; 8,500/8,400-7,000/6,800 cal BC).[1] Because I am interested in what humans were doing in the landscape,

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[1] I focus primarily on western Cyprus in this dissertation because all data comes from a single site from this area. Cyprus has a number of micro-climates and micro-environments and as a result it would be challenging to extrapolate data from this dissertation to the entire island.

particularly as a result of the introduction of plant and animal species in the face of key physical and environmental constraints, I adopt a modified human niche construction perspective. To address land use strategies, I integrate carbon, nitrogen, and oxygen stable isotope analyses of both the botanical (two-grain einkorn, hulled barley, and lentil) and faunal remains (domesticated sheep, goat, cattle, and pig, and wild deer) from the archaeological site Kritou Marottou *Ais Giorkis* (hereafter *Ais Giorkis*) located in western Cyprus.[2] Most of these resources were introduced to Cyprus by humans during the early Neolithic. Barley is perhaps the only exception as it is believed to be an endemic plant species on the island (Chapter 2).

Traditional zooarchaeological and botanical studies have allowed for a more fine-grained view of how Neolithic lifeways, including animal and plant management strategies, varied by site and region. However, some critical aspects of these strategies are less visible through traditional methods, including animal diet, animal movement, animal birth seasonality, soil nitrogen composition, and crop water management practices. Stable carbon, nitrogen, and oxygen isotope analyses offer a systematic approach to understanding these issues. Plant and animal management strategies allow us to infer about land and water management strategies. Stable isotopic studies have been successfully conducted at a number of PPNB sites on the mainland to address animal and plant management strategies. However, these geochemical studies have been under-utilized in Cyprus (but see Hadjikoumis et al. forthcoming; Lange-Badré and Le Mort 1998; Leon 2016; Scirè Calabrisotto 2017a, 2017b).

By shedding light on plant and animal management tactics, I can infer land use by Neolithic inhabitants of western Cyprus. Thus, by incorporating stable isotope analyses into this

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[2] Cypriot archaeological sites are normally referred to by both the village name and local toponym. The latter is typically italicized (e.g., Kritou Marottou *Ais Giorkis*). I will always present the complete site name first and then use the most common single name, which is typically the local toponym (McCartney et al. 2010:133).

study I am providing a new window into this time period and improving our understanding of land use strategies which is a problem not limited to the past.

1.2 Methodology and Research Questions

My research goal is to better understand the inhabitants themselves. My primary research question is: how did the Neolithic inhabitants of western Cyprus manage their landscape? We currently have very little direct archaeological evidence for land and water management strategies. It is likely that other strategies occurred that left ephemeral remains, such as seasonal movement between the lowlands and uplands. Ethnographic data from 19th and early 20th centuries Cypriot peasant subsistence farmers also provide some information about possible management strategies in the early Neolithic. These data are thought to provide suitable analogies to past resource management strategies because daily life for most Cypriots before the mid-20th century was still primarily based on the availability of local resources (Stewart 2006, 2016). Based on ethnographic data, it is thought that grazing routes changed seasonally depending on the availability of water, herd composition, and the ratio of cultivated to fallow fields. Furthermore, responses to risks of crop shortages or losses included varying the use of domesticated animals, using different land fragmentation strategies, polycropping, and varying crop-dispersal strategies (Christodoulou 1959; Marks 1999; Sallade 1978, 1979; Sallade and Braun 1982; Stewart 2006, 2016). Interestingly, for the western region, wheat cultivation and pastoralism appear to have a long tenure (Della et al. 2006), perhaps even starting in the Cypro-PPNB. In examining animal and plant management strategies through geochemical studies, I am trying to better understand human resourcefulness at the beginning of permanent settlement on the island.

I have three secondary research questions that will allow me to examine my primary research question.

1. What are the baseline standards for $\delta^{13}C$*,* $\delta^{15}N$*, and* $\delta^{18}O$ *in the western region of Cyprus?*

2. What were the plant management strategies for two-grained einkorn, hulled barley, and lentil?

3. What were the animal management strategies for sheep, goat, cattle, and pig?

The application of stable isotopic studies to problems of archaeological and anthropological interest began in the late 20th century (Ambrose and Krigbaum 2003). Since these early studies, there has been an increase in both the types of stable isotopes used (e.g., δ^{13}C, δ^{15}N, ^{87}Sr/^{86}Sr, and δ^{18}O) as well as their application to address a variety of research questions at archaeological sites throughout Europe and mainland Southwest Asia, including ancient crop and animal management strategies (e.g., Balasse et al. 2012; Henton 2012; Henton et al. 2010; Pearson et al. 2007, 2015; Vaiglova et al. 2014; Wallace et al. 2015; Zavodny et al. 2014), the domestication processes (e.g., Balasse et al. 2016; Makarewicz and Tuross 2012), human land use (e.g., Fraser et al. 2013), and environmental reconstructions (e.g., Balasse et al. 2013).

In contrast to the European and Southwest Asian mainlands, there are currently less than a handful of published studies on Cyprus that rely on the incorporation of stable isotopes. These published studies primarily focus on *modern* regional hydrology and groundwater flow (Boronina et al. 2005a, 2005b; Jacovides 1979). Cyprus was briefly part of the Global Network of Isotopes in Precipitation (GNIP) from 1964-1972 (IAEA/WMO 2015), which does provide some general trends for oxygen isotopes on the island. There are only a few published studies (Scirè Calabrisotto 2017a) and dissertations (Leon 2016; Scirè Calabrisotto 2017b;) that use material from the prehistoric time period. In addition, there is only one other ongoing study (Hadjikoumis et al. forthcoming) that uses stable isotope analyses on Neolithic faunal remains. Thus, this dissertation contributes to stable isotope research on archaeological material from the island.

Carbon and nitrogen stable isotope analyses were conducted on bone collagen from *Ais Giorkis* domesticated sheep, goat, cattle, and pig and wild deer remains. Samples were taken from the compact mid-shaft of adult animals. Carbon and oxygen stable isotope analyses were conducted on mandibular molars (M_2 and M_3) from caprines. All of the bone and molar samples have been analyzed by the project's zooarchaeologist, Dr. Paul Croft. Serial sampling was employed for the caprine teeth. For the two-grain einkorn, hulled barley, and lentil, carbon and nitrogen stable isotope analyses were conducted. The samples have been analyzed by the project paleobotanist, Dr. Leilani Lucas.

One important issue that archaeologists working in the early prehistory of Cyprus face is the small number of sites, particularly in comparison to the European and Southwest Asian mainlands. In turn, this results in a smaller sample size. There is only one clear upland site in the Cypro-PPNB (*Ais Giorkis*), and it is located in the western region. Because of these constraints, I have chosen to sample from one archaeological site. While conclusions from this research will be tentative until more upland Cypro-PPNB sites are excavated and studied, the small sample sizes for this time period should not act as a limitation for conducting scientific research. The other issue that directly impacts this research is that we do not know the role C_4 plants played in human and animal diets (but see Scirè Calabrisotto 2017a). Below, I discuss how stable isotopes can enable me to address each of the secondary research questions.

1.2.1 Secondary Question 1

As mentioned above, there are very limited baseline data for carbon, nitrogen, and oxygen stable isotopes. Because of this, I collected land snails from the western region to help begin to establish carbon and nitrogen baselines. There are also now several studies (Hadjikoumis et al. forthcoming; Lange-Badré and Le Mort 1998; Leon 2016; Scirè Calabrisotto 2017a, 2017b) that can be used as comparative data for my results. These data all help with interpretation of the isotope results from this study. In addition, the carbon and nitrogen stable isotope values from the *Ais Giorkis* deer remains provides general information on the environmental setting of animal husbandry practices at the site (Balasse et al. 2013). I also synthesize the oxygen isotope baseline data on the island (Boronina et al. 2005a; IAEA/WMO 2016; Jacovides 1979), which Leon (2016) has also recently done.

1.2.2 Secondary Question 2

Based on ethnographic data, responses to risks of crop shortages or losses included varying the use of domesticated animals, using different land fragmentation strategies, polycropping, and varying crop-dispersal strategies (Marks 1999). Below are scenarios for the plant management strategies that may be detected and what these can allow us to infer about land use by the Neolithic inhabitants.

1.2.2.1 Nitrogen Enrichment of Soil. The $\delta^{15}N$ values of the two-grained einkorn wheat and hulled barley are enriched. Today, ^{15}N soil enrichment can be caused by a number of anthropogenic factors; however, the primary factors that could impact the crops in the Neolithic is the addition of manure or possibly crop rotation or polycropping with lentils. Experiments conducted on domesticated wheat and barley crops in modern farm settings have found that farmyard manure leads to an increased $\delta^{15}N$ value (Bogaard et al. 2007; Fraser et al. 2011; Vaiglova et al. 2014). Furthermore, Fraser et al (2011) have identified three different isotopic ranges that correspond to three different levels of manure treatment. These data will allow for a better understanding of the extent of possible manure treatment of the crops from *Ais Giorkis*. Manure treatment implies a conscious and planned manipulation of the soil in order to help crop growth. It takes a number of years for the enriched nitrogen from the manure to become available for uptake for the crops. This further implies that the same field was used over a long period of time by human groups. While crop rotation has been suggested to increase nitrogen values, we do not know is this strategy would impact the isotopes of the other crops being grown with the legumes. To help determine if the botanical remains have an enriched ^{15}N signal, I compare the crop stable isotope values with forage values estimated from the collagen of the local herbivores examined in this study. The local herbivores represent a local unmanured baseline. This is because their diet is mostly composed of a mixture of wild plants.

1.2.2.2 No Nitrogen Enrichment Detected in the Soil. The δ^{15}N values of the two-grained einkorn wheat and hulled barley are not enriched, suggesting that humans were not consciously manipulating the soil where crops were grown to increase fertility.

1.2.2.3 Water Status of the Crops and Pulses. Wallace and colleagues (2013), through controlled experiments, defined three categories that indicate water status of cereals and pulses. These categories are ‘poorly watered,’ ‘moderately watered,’ and ‘well-watered’ crops. Each category has a specific δ^{13}C range. Therefore, the mean δ^{13}C values of two-grained einkorn, hulled barley, and lentil from *Ais Giorkis* can enable an approximation of the water management strategy of each plant. If one of the plants is better watered than the other two, then this would imply the plant is given preferential treatment towards its growth.

1.2.3 Secondary Question 3

Based on ethnographic data, it is thought that grazing routes changed seasonally depending on the availability of water, herd composition, and the ratio of cultivated to fallow fields (Marks 1999). Below are scenarios for the animal management strategies that may be detected and what these can allow us to infer about land use by the Neolithic inhabitants. In addition to these scenarios, I will also briefly discuss birth seasonality of the caprines in this study from carbon and oxygen isotope analyses of the caprine molar enamel. While this is not necessarily tied to land use, since we do not know where animals were born based on carbon and oxygen stable isotopes, birth seasonality is a key part of animal management strategies.

1.2.3.1 Scenario 1: Evidence for Mobility and Seasonal Movement. The carbon and nitrogen values of the sheep, goat, and cattle remains have large ranges. As herbivores, large isotopic ranges can only be attributed to large variations in the local plants, soils, and in the animals themselves. In turn, this implies that the animals were moved across a landscape that varies isotopically (different pastures) (Pearson et al. 2007). Documentation of mobility implies that some Neolithic groups moved across the landscape with their animals likely to mitigate risks associated with limited or uneven rainfall, which impacts water sources, graze availability, and arable agriculture land. Mobility strategies incorporate not only herding of domestic animals, but also hunting and foraging of wild resources. Mobility associated with herd animals was common for at least some Cypriots in the recent past.

The oxygen and carbon stable isotopic values of the caprine molars will have broad ranging isotopic values due to the animals being moved over large distances from the site, and consuming vegetation and water from wider habitat ranges. In addition, there will be inverse directionality in δ^{18}O and δ^{13}C sequences, indicating that the animals were moved as part of a vertical transhumant mobility strategy, which included winter lowland and summer upland pastures. On Cyprus, coastal areas receive substantially less rain than upland areas. This would impact the availability of graze, water, and arable land, particularly during the summer. Thus, seasonal movement would be one type of management strategy to ensure more strategic land and water use by Neolithic groups.

1.2.3.2 Scenario 2: No Evidence for Mobility or Seasonal Movement. The carbon and nitrogen, and oxygen stable isotopic values of each of the animal species cluster around their respective means (or have a relatively narrow range). In addition, we do not have patterns of inverse cyclical variation in the oxygen and carbon isotope measurements of molar enamel samples. Rather, we see δ^{18}O and δ^{13}C values increase together. The most parsimonious explanation for these scenarios is that the animals were all raised locally within a similar environment. The narrow range for the carbon values could also mean that we do not have C_4 plants at or near the site as well. The lack of evidence for mobility and seasonal movement implies that some humans, or at the very least domestic animals, at *Ais Giorkis* stayed either at the site or near the site year-round.

1.2.3.3 Combination of Scenarios 1 and 2. Some of the animal remains from *Ais Giorkis* have large carbon, nitrogen, and oxygen stable isotopic ranges and others have more restricted ranges. This scenario implies that some of the individuals were moved over different pastures and others were raised at or near the site. Thus, some of the humans at the site remained there year-round and others seasonally moved their animal herds across the landscape and possibly between the coast and uplands. Different management strategies were occurring at the site depending on where the animal and its human owner originated from.

1.2.3.4 Pig Management Strategies. Pig can offer an interesting comparison with the herbivores at the site, including enabling an assessment of whether pigs were consuming human food waste. If this is the case, their nitrogen values should be elevated, as compared with the other medium-sized herbivores (i.e., sheep and goat). Domestic pigs were likely kept at the *Ais Giorkis* and fed domestic refuse, including other animal products (Balasse et al. 2013). The stable isotopic values from the pig remains will be tricky to interpret since I do not have values from wild boar samples. In addition, it is tough to know for certain if the pig samples I chose are domestic or wild, in part because determining the domestic status of pigs is challenging.

1.2.4 Summary

These three secondary questions enable me to address my larger research question. We need baseline data (secondary question 1) in order to interpret the isotopic data from the *Ais Giorkis* botanical (secondary question 2) and animal (secondary question 3) remains. Based on the isotope data, the plant and animal management strategies will then allow us to infer land use by Neolithic inhabitants in western Cyprus.

The rest of this chapter will discuss the key elements of this dissertation, including: the Neolithic Revolution, chronology of the Cypriot Neolithic, the study site (i.e., *Ais Giorkis*), the theoretical framework in this dissertation (modified niche construction), and the broader significance of this study. All of these elements help to better frame the above research questions.

1.3 Neolithic Revolution

The Neolithic Revolution first occurred on mainland Southwest Asia. It partly refers to changes between human and plant and animal relationships, including for the first time the incorporation of domesticated resources into economic strategies that had solely depended on hunting and foraging (Larson et al. 2014; Simmons 2007; Zeder 2008; 2011). The transition began on the mainland by at least the Pre-Pottery Neolithic A (PPNA; Table 1.1). During the PPNA, there is evidence of humans cultivating morphologically wild cereals and pulses as well as managing morphologically wild animals (Asouti and Fuller 2013; Bar-Yosef and Meadow 1995; Byrd 2005; Kuijt and Goring-Morris 2002; Zeder 2008). By the succeeding period, known as the Pre-Pottery Neolithic B (PPNB; Table 1.1), the earliest domesticates appear on the Southwest Asian mainland (e.g., Arbuckle 2014; Asouti and Fuller 2013; Zeder 2008).

Table 1.1. Late Epipaleolithic to Early Neolithic Chronocultural Horizons in Southwest Asia

Chronoculutral Horizons	**Calibrated years BC**
Late Epipaleolithic	~12,000 - 10,000
Pre-Pottery Neolithic A (PPNA)	~9700 - 8700
Pre-Pottery Neolithic B (PPNB)	
Early PPNB (EPPNB)	~8700 - 8200
Middle PPNB (MPPBB)	~8200 - 7500
Late PPNB (LPPNB)	~7500 - 7000

Modified from: Asouti 2013; Asouti and Fuller 2012: Table 1; Asouti and Fuller: 2013: Table 1

This complex of domesticated animals and crops includes sheep, goat, pig, cattle, cereal (e.g., einkorn wheat, emmer wheat, and barley), pulses (e.g., lentil, pea, and chickpea), and flax. It is often known as the ‘Neolithic package’ (Arbuckle 2014; Belfer-Cohen and Goring-Morris 2011; Weiss and Zohary 2011; Zeder 2011). Sheep are regarded as one of the first domesticated livestock, with genetic evidence indicating that all domestic sheep (*Ovis aries*) are descended from the Asiatic mouflon (*Ovis orientalis*). The earliest evidence for intensive management of local mouflon populations occurs in eastern Turkey/northeast Iraq/northwest Iran by the early tenth millennium cal BC. There is clearer evidence of domestic sheep management in southeastern Turkey during the mid-ninth millennium BC, which occurs in the area outside of the region with intensive mouflon hunting, and represents some of the earliest evidence for morphologically domestic sheep (Arbuckle 2014:56-59; Zeder 2008:11598). Domestic goats (*Capra hircus*) are derived from the Asiatic bezoar (*Capra aegagrus*) and were first thought to have been domesticated in modern-day Iraq and Iran during the ninth millennium BC (Arbuckle 2014:59-62; Zeder 2008:11598). It has been more difficult to reconstruct the processes leading to the domestication of cattle and pig because of the small sample size and fragmentary nature of faunal assemblages (Arbuckle 2014:62). Domestic cattle (*Bos taurus*) are descended from aurochs (*Bos primigenius*); the latter is found throughout mainland Southwest Asia, excepting the most arid parts, in the Pleistocene and early Holocene. It is thought that intensive management of cattle first occurred in the upper Tigris and Syrian Euphrates region (Arbuckle 2014:62-64; Zeder 2008:11598), with morphological changes first beginning in the early ninth millennium cal BC. Wild boar (*Sus scrofa*) are the ancestors of domestic pigs. Genetic studies have demonstrated that the Near East was one of several areas where pigs were domesticated (Larson 2005). It is thought that pigs were first domesticated somewhere in southeastern Anatolia, likely by the mid to late eighth millennium BC (Arbuckle 2014:64-65; Zeder 2008:11598).

Similar to the domestication of animals, there was no single center of origin for plant domestication. Two-grained einkorn, rye, and barley were cultivated in the upper Euphrates Basin, and emmer and barley were grown primarily in the southern Levant. Of note, genetic studies have failed to determine a geographically focused nuclear zone for the origin of the main domestic crop species in the Neolithic. Several of the main crop species have separate gene pools in different sub-regions of Southwest Asia (Asouti and Fuller 2013).

The Neolithic Revolution involved significant transformations in not only human economy, but in technology (Belfer-Cohen and Goring-Morris 2011; Garfinkel et al. 2006), demography (Bocquet-Appel 2011), social organization (Belfer-Cohen and Goring-Morris 2011; Bowles and Choi 2013; Byrd 2002; 2005; Kuijt and Goring-Morris 2002; Kuijt et al. 2011; Wright 2014), and ideology (Belfer-Cohen and Goring-Morris 2011; Cauvin 2002; 2007; Kuijt 2002).

Recent archaeological advances on the Southwest Asian mainland have focused on a more fine-grained view of the variation in Neolithic lifeways by site and region. Specifically, it has become increasingly clear that most areas had mixed economies before agricultural intensification. In addition, domestic species were not uniformly adopted across Southwest Asia (e.g., Arbuckle 2013, 2014; Arbuckle and Makarewicz 2009; Conolly et al. 2011, 2012; Zeder 2011). For example, evidence for domestic cattle in central Anatolia does not occur until around 6500 cal BC, although aurochs were hunted in this region. Surrounding areas did have domestic cattle, leading to the argument that they were imported into central Anatolia from these areas (Arbuckle 2013; Arbuckle and Makarewicz 2009). Cattle were particularly important at settlements in northwest Anatolia. In fact, based on the presence of dairy fats preserved on ceramic vessels, milk and associated products were thought to have been important in this region (Evershed et al. 2008).

The Levantine region also display significantly different patterns of domestic animal incorporation and use in daily life. Until the late/final PPNB, Mediterranean Levantine sites have low numbers of domestic animals (less than 1%). However, this number increases dramatically by the end of the PPN. This delayed adoption pattern can also be seen in the more arid regions of the southern Levant, where there are, on average, low levels (less than 1%) of domestic animals in faunal assemblages (Conolly et al. 2011). The story is not any different with plants. For example, we find naked barley and free threshing wheat in Jordan, the Euphrates Valley, and central and southeastern Turkey, but not on Cyprus (Lucas 2014:70).

By focusing on local and regional differences during the Neolithic, including the varied adoption of domestic plants and animals, researchers have been able to better understand Neolithic groups' management of the landscape across Southwest Asia. Unfortunately, Cyprus has yet to be examined with such an approach. Current archaeological evidence suggests that Cyprus was first permanently settled around 11,500 years ago during the Neolithic Revolution. The island presents a unique opportunity for investigating a small-scale society during the early Neolithic, and specifically the Cypro-PPNB (Table 1.2), because human groups had to translocate all major economic resources (plants and animals) to the island, including wild and domesticated resources. By this time period, Cyprus lacked both a large endemic fauna and many of the economically important plant species found on mainland Southwest Asia (Stanley-Price 1979; Lucas 2014; Vigne et al. 2012). By introducing familiar plants and animals to the island, it seems that these early Neolithic peoples were trying to intentionally (and unintentionally) work to make the island similar to previous environments that they came from (Hofman and Rick 2017:9). These inhabitants had to develop land and water management strategies to successfully maintain a livelihood. This study is a contribution to the investigation of land use by early Neolithic groups on Cyprus, and will ultimately allow us to place what is going on in Cyprus within a broader pan-Mediterranean/Southwest Asian perspective.

1.4 Chronology of Cypriot Neolithic

The earliest evidence that we have for a human presence on the island dates to the Late Epipaleolithic (Table 1.2). This period is known as the Akrotiri phase. It is named after the archaeological site of Akrotiri *Aetokremnos* (hereafter Akrotiri), which, thus far, provides the earliest and most secure evidence for people being on the island. The succeeding period is known as the Aceramic Neolithic or Pre-Pottery Neolithic (PPN), and is further broken down into the Early Aceramic Neolithic and the Late Aceramic Neolithic.[3] The former is comprised of two phases (Table 1.2): Cypro-PPNA and Cypro-PPNB. The latter is comprised of one phase (Table 1.2): the Khirokitia Culture.[4] The primary phase discussed in this dissertation is the Cypro-PPNB. In order to provide context for a discussion on land and water management strategies, however, I also discuss the other phases/cultures (Chapter 2).

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[3] I will use the term Early Neolithic to refer broadly to both of these periods. They both do not have pottery.

[4] There is substantial debate surrounding the use of terms like *PPNA* and *PPNB*, in part because many scholars believe these terms have cultural and evolutionary assumptions (e.g., Knapp 2013; Peltenburg 2004a). To overcome these issues, Knapp (2013:25-28, Table 2) has created a different chronological schema. For him, the Early Neolithic is divided into the Initial Aceramic Neolithic (synonymous with the Cypro-PPNA), Early Aceramic Neolithic (synonymous with the Cypro-PPNB), and Late Aceramic Neolithic (synonymous with the Khirokitia Culture). However, as a discipline of Near Eastern archaeologists working in the Neolithic, we have yet to adopt new chronological, culture, or other classificatory systems that satisfies all parties and can be used on both mainland Southwest Asia and Cyprus. The terms *PPNA* and *PPNB* are still primarily used on the mainland. Following Peltenburg (2003:86-87, 2004a:20), I opt for a dual region plus period term (e.g., Cypro-PPNB), which captures both the local and supraregional characteristics of this momentous period.

Table 1.2 Chronological Schema of Cyprus: Late Epipaleolithic to Ceramic Neolithic

Periods	**Phase/Culture**	**Calibrated years BC**
Late Epipaleolithic	Akrotiri Phase	11,000 - 9000
Early Aceramic Neolithic		9000-7000/6800
	Cypro-PPNA	9000 - 8500/8400
	Cypro-PPNB	
	Cypro-EPPNB	8500/8400 - 7900
	Cypro-MPPNB	7900 - 7600
	Cypro-LPPNB	7600 - 7000/6800
Late Aceramic Neolithic	Khirokitia	7000/6800 - 5200
Ceramic Neolithic	Sotira	5200/5000 - 4500/4000

Modified from Knapp 2013: Table 2

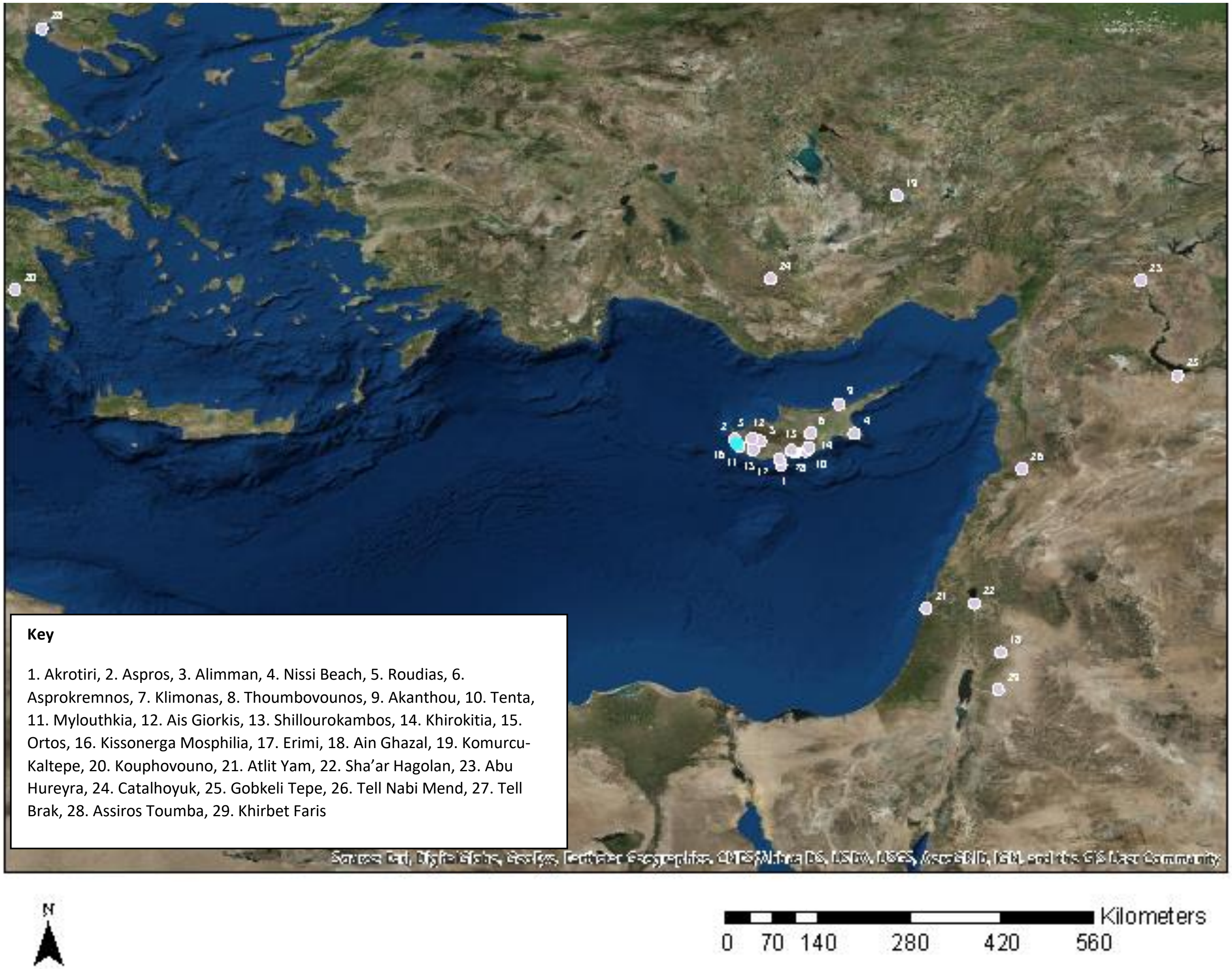
For all sites discussed in this study, I recalibrated, if available, original uncalibrated radiocarbon ages using Oxcal 4.3 (Bronk Ramsey 2009, 2017) and the Intcal 09 calibration curve (Appendix A) (Bronk Ramsey 2009, 2017; Reimer et al. 2009). The choice to use an earlier calibration curve was made for two reasons. The first is so that the dates in this dissertation are comparable to Levi Keach's dissertation (2018), which also focuses on research questions related to the inhabitants of *Ais Giorkis* and early Cyprus. The second reason is to ensure that the dates are directly comparable with those used in the most recent synthesis of the archaeology of Cyprus (Knapp 2013; Manning 2013).

Chronological information (especially for archaeological sites) is typically expressed in calibrated calendar years BCE/CE. Radiocarbon dates are occasionally expressed in terms of cal BP if the dates are expressed as such in the primary source. This expression is typically retained for the radiocarbon dates of bone. Uncalibrated dates are expressed as BP. The expression *ka* (thousand years) is retained when the original chronological information is expressed as such. In comparison to other chronological information, this expression indicates the relative imprecision of the original data (Dusar et al. 2011).

1.5 Study Site: Kritou Marottou *Ais Giorkis*

The study site was chosen because it is uniquely located in the uplands during the Cypro-PPNB (Figure 1.1). It is situated 25 km northeast of Paphos, at approximately 480 meters above sea level (masl) in the foothills of the Troodos Mountains. It overlooks the Ezousas River. Excavations have been completed and a monograph is currently being written about the findings. Approximately 300 sq m have been excavated, producing one of the largest faunal assemblages on the island. The assemblage is comprised of Mesopotamian fallow deer, followed by pig and caprine. There are also small quantities of cattle remains (less than 2%). Dog and cat, presumably domesticated, are also represented in very small numbers. Radiocarbon determinations suggest a site occupation of around 400-500 years (7956-7058 cal BC). Two of the three Near Eastern founder cereal crops are present: einkorn and hulled barley. Pulses and wild taxa, such as pistachio and pea/vetch, were also recovered. Material artifacts recovered include: a large chipped stone assemblage (around 300,000 pieces); numerous ground stone implements; picrolite (local mineral whose color varies from light blue-green to dark olive-green) ornaments; shell beads; and several circular/oval, cobbled structures, which would have required substantial labor investment in their construction and maintenance. Combined with the faunal and floral assemblage, all of these material artifacts and structures suggest that people were present at the site for at least part of the year (Lucas 2014; Lucas et al. 2012; Simmons 1998a, 1998b, 2009a, 2009b, 2010, 2012; Simmons et al. in press).

Figure 1.1 Map of main sites discussed in this study



Key

1. Akrotiri, 2. Aspros, 3. Alimman, 4. Nissi Beach, 5. Roudias, 6. Asprokremnos, 7. Klimonas, 8. Thoumbovounos, 9. Akanthou, 10. Tenta, 11. Mylouthkia, 12. Ais Giorkis, 13. Shillourokambos, 14. Khirokitia, 15. Ortos, 16. Kissonerga Mosphilia, 17. Erimi, 18. Ain Ghazal, 19. Komurcu-Kaltepe, 20. Kouphovouno, 21. Atlit Yam, 22. Sha'ar Hagolan, 23. Abu Hureyra, 24. Catalhoyuk, 25. Gobkeli Tepe, 26. Tell Nabi Mend, 27. Tell Brak, 28. Assiros Toumba, 29. Khirbet Faris

Sources: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

1.6 Small-scale Societies and Agriculture

There is a long history in archaeology of examining the domestication processes and the subsequent developments of agricultural economies and economic intensification, largely because these processes represent a major evolutionary transition for human society (Smith 2012). The Near East is not the only place where we see domestication processes occur. In around a dozen areas in the world, small-scale human societies independently brought a wide variety of plant and animal species under domestication between 11,000 and 5,000 years ago. Many of these domesticates "provided the lever with which we have transformed much of the earth into agricultural landscapes that feed an increasing global population (Smith 2012:260)." By small-scale society, I mean one that is characterized by relatively uncentralized political systems (i.e., political autonomy is at the level of one or a few local communities) and that ranges from several hundred to several thousand people in size (Bodley 1996:12; Smith and Wishnie 2000:493; Spielmann 2002:195).

Agriculture is a contentious term within the archaeological literature on the early Neolithic, in part because there is little agreement over how the term should be defined (Harris 1996:3). Some scholars deny the applicability of the term *agriculture* until the Late PPNB and ascribe "true" agricultural status only to economies from the Pottery Neolithic (PN) onwards when we see economies dominated by domesticate plants and animals (e.g., Akkermans 2004). Others (e.g., Harris 1989 , 2002) have subdivided the economies during the PPN into four developmental stages: 1) hunting and gathering; 2.) cultivation of predomesticated plants, primarily cereal crops, which is supplemented by hunting and gathering; 3.) cultivation of fully domesticated plants; and 4.) the integration of agropastoral production with the adoption of domesticated caprine herding (Asouti and Fuller 2013:303, Figure 2; Harris 1989, 2002).

In the first paragraph of Smith's seminal article (2001) on low-level food production, he provides two seemingly straightforward definitions for hunter-gatherers and agriculturalists. The former is defined as economies that are based exclusively on wild resources; the latter are economies that strongly depend on domesticated resources (Smith 2001:1). However, he points out later in the article how these definitions are not overly useful, particularly when discussing small-scale societies that incorporate both wild and domesticated resources.

> But when these boundary conditions are considered more closely, a number of more complex and elusive questions come into clearer focus. On one side of the middle ground, for example, along the boundary line for agriculturalists, what exactly is meant by "strongly dependent" on domesticates? Should perhaps a consistent annual caloric budget reliance on domesticates of, say, 40, 50, or 60% be the dividing line between nonagriculturalists and agriculturalists, or should some other minimal qualifications for agricultural status be employed? (Smith 2001:9).

Smith (2001) argues for using the term *low-level food production*, which refers to the middle ground of small-scale societies who are distinct from hunter-gatherers and agriculturalists. Low-level food producers are not pale reflections or extensions of either hunter-gatherers or agriculturalists (Smith 2001:33-34). Rather, their resource management involves a combination of intensive and non-intensive exploitation of some wild species (such as deer in Cyprus) with management of domesticated animals, planting of domesticated seed stock, and storage (Smith 2001:35). The early Neolithic inhabitants of Cyprus appear to have been low-level food producers because they incorporated both wild and domesticated resources. However, in this study, to move away from the terminology debate in the literature, I use the term *mixed economy* rather than low-level food producers. In addition, when the term *agriculture* is used here, it will apply in a general sense to activities associated with domesticated plants and animals (Zeder 2011).

1.7 Theoretical Framework: Domestication, Translocation, and Human Niche Construction

The inhabitants of Cyprus introduced a variety of wild and domesticated plant and animal resources to the island, which will be discussed in Chapter 2. Hofman and Rick (2017:9-10) note:

> When people, past and present, move into a new environment, they often intentionally and unintentionally work to make it similar to their previous environment, with familiar plants, animals, and overall habitat. This landscape alteration can be viewed as an aspect of niche construction (Smith 2011) or landscape domestication (Terrell et al. 2003) that has significant repercussions for endemic ecosystems often shortly after human colonization. Why people translocate animals and plants to islands is one component of human niche construction.

Button (2010:10) argues that niche construction could be considering a risk-buffering behavior, especially in cases of people moving into new environments and bringing domesticates with them. Niche construction theory is a branch of evolutionary biology that was developed in the 1990s. It places emphasis on organisms' capacity to modify and transform their environment. This environmental alteration has evolutionary consequences. As such, the organisms act as co-directors of their own evolution. Furthermore, they can also impact the evolution of other species that inhabit their environment (Ellis 2015; Laland and O'Brien 2010, 2011; Laland et al. 2000; O'Brien and Laland 2012; Odling-Smee et al. 2003; Smith 2009, 2015). The term *niche construction* refers to the choices, metabolic processes, and activities of organisms through which they choose, define, modify, and partly create their own niches (Laland et al. 2000:132-133). As noted by Laland et al. (2000:133), it consists of the same processes that Jones et al. (1997) called *ecosystem engineering*. Hence, these two terms are often used interchangeably. In addition, Smith (2009:174) provides several other terms that fall under the general heading *niche construction*: domesticated landscapes, indigenous management, indigenous resource management, and traditional resource management.

Ecosystem engineering is not a uniquely human capability. Many animal species have been observed to modify their surroundings in a variety of ways. These modifications have demonstrable impact on both their own and other affected species' evolutionary trajectories (for examples see Laland and O'Brien 2011:192, and citations therein). Humans are set apart from other niche-constructing animals by our ability to create new niche-constructing behaviors. Furthermore, we have the ability to transmit these behaviors across multiple generations via social learning (Smith and Zeder 2013:12). Because of this ability to modify our surroundings to meet certain perceived goals, humans are considered "the ultimate niche constructors" (Odling-Smee et al. 2003:28; Smith 2007, 2009, 2012, 2015; Smith and Zeder 2013:12).

In small-scale societies, knowledge acquired about the environment and the ways in which it can be modified to enhance its biotic potential are passed down to multiple generations in the form of *Traditional Ecological Knowledge* (TEK; Berkes 2008:7; Zeder 2012:257). TEK is multi-layered and continuously updated, which allows small-scale human societies to "bequeath to the next generation landscapes that have already been modified and shaped in a variety of ways, and over many generations (Smith 2012:265)." Humans are such proficient niche constructors because of this sustained, multigenerational transmission of large amounts of environmental information. This ability provides our species with a tremendous evolutionary advantage (Boyd and Richerson 1985; Laland and O’Brien 2010; Richerson and Boyd 2005; Zeder 2012:257).

Smith (2011) argued for six major categories of human niche construction: 1) general modification of vegetation communities; 2.) sowing of wild annuals at the edges of rivers and lakes; 3.) transplanting perennial fruit-bearing species near settlements; 4.) experimenting with (in-place encouragement of) perennial fruit and nut-bearing species; 5.) creating root gardens, which expands their nature habitat; and 6.) landscape modification to increase the abundance of prey in targeted areas. These categories primarily deal with the management and manipulation of wild resources. Hofman and Rick (2017) added a seventh category to Smith’s model, which is the translocation of wild plants and animals. Boivin et al. (2016) looked at 4 key phases of anthropogenic transformations to better understand human engagement in niche construction: near global colonization by Late Pleistocene modern humans; the emergence and spread of agriculture, which began in the early Holocene; island colonization; and premodern expansion of trade and urbanization beginning in the Bronze Age. The different ways of examining human niche construction raises the question: when did humans become the ultimate niche constructors?

Cultural niche construction likely began at least with the emergence of modern humans. However, in terms of the archaeological record, there is limited evidence for substantial, sustained, and intensive efforts at niche construction until the end of the most recent Ice Age (Boivin et al. 2016; Laland and O’Brien 2010; O’Brien and Laland 2012; Smith 2011, 2012; Smith and Zeder 2013; Zeder 2012). In particular, the “Neolithic period opened the way for a radical transformation in the human capacity for niche construction, increasingly demonstrated through the accumulation of zooarchaeological and archaeobotanical data, as well as the application of biomolecular techniques” (Boivin 2016:6390).

One of the major outcomes of this time period was the spread of agriculture, which had unprecedented and long-lasting impacts on the distribution of species. Key environmental transformations include: newly created species and subspecies of domesticated animals and crops; the expansion of domesticated taxa favored by humans into areas where they had not previously existed; and the expansion of agricultural crops carried along other species (e.g., non-domesticated or weed species), many of which became important components in regional wild vegetation. In the latter case, some of the introduced weeds became more common than in their places of origin (Boivin et al. 2016:6390).

Another example of niche construction, which in the case of Cyprus is related to the Neolithic, is island colonization (Boivin et al. 2016). While the colonization of islands accelerated in the Holocene, it was a feature of modern human (*Homo sapiens*) expansion from the Late Pleistocene onwards (e.g., Sahul/Greater Australia, see Kealy et al. 2016; O'Connell and Allen 2015; O'Connell et al. 2010; Simmons 2014).[5] Based on evidence from island-focused research programs around the world, it is apparent that humans had significant impacts on island ecosystems (Erlandson and Rick 2010; Rick et al. 2013). This is largely due to the fact that island ecologies are characterized by low functional redundancy, naïve and/or disharmonic fauna, and high endemism (Boivin et al. 2016:6391; Braje et al. 2017; O'Dowd et al. 2003).

Human dispersals to islands often included the translocation of animals and plants (Boivin et al. 2016:6391; Braje et al. 2017). These species translocations to islands were common globally. As such archaeologists use the term *transported landscapes* to refer to these

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[5] There is increasing evidence that suggests our hominin ancestors, such as the Neanderthals, *Homo erectus*, and possibly even an early hominin lineage, colonized (or visited) islands (e.g. Flores: Argue et al. 2017; Gómez-Robles 2016; Simmons 2014; Stringer 2014; Mediterranean: Broodbank 2014; Cherry and Leppard 2015, 2017; Howitt-Marshall and Runnels 2016; Leppard 2014; Leppard and Runnels 2017; Runnels et al. 2014; Simmons 2014; Strasser et al. 2010, 2011). It is still debated whether colonization prior to the early Holocene was intentional or accidental (see Simmons 2014 for a general discussion, and citations therein; Leppard 2015).

events (Boivin et al. 2016:6391; Braje et al. 2017; Kirch 1997). These new landscapes included a range of weeds, crops, commensals, domesticated and wild animals, microbes, and other species that were brought both intentionally and unintentionally by humans (Boivin et al. 2016:6391). These translocations are often linked to the extinctions of endemic taxa on islands (Braje et al. 2017:288-289).

Humans brought animals and plants to Cyprus (Chapter 2). The first introduction possibly was that of the wild boar during the Late Epipaleolithic (Vigne et al. 2009; 2011; 2013). This event was followed by the introduction of domesticated sheep, goat, cattle, and pig, dogs, cats, domesticated cereals and pulses, and wild mainland animals such as the Mesopotamian fallow deer and fox (Vigne et al. 2013). It has been suggested that such introductions played a role in making the island more habitable for humans, particularly since the island lacks large endemic animals (Vigne et al. 2012).

It is important to note that Cyprus was not entirely devoid of resources prior to the arrival of humans. McCartney et al. (2010:136) note that the locations of early coastal sites in Cyprus are near sea-turtle nesting sites, which is unlikely to be fortuitous. The turtles and their eggs are available primarily during the summer. However, these resources would have been complemented by a variety of other marine resources throughout the year. During the autumn and spring, the availability of fish increases. Sea plants, birds, seals, and mollusks are available all year round. It is likely that the abundance of these marine resources varied through time, although even the modern-day low fish stocks would have been able to support small groups of prehistoric foragers (McCartney et al. 2010:136). In addition, endemic birds and freshwater crab were consumed at several Late Epipaleolithic and early Neolithic sites. Wild plant species would also have been important; in fact, some 66 species are still utilized on the island today

(McCartney et al. 2010:136; Savvides 2000; Wilcox 2003). Wilcox (2003:235) hypothesizes that barley, endemic to Cyprus, might have been cultivated on the island, independent of the mainland. Snails, of which there are 120 species, reptiles, and amphibians could have been important sources of fats and proteins (McCartney et al. 2010:136-137).

McCartney et al. (2010) raise valid points about the importance of the endemic species, while limited, to the earliest inhabitants of Cyprus. However, when domesticated animals and plants are added to the equation, it becomes more apparent that people were working to enhance island resources (Hofman and Rick 2010:10). Key benefits of translocation of domesticated species include reducing risk and increasing the certainty of having animals and plants as hunting companions, for pest control, for sustenance, and as companions of broader ritual, symbolic, and cultural systems (Hofman and Rick 2017:10).

The introduction of animal and plant species, combined with habitat modification, would have reshaped the island's ecosystem, including abundance, composition, genetic diversity, and distribution of species. I am not adopting a human niche construction lens *per se* in this dissertation, because the data I have collected do not allow me to discuss the environmental modifications as an evolutionary process (O'Brien and Laland 2012:436). In fact, there are limited data from Mediterranean islands, including Cyprus, that enable the identification and quantification of impacts that the introduction of domesticated species had on island ecosystems. There is believed to be a Holocene reorganization of regional vegetation regimes. This, in part, could be driven by ovicaprids, especially goats. In the short term, their preferred food sources likely drove woodland fragmentation. Over evolutionary time, they would have exerted selective pressures on preferred food sources versus non-preferred species. In turn, these transformations would also affect other components of environmental organization, including soil nutrient cycling. In addition, on many of the Mediterranean islands vegetation clearance and overgrazing also decreased slope stability and drove soil runoff between 9,000 and 4,000 B.P., although evidence for this on Cyprus is currently lacking. Terracing regimes were one way that these processes might have been mitigated (Braje et al. 2017:289-291).

Similar to Smith (2011:837), I believe that human niche construction provides a general unifying perspective for integrating consideration of human efforts at modification and management of ecosystems. Ultimately, I am interested in the plant and animal management strategies by Neolithic peoples on Cyprus, and what this can potentially enable us to infer about land use.

1.8 Significance of Research

This research is significant on three levels. The first is in regard to Cypriot archaeology. As noted above, this dissertation represents one of only a handful of studies on the island that incorporate stable isotope analyses, which is in sharp contrast to the mainland. My study adds to the slowly growing body of literature on Cyprus that demonstrates that stable isotopes analyses of bone and seed remains can yield interpretable results. These results provide insight into issues, including animal diet, animal movement, crop water management strategies, and soil nitrogen composition, that rarely can be addressed through traditional archaeological methods, further enabling us to better understand past peoples on the island.

This study also enables the early Neolithic lifeways on the island to be better incorporated into what was occurring on the mainland. As noted above, recent research has demonstrated that the Neolithic was not a homogenous culture by any means on the mainland. There was local and regional variation across Southwest Asia, including with the adoption and incorporation of animal and plant domesticates into economies. Thus, by shedding light on practices on Cyprus, we continue to more fully understand variation in lifeways during this critical time period in human history. In addition, this research also demonstrates that we are still missing key pieces of information from the Neolithic, specifically exchange networks. It seems increasingly clear that the inhabitants of the island were far more interconnected with one another and perhaps even with the mainland than previously thought. These types of issues are difficult to document because they do not always leave tangible remains behind in the archaeological record. However, I think it is important that we move away from the assumption that the inhabitants of Cyprus were isolated from one another and from the mainland, because current archaeological evidence suggests an interactive landscape.

Finally, this research also has modern implications. Land use and issues surrounding this topic are not just relevant to past societies, but continue to be modern problems as well. Issues surrounding agricultural activities, including land and water management, are still significant factors today in Cyprus, particularly as the island's climate continues to grow more arid. Providing a greater understanding of more ancient land use practices, might allow us to better analyze and solve current problems that revolve around access to land and water.

1.9 Conclusion

To begin to better understand how humans utilized the landscape in Cyprus, I have designed a program of research that will look at aspects of the economic livelihood of these early Neolithic groups: animal and plant management strategies. Any attempt at understanding these strategies by the Neolithic inhabitants requires as accurate of a reconstruction of the ancient environment as possible (Leon 2016:195-197). Unfortunately, archaeological data useful for reconstructing local and regional climates and environments on Cyprus during the early Holocene are fairly scarce. As such, we have to use data from the surrounding basin to infer early Holocene conditions on the island (Chapter 2). Ultimately, I believe that the early Holocene climate conditions were relatively similar to the present (i.e., continuation of seasonality since the early Holocene and variability in precipitation). As a result, I use modern environmental and climatic data to provide an approximation of early Holocene conditions in Cyprus (Chapter 2). Following Leon (2016:195-197), such a reconstruction can be effectively achieved by considering aspects of the natural environment layered onto one another. This begins with a discussion of the geologic/topographical regions of the island, because both lay the groundwork for the other environmental factors. It then expands to consider the modern climate, including precipitation and temperature regimes, and the flora and fauna of the island (Chapter 2).

Tied to understanding animal management strategies, in particular, is an understanding of animal biology (Chapter 3). All animals create niches through their basic foraging biology (McClure 2015). Human management decisions also influence these niches. There is evidence of Cypro-PPNB animal and plant management strategies in the archaeological record, which is explored in Chapter 3. By presenting the natural environment, animal biology, and archaeological evidence of animal and plant management strategies, I build a testable model of early Neolithic society. This model is discussed in Chapter 3, but I present an outline of it below.

The presence of wells at two Cypro-PPNB sites indicates that access to a year-round, consistent supply of water was an issue for the island's inhabitants. This is especially true for people in the lowlands/coastal areas during the summer. Issues related to access to water would not just impact human and animal drinking water, but also crop fields, grazeland, and other physiological needs of the herd animals.

The current evidence suggests there was minimal field maintenance during the Cypro-PPNB, meaning there is no crop rotation or soil disturbance (Jones 1992:140; Lucas 2014:59-60). This seems to suggest that livestock keeping and crop cultivation were not integrated (Bogaard et al. 2005, 2013). There are also very limited data that allow us to discuss crop water management practices. Studies from mainland botanical assemblages have demonstrated that practices varied depending on the crop species. In turn, these differences might be tied to human preferences (e.g., Wallace et al. 2015).

Based on what we know about both past and modern Cypriot climate data, in combination with the temperature prescriptions on sheep, goat, and cattle, I argue that settlement at *Ais Giorkis* was tied to seasonal mobility by people in the western region of the island. Seasonal movement to the uplands was also likely associated with deer hunting (Croft 2012; Frankel et al. 2013). We also know that people at *Ais Giorkis* were exploiting non-subsistence resources (e.g., chert, diabase, and picrolite). The substantial architecture, abundance of chipped stone and ground stone, the large and diverse botanical and faunal assemblages, and presence of exotic artifacts all indicate that the site was inhabited for at least some part of the year. Thus, I believe it makes sense to tie habitation to seasonal mobility during at least the early spring and summer.

Scientific advances in archaeology, including paleobotany and zooarchaeology, have allowed for a more fine-grained view of the relationship of Neolithic peoples with their landscape. However, aspects of animal and plant management strategies are less visible through traditional methods. These include seasonal movement, animal diet, soil nitrogen composition, and crop water status. Recently, innovative ways for examining past landscape usage in early prehistoric Southwest Asia have been developed using stable isotope analyses on archaeological faunal and botanical remains (e.g. Bogaard et al. 2013; Henton 2012; Henton et al. 2010; Makarewicz 2014; Makarewicz and Tuross 2012; Makarewicz et al. 2016; Pearson et al. 2007, 2015; Wallace et al. 2015). However, there are few published studies to date on Cyprus (see Scirè Calabrisotto 2017a, 2017b; Leon 2016). To better understand early Neolithic land use, stable isotopic analyses were conducted on the botanical and faunal remains from *Ais Giorkis*.

The results from each of the stable isotope analyses are presented in Chapter 5 and Chapter 6, respectively. In Chapter 7, I tie all elements discussed in this dissertation together. Ultimately, based on the isotopic evidence, in combination with zooarchaeological and botanical data, we do not have evidence for seasonal movement of animals. In fact, the scale of herding seems to be relatively small, and domestic plants and animals are not the focus of the inhabitants at *Ais Giorkis*. I argue that the inhabitants of the site seem to be focused on craft production, likely for inter-island and even perhaps island-mainland exchange networks. Thus, these data illustrate that during the Cypriot Neolithic there was a complex and interactive landscape within which human activities were occurring.

CHAPTER 2: LANDSCAPE AND CHRONOLOGY OF EARLY NEOLITHIC CYPRUS

2.1 Introduction

This chapter first describes the physical environment of Cyprus, including the geology/topography, climate, and flora and fauna, because any attempt to reconstruct land use by the Neolithic inhabitants requires as accurate of a reconstruction of the ancient environment as possible. First, I explore the climate and environment of the Early Holocene in Cyprus and the Eastern Mediterranean.[6] The latter must be included in this discussion due to the limited data available from the island that are useful for reconstructing local and regional paleoclimates and paleoenvironments. Given that the Early Holocene climate of the Eastern Mediterranean is more or less comparable to the present arid climatic conditions on the island, I then discus the modern physical environment. This serves as a proxy for what the ancient climate and environment may have been like. This chapter then discusses the chronology and major excavated sites of the two major time periods leading up to (e.g., the Late Epipaleolithic and the Cypro-PPNA) and including the Cypro-PPNB. These data emphasize the dynamic relationship that the earliest inhabitants have with their landscape and people from the mainland. The archaeological site of *Ais Giorkis* is then discussed, because it is the primary study site.

2.2 Climate and Environment of the Early Holocene in Cyprus and the Eastern Mediterranean

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[6] In the circum-Mediterranean area, the Holocene can be divided into three periods: early (11,500-7,000 cal BP), middle (7,000-5,500 cal BP), and late (5,500 cal BP to present) (Jalut et al. 2009; Rosen 2007). Due to the chronological context of this dissertation, paleoenvironment and paleoclimate evidence from the Early Holocene will primarily be discussed.

In order to draw correct inferences about water and land use, it is important to understand the paleoclimate and paleoenvironmental settings within which Neolithic peoples on Cyprus interacted. Unfortunately, there are limited data useful for reconstructing local and regional climates and environments on the island. This has been an ongoing issue for Cyprus. Over thirty years ago, Stanley-Price (1979:1) noted:

> There are severe limitations to the evidence available to attempts to reconstruct the probable natural environment of Cyprus in the Early Holocene. In contrast to neighboring areas of the Mediterranean coastlands and Near East, almost no systematic work to this end has been carried out in Cyprus. Until it is, any reconstruction has to be based on extrapolation from more recent and contemporary environments in Cyprus and from the results of palaeoenvironmental research in adjacent countries.

Unfortunately, the present-day situation has not significantly changed. Butzer and Harris (2007) identify several reasons for the lack of paleoclimate and paleoenvironmental data. The first is that land use studies have paid little attention to the charcoal record, which can help identify local shrubs and trees. Instead most studies focus on the types and frequencies of cultivars in the paleobotanical record. Pollen also does not typically survive in the Cypriot archaeological record. Pollen studies at Neolithic and Chalcolithic sites have demonstrated that there is selective preservation. Specifically, 40-90% of pollen counts are from the *Cichoriae,* a weedy family that has tough-shelled grains. Findings from the few charcoal studies, which have found evidence for diverse arboreals, contrasts with the pollen studies (Butzer and Harris 2007:1936-1937). There have also been limited phytolith analyses, which can provide evidence for a range of botanical taxa. Cyprus also lacks peat bogs and montane lakes, which have major sediment traps (i.e., sediment that has slowly accumulated). This means that deep sediment cores, useful for both palynology and stable isotope studies, cannot be taken (Butzer and Harris 2007:1937).

As a result, data from terrestrial sedimentary records, terrestrial paleobotanical records, geochemical records, and marine records from the surrounding areas in the Eastern Mediterranean must be used to better understand Early Holocene climate and environmental conditions on Cyprus. Similar to Wasse (2007:48), I believe that this situation is not ideal. However, the increasingly refined resolution of Early Holocene climatic and environmental conditions from neighboring areas has the potential to shed light on contemporaneous conditions on Cyprus. Several scholars (e.g., Roberts et al. 2011; Robinson et al. 2006, 2010; Rosen 2007) have presented comprehensive reviews of the geological evidence for environmental and climatic change in the Eastern Mediterranean and Levant from 25,000 years ago to the present. In this dissertation, I will present a synopsis of these major findings, and include updated literature.

2.2.1 Paleoclimate of the Eastern Mediterranean

Across much of the Eastern Mediterranean and Southwest Asia, the Early Holocene appears to have been the wettest phase of the last 25,000 years. Increased rainfall has been suggested by: the Negev Desert (Israel) boundary having moved southward (Goodfriend 1999; Rosen 2007:71); increases in oak and *Pistacia* in the pollen records (Rossignol-Strick 1995; Rossignol-Strick 1999); streams in southern Jordan (McLaren et al. 2004); and the deposition of red-hamra type palaeosols on the Israeli coastal plain, indicating greater precipitation than evaporation (Gvirtzman and Wieder 2001; Robinson et al. 2010:61). A combination of lake cores and shoreline features indicate that water levels for the Dead Sea were high during the Early

Holocene, as compared to the Late Pleistocene and the middle Holocene and onwards. High water levels are associated with wetter conditions (Migowski et al. 2006; Roberts et al. 2011:148; Rosen 2007:78; Yechieli et al. 1993). Evidence, such as reconstructed lithofacies and freshwater diatoms, from lakes in the Arabian Peninsula, North Africa, and Anatolia also support deep-water conditions during the Early Holocene (Roberts et al. 2011:148; Rosen 2007:77 and citations therein). There is also a general regional trend for more depleted (or negative) $\delta^{18}O$ values from Eastern Mediterranean lake sediment cores in the Early Holocene and higher (or more positive) $\delta^{18}O$ values beginning around 7600 years BP. Periods of greater moisture availability are indicated by depleted $\delta^{18}O$ values (Dean et al. 2015; Eastwood et al. 2007; Jones and Roberts 2008; Roberts et al. 2008, 2011:148). Similarly, the oxygen-isotope composition of speleothems displays a shift toward more depleted values. This shift is also consistent with warmer, wetter conditions (Ayalon et al. 1999; Bar-Matthews et al. 1997, 1999; Roberts et al. 2011:149; Robinson et al. 2010:61; Rosen 2007:73). Bar-Matthews and colleagues (2003) estimated rainfall amounts during the Early Holocene to be around 550-700 mm/year. Comparable estimates have also been obtained from lake sediment cores in central Turkey (Jones et al. 2007). Terrestrial palaeotemperatures have been estimated to be around 16-21°C, similar to or above modern-day temperatures (Affeck et al. 2008; McGarry et al. 2004; Robinson et al. 2010:61).

Marine records from the Eastern Mediterranean and Red Sea also provide support for wetter conditions during the Early Holocene. Between ~9.5 and 7 cal ka BP, sediments rich in organic matter (Sapropel 1 or S1) were deposited in the Eastern Mediterranean.[7] The conditions

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[7] The term sapropel is used to describe dark-colored sediments that are rich in organic matter. The deposition of sapropel typically occurs under anoxic events (oxygen depleted waters). Sapropel 1 represents the most recent organic-rich sapropel deposit in the Eastern Mediterranean Sea (ca. 10.8 to 6.1 cal ka BP) (Tachikawa et al. 2015).

during this deposition were anoxic, which was induced through stratification of a water column. This stratification was driven by a large freshwater surface layer. It has been suggested that the origin of the freshwater surface layer was the Nile River, whose outflow was enhanced due to increased rainfall in parts of Africa (Black et al. 2011:107; Emeis et al. 2000; Roberts et al. 2011:149-150; Robinson et al. 2010:61). Marine cores also show a marked decrease in dust, suggesting that adjacent dryland regions (e.g., the Sahara) were not as arid as present-day (Roberts et al. 2011:149-150).

Recent paleoclimate integrations (coupled with pollen-based climate reconstructions, lake levels, and isotopic data) suggest that there is little evidence for substantial summer precipitation in the Eastern Mediterranean during the Early Holocene (Brayshaw et al. 2011a, 2011b; Jalut et al. 2009; Peyron et al. 2011). In fact, summer drought is thought to have persisted in parts of the Mediterranean until 8000 cal. BP, based on palynological, archaeobotanical, and lake isotopic evidence (Jaylut et al. 2009; Peyron et al. 2011:140; Turner et al. 2010; Vannière et al. 2011). This contrasts with Rossignol-Strick's (1995, 1999) interpretation of pollen records from the Eastern Mediterranean, which suggest milder winters and summer precipitation. Increased precipitation during the Early Holocene is now thought to occur in the winter (and likely in the autumn and spring) (Brayshaw et al. 2011a, 2011b; Peyron et al. 2011; Turner et al. 2010). Based on pollen cores from Lake Accesa (central Italy) and Tenghi Philippon, Greece (Eastern Mediterranean), Peyron and colleagues (2011:136, Figures 3-5) found that, "Winter precipitation during this time reached a maximum while summer precipitation reached a minimum (60-80 mm), close to or even below modern values, resulting in the highest degree of seasonality found within both records." These results show that the Early Holocene has a complex pattern of climatic changes across the Mediterranean. Seasonality appears to be particularly important, which would likely impact land use on Cyprus.

Despite the generalized picture of wetter conditions during the Early Holocene, there is also evidence for at least three brief (centennial-scale) cold, dry events: the 10.2 ka (10,200 years BP) event, the 9.3 ka (9,300 years BP) and the 8.2 ka (8,200 years BP) events. In contrast to today, the climate during the Early Holocene was more sensitive to freshwater forcing than to solar activity. Specifically, disruption of the North Atlantic thermohaline circulation due to glacial outburst floods has been hypothesized as the cause of global cooling trends, including these climatic events (Berger et al. 2016:1848, and citations therein; Dean et al. 2015:170, and citations therein). These events have been primarily documented in paleoclimate records from the North Atlantic region (Dean et al. 2015:163; Rasmussen et al. 2006).

There are almost no data supporting the 10.2 ka event in the Eastern Mediterranean, whereas the 8.2 ka event has been identified in some Eastern Mediterranean records (Bar-Matthews et al. 2003; Landmann and Kempe 2005; Turner et al. 2008). There are also more limited data supporting the 9.3 ka event (Dean et al. 2015). Lake sediment cores from Nar Gölü in central Turkey document a cooling trend around this time. Although it lasts around 300 years as compared with around 100 years from the North Atlantic region (Dean et al. 2015:169). These centennial-scale events, particularly the 8.2 ka event, are associated with a reversal of the seasonal pattern: wet summers and dry winters. Changes in vegetation cover appear to vary by sub-region. For example, there does not appear to be vegetation changes at Lake Accesa (central Italy). In contrast, pollen data from Tenghi Philippon, Greece (Eastern Mediterranean) supports a vegetation turn-over shortly after 8200 yr. BP. Specifically, there is a decline in arboreal pollen taxa (*Quercus ilex*), and an increase in steppe elements (*Artemisia*, Chenopodiaceae, *Ephedra*), low-temperature adapted tree taxa (*Betula*, *Pinus*), and Poaceae (family of monocotyledonous flowering plants known as grasses, including cereal grasses) (Peyron et al. 2011:140-141).

2.2.2 What are Possible Drivers of the Eastern Mediterranean Paleoclimate?

The extension of the Siberian anticyclone to the Eastern Mediterranean (i.e., influx of cold air masses on a regular basis) is believed to have played a role throughout the Holocene period. For example, there is evidence during the Early Holocene that cold air from the Siberian High extension rapidly lowered sea surface temperatures. The Siberian High is believed to be stronger during some of the cold periods, with repeated impacts on the Anatolian/Aegean areas (including Cyprus). These cold, dry conditions might have lasted several hundred years longer in the Eastern Mediterranean than other places around the world because of the combined effects from the Siberian High (Berger et al. 2016:1848, and citations therein). There is also believed to be a strong teleconnection between the North Atlantic and Eastern Mediterranean (Dean et al. 2015, and citations therein).[8] A significant amount of precipitation that falls in parts of the Eastern Mediterranean (e.g., central Turkey) has North Atlantic origins (Harding et al. 2009). A reduction in cyclogenesis during cooler times potentially changed the path and reduced the frequency of storm tracks from the Atlantic. This likely would have resulted in a reduction in Mediterranean cyclogenesis. Combined, this would have resulted in lower precipitation in the Eastern Mediterranean (Dean et al. 2015, and citations therein). Other teleconnections could have impacted the hydroclimate in the Eastern Mediterranean, including the Indian Summer

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[8] In atmospheric science, teleconnection refers to reoccurring and persistent large, scale patterns of circulation and pressure anomalies that spans large geographical areas (Kucharski et al. 2010; National Weather Service, Climate Prediction Center 2008).

Monsoon dynamics and the North Sea-Caspian Index (Dean et al. 2015:170; Jones et al. 2006; Kutiel and Türkeş 2005; Rosen 2007:80).

Reduced solar output has also been hypothesized to cause climate deterioration, but starting around 8500 years BP. This idea is not unanimously accepted by all scholars (Dean et al. 2015:171, citations therein). There are also believed to be additional drivers of Eastern Mediterranean paleoclimate, but these act at millennial-scales (Dean et al. 2015:171). For example, the Northern Hemisphere summer insolation is believed to be at a maximum during the Early Holocene. In contrast, its decline is thought to be linked to the Mid Holocene Transition, when the climate becomes more arid (Dean et al. 2015:171).

2.2.3 Centennial-Scale Paleoclimate Events in the Early Holocene on Cyprus

The effects of the 8.2 ka event on societies has been studied in far greater detail than the effects of the 9.3 ka event. During the 8.2 ka event, interpretations vary from "…abandonment of sites to collapse, and from large-scale migration to sustainability of occupation and social adaptation" (Berger et al. 2016:1848; for overview, see Berger and Guilaine 2009; Flohr et al. 2016). The 8.2 ka event would likely not have impacted the Cypro-PPNB; it would have affected the succeeding time period (Khirokitia Culture). Berger and colleagues (2016) conducted soil and geomorphological studies from the river channel near Khirokitia *Vouni* (hereafter Khirokitia), the type site for the Khirokitia Culture. Their results suggest that the region experienced strong modifications in the hydro-geomorphological configuration around 8.5 and 8.1 ka (although the modifications were greater for the latter time). These modifications can be attributed to erratic and heavy rainfall conditions. Around 8.2 ka, it is thought that the village contracted and there were changes to the zoological and botanical records. Thus, climatic changes possibly played a role in these social changes (Berger et al. 2016).

In contrast to the 8.2 ka event, the 9.3 ka event might have impacted the Cypro-PPNB. Unfortunately, there is currently a lack of clear temporal synchronization between the two sets of data (Berger et al. 2016:1852). There are some hints for societal changes towards the end of the Cypro-PPNB, perhaps because of the return of dry, cold conditions. Grinding instruments decrease around 9.2 ka. There is also the decline of lamellar tools, which are obtained by bipolar knapping. These tools are strong PPNB markers in the Levant. Imports of obsidian from Cappadocia also appear to collapse. In fact, it appears as if Cyprus no longer has much contact with the Anatolian and Levantine mainlands, although this could be due to a change in exchange networks. Sheep husbandry also appears to increase in importance around this time. There is some suggestion that *Shillourokambos* (a Cypro-PPNB site discussed below) shrinks in size (Berger et al. 2016:1852). Based on results from Berger et al. (2016) for the impact of the 8.2 ka event on the inhabitants of Khirokitia, it seems very possible that rapid and short climatic changes might have had an impact on inhabitants of Cypro-PPNB sites, including their plant and animal management strategies.

2.2.4 Paleoenvironment of the Eastern Mediterranean

In regard to the environment, the $\delta^{13}C$ values of cave speleothems were higher than values from the middle Holocene and onwards, suggesting that the environment was dominated by C_3 plants (Bar-Matthews et al. 1997). This situation is also consistent with wetter conditions (Robinson et al. 2010:61). Goodfriend (1999) conducted stable isotopic analyses on snail remains from the Negev Desert to determine whether they were consuming C_3, C_4, or C_3/C_4

vegetation.[9] Goodfriend found that the snails were consuming C_3 plants during the Early Holocene. Interestingly, today these areas are dominated by C_4 plants, indicating wetter conditions during the Early Holocene. However, these results should not be extrapolated to the entire Eastern Mediterranean/Southwest Asia region. There are certain areas of Southwest Asia whose environment appears to have a combination of C_3 and C_4 plants, including Çatalhöyük in Central Anatolia (e.g., Pearson et al. 2007, 2015). There are both C_3 and C_4 plants on Cyprus, although the former is far more prevalent than the latter. In addition, we do not yet know the importance of C_4 plants in human and animal diets for prehistoric Cyprus (discussed in greater detail in Chapter 4; Elmore and Paul 1983; Hansen 1999; Lucas 2014; Pyankov et al. 2010). An increase in arboreal pollen is also found in southwest Turkey, Syria, and Israel during the Early Holocene. This increase implies that the open steppe vegetation of the Late Glacial period was replaced by a more tree-dominated landscape (Dusar et al. 2011:144; Jalut et al. 2009).

2.2.5 Summary

In sum, the evidence from the Eastern Mediterranean supports wetter conditions during the Early Holocene, with several centennial-scale fluctuations to drier conditions. The importance of seasonality has also been recently highlighted. Specifically, precipitation is thought to have increased during the winter (and possibly spring and autumn). Summers still had relatively low precipitation, at levels similar to or lower than today. Environments appear to be dominated by C_3 vegetation, although this was perhaps not uniform throughout the region. Many

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[9] During photosynthesis, carbon enters the food chain via plants. In regards to carbon isotopes, there are three types of plants: C_3, C_4, and CAM. These names each relate to the pathway followed by elemental carbon during photosynthesis of particular pants. The pathway names, respectively, are: Calvin-Benson cycle (C_3 cycle), dicarboxylic acid pathway (C_4 pathway), and crassulacean acid metabolism (CAM) (van der Merwe 1982). Cyprus is a classic Mediterranean phytogeographical region (Lucas 2014; Zohary 1973); thus, both C_3 and C_4 plants will be found in varying proportions on the island, although the former dominate (Akhani et al. 1997).

studies have demonstrated the importance of local and sub-region-scale climate data, even within the Eastern Mediterranean. Archaeological data useful for reconstructing local and regional climates and environments on Cyprus are scarce, although there is some evidence that centennial-level climatic fluctuations could have impacted the island's inhabitants. Thus, while seasonality seems to be more pronounced during the Early Holocene and there is evidence of centennial-scale fluctuations, I would argue that the evidence suggests that climatic conditions were similar to the present. This evidence includes the occurrence of seasonality and likely variable precipitation from year to year. Given this conclusion and the fact that there are limited paleoenvironmental and paleoclimatic data, we must turn to modern environmental and climatic data to provide an approximation of Early Holocene conditions in Cyprus.

2.3 Modern Cypriot Environment

Extrapolating the ancient environment and climate from modern data can be problematic largely because it assumes uniformity for both. Clearly, this is not the case, and environments have been modified over the last ten thousand years by natural processes and humans. Nevertheless, any attempt at understanding land and water management by the Neolithic inhabitants requires as accurate of a reconstruction of the ancient environment as possible (Leon 2016:195-197). Following Leon (2016:195-197), such a reconstruction can be effectively achieved by considering aspects of the natural environment layered onto one another. This begins with a discussion of the geologic/topographical regions of the island, because both lay the groundwork for the other environmental factors. It then expands to consider the modern climate, including precipitation and temperature regimes, and the flora and fauna of the island. This approach diverges slightly from Leon (2016) who uses paleoclimate data, rather than modern climate data. However, the paleoclimate data of the Eastern Mediterranean were discussed above.

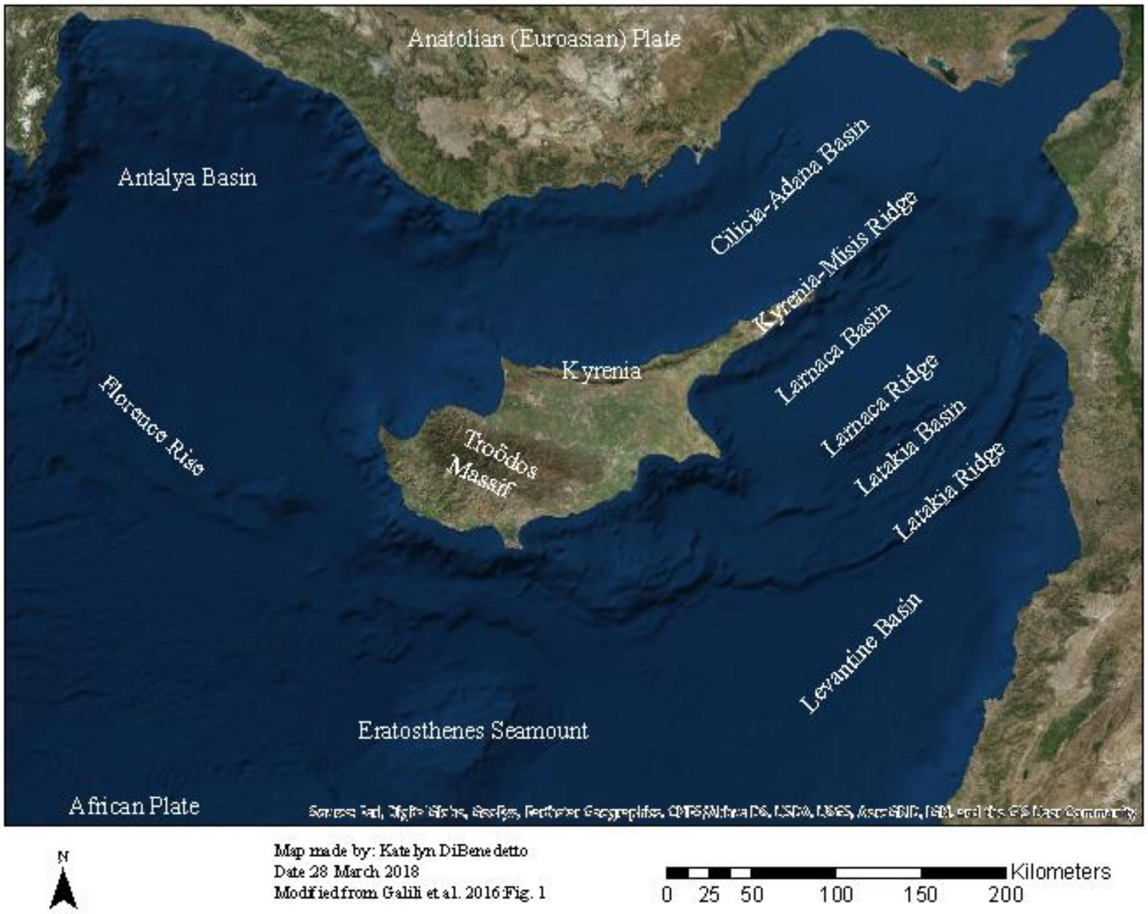
2.3.1 Geology and Topography

Cyprus lies in the northeastern Mediterranean Sea about 105 km west of Syria and 65 km south of Turkey. The island is surrounded by the deep Cilicia-Adana Basin in the north, the Cyprus Trench and Eratosthenes Seamount in the south, the Kyrenia-Misis Ridge and Latakia

Ridge and Basin in the east, and the Florence Rise and Antalya Basin in the west (Figure 2.1) (Christodoulou 1959:5; Galili et al. 2016:180, Figure 1; Harrison et al. 2004; Meikle 1977:1).

Figure 2.1 Geographical setting of the island of Cyprus and the Eastern Mediterranean

Figure 2.1 Geographical setting of the island of Cyprus and the Eastern Mediterranean



Sources: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map made by: Katelyn DiBenedetto
Date 28 March 2018
Modified from Galili et al. 2016 Fig. 1

It is the third largest island in the Mediterranean, following Sicily and Sardinia, with an area of about 9,251 square km (Christodoulou 1959:5; Stanley-Price 1979:1). Due to the pace of the geologic time-scale, it is unlikely that the geology and topography of Cyprus have changed substantially since the Early Holocene. In fact, the effect of tectonic uplift since the end of the

Pleistocene was, at most, 1.5 m along the coast. Compared with the magnitude of sea-level changes, this effect is relatively negligible (Galili et al. 2016:212).[10]

Christodoulou (1959) separates the island into 9 topographically defined regions: 1.) the Kyrenia Range and the Kyrenia Lowlands; 2.) the Karpas Peninsula; 3.) the Troödos Massif; 4.) the Central Lowlands; 5.) the Larnaca Region; 6.) the Chalk Plateaus of South Cyprus; 7.) the Polis Lowlands; 8.) the Ktima Lowlands; and 9.) the Limassol lowlands (1959:9-18). Zohary (1973:10) and Meikle (1977:1-3) collapsed them into 4 categories: 1.) the Coastal Belt; 2.) the interior lowland Mesaoria or Central Plain; 3.) the Kyrenia or Northern Range; and 4.) the Troödos or Southern Range. More recently, Leon (2016:197) grouped these zones into three main types: the mountains (the Kyrenia and Troödos ranges); the lowlands (the Central lowlands/Mesaoria, the Larnaka Region, the Limassol Lowlands, the Ktima Lowlands, and the Polis Lowlands); and the Chalk Plateaus. This discussion follows Leon (2016) (Figure 2.2).

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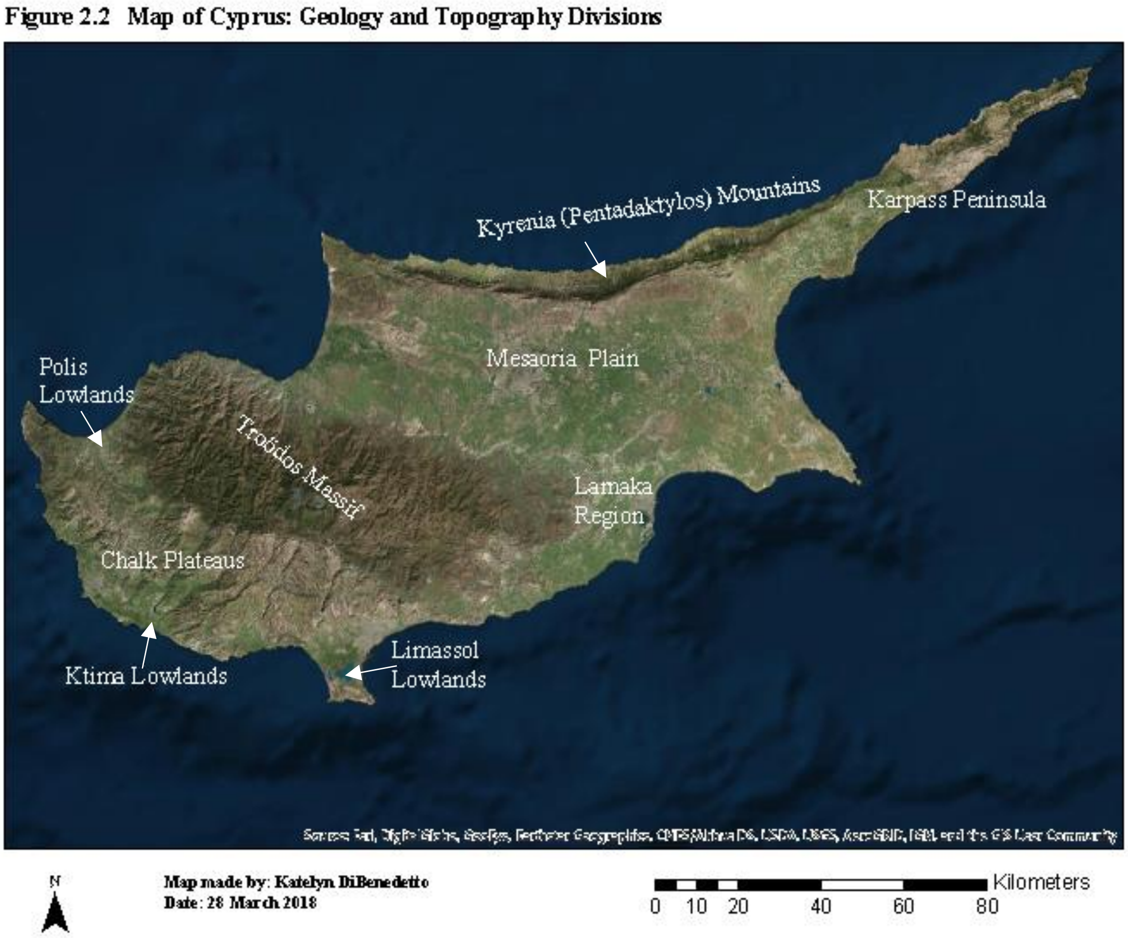
[10] Sea-level rise at the beginning of the early Holocene may have reached a rate of around 13 mm a^{-1}, meaning a rise of around 32 cm per life span (average life span during the Neolithic period is thought to have been 25 years: Eshed and Galili 2011). In geologic terms, this is a rapid change. However, it might have been masked by winter storms and changes in tides. Thus, Neolithic peoples might not have detected the sea-level rise. Sea-level stabilized by the middle Holocene (Galili et al. 2016:212).

Figure 2.2 Map of Cyprus: Geology and Topography Divisions



The lowlands comprise roughly one-third of the island and provide the greatest potential for intensive agricultural production (Leon 2016:197). The largest of the lowlands is the *Mesaoria*, accounting for approximately 3,000 km^2.[11] Its elevation varies from sea level to 230 m above sea level (asl). It consists of alluvial deposits, silt, and a central limestone plateau. It is topped in its eastern edges by a hardpan calcrete, locally known as *kafkalla*, which is formed through the accumulation of calcium carbonate. The plateau is covered by thin layers of *terra*

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[11] A Greek term which roughly translates to "between the mountains," referring to the Kyrenia (or Pentedakytlos) Mountains and the Troödos Mountains (Christodoulou 1959:12; Knapp 2013:4).

rossa soils (Knapp 2013:5; Simmons 1999:9). The fertile soils of this lowland have resulted in it being the breadbasket of Cyprus (Christodoulou 1959:44; Yerkes 2000: 27). Agriculturally fertile geology can also be found in smaller pockets of the lowlands. These are the coastal plains of Cyprus. Many are cross-cut by seasonal river drainages and have alluvial deposits (Leon 2016:202). Christodoulou (1959:189) notes that sheep are found primarily in the lowlands, but also the lower parts of the Chalk Plateaus. A Cypriot saying reaffirms this: "A sheep likes the dry plain even if it eats earth" (Christodoulou 1959:189).

Cyprus has two major mountain ranges: the Kyrenia (or Pentedakytlos) Mountains in the north and the Troödos Mountains which extend over much of the southern and southwestern parts of the island (Christodoulou 1959:12; Knapp 2013:4; Stanley-Price 1979:5-6, Figure 3). The Kyrenia range separates the northern coast from the central lowlands. There are three main passes, all of which are steep: Panagra, Kyrenia, and Lefkoniko. The highest point reaches 1053 m (Stanley-Price 1979:6; Steel 2004:3). The Troödos are much larger in area, covering at least one-third of the island. Mt. Olympus is the highest peak on the island at 1952 m (Christodoulou 1959:9-10; Stanley-Price 1979:5, Figure 2; Steel 2004:2). The mountain range is known world-wide for its ophiolite complex. The upper reaches are made of igneous rock (gabbros and diabase) and are surrounded by a ring of pillow lavas in the lower areas. This ring is seldom more than 5-7 km wide (Christodoulou 1959:11-12; Knapp 2013:3; Stanley-Price 1979:4-6; Steel 2004:3). Massive copper sulphide deposits are embedded in the pillow lavas, and served as the backbone of Cyprus' economy for several thousand years (Knapp 2013:3). In addition, the Troödos is the main source of picrolite, a local mineral whose color varies from light blue-green to dark olive-green (Steel 2004:3; Xenophontos 1991:129, 132).[12] Picrolite was used extensively by Neolithic and Chalcolithic inhabitants (see below).

Both the Kyrenia and Troödos Mountains could have been used for herding purposes. On Cyprus, these mountains provide the greatest amount and most consistent access to water sources, a primary concern for herders (Leon 2016:203-204). It is important to note that both ranges lack large, highland meadows (in contrast to Cretan Mountains: see Leon 2016). Research has shown that during the Ottoman period, goat folds were located in the forested Troödos Mountain (Given 2000:15). This region was important for both small-scale household production (8-10 goats or sheep) and for larger-scale production, typically linked to monasteries or estates (60-80 animals) (Given 2000:15). Goats are browsers; thus, they consume tree leaves and were perhaps better suited for this environment. Sheep, in contrast, require pasture. Ethnohistorical information also confirms that goats were herded in the mountains: “villagers on several occasions indicated that forested mountains above their villages and declared that there used to be several goat folds there” (Given 2000:15).

The Chalk Plateaus are located in the south and southwest of the island, and include the Paphos Plateau, the Limassol Plateau, and the Lefkara Plateau. Christodoulou (1959:16) describes them as, “white or light-coloured rocks which produce a surface of plateaus falling step-like seawards, but cut into gigantic slices by deep canyon-like valleys. The plateau region consistently presents a steep scarp to the Massif and seawards again ends either in scarps

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[12] Picrolite belongs to the serpentine group (a metamorphic rock). Specifically, within serpentinized harzburgite, veins of picrolite, varying in thickness from a few millimeters to 3-4 centimeters, are found in the Troödos. Many of these veins extend for several meters. The majority of unworked stone for archaeological objects likely originated in the Troödos. However, people did not necessarily have to travel to this area for picrolite. Because of substantial erosion of picrolite veins in the Troödos, the watersheds of the Kouris and Karyotis rivers are also places where the mineral can be procured (Steele 2004:3; Xenophontos 1991:129-137). Serpentinite outcrops are also found in the Paphos and Limassol districts, but the material is deformed and sheared in such a way, that usable vein material is not present. Picrolite veins are present, but these veins are rarely more than a few millimeters thick (Xenophontos 1991:132).

overlooking raised beaches or in sea cliffs.” The region forms a distinct drainage unit and includes a number of rivers and streams; however, most of these rivers and streams are seasonal, largely due to the area being comprised of limestone, which does not hold water well (Christodoulou 1959:41). The southern and particularly the western plateaus receive most of the available surface water on the island, largely due to runoff from the Troödos massif. The central lowlands and northern portions of the island receive considerably less. Christodoulou refers to this situation as, “a well-watered west and south mountainous Cyprus and a thirsty lowland Cyprus (1959:40).” Wells and aquifers are not plentiful in the western region, again due to its geologic formations (Christodoulou 1959:40-41). While not as fertile as the lowlands, the Chalk Plateaus can maintain fertility under a cereal crop rotation system where crops lie fallow for one to three years (Yerkes 2000:27). Legitimate grazeland environments can also be found, particularly in the southwest. Thus, the plateaus provide land suitable for both agriculture and graze land, and at least access to winter water (Leon 2016:204-205). In fact, the land was used for both in the recent past (Christodoulou 1959).

There are a number of rivers in Cyprus (Figure 2.3), including the Ezousa, Dhiarizos, Khapotami, Kouris, Garillis, Vasilikos, Maroni, Pendaskino, Xeropotamos, and Pouzis (Orphanides 1985:21). As discussed below, however, many of these rivers are seasonally active.

Figure 2.3 Map of Major Rivers in Cyprus

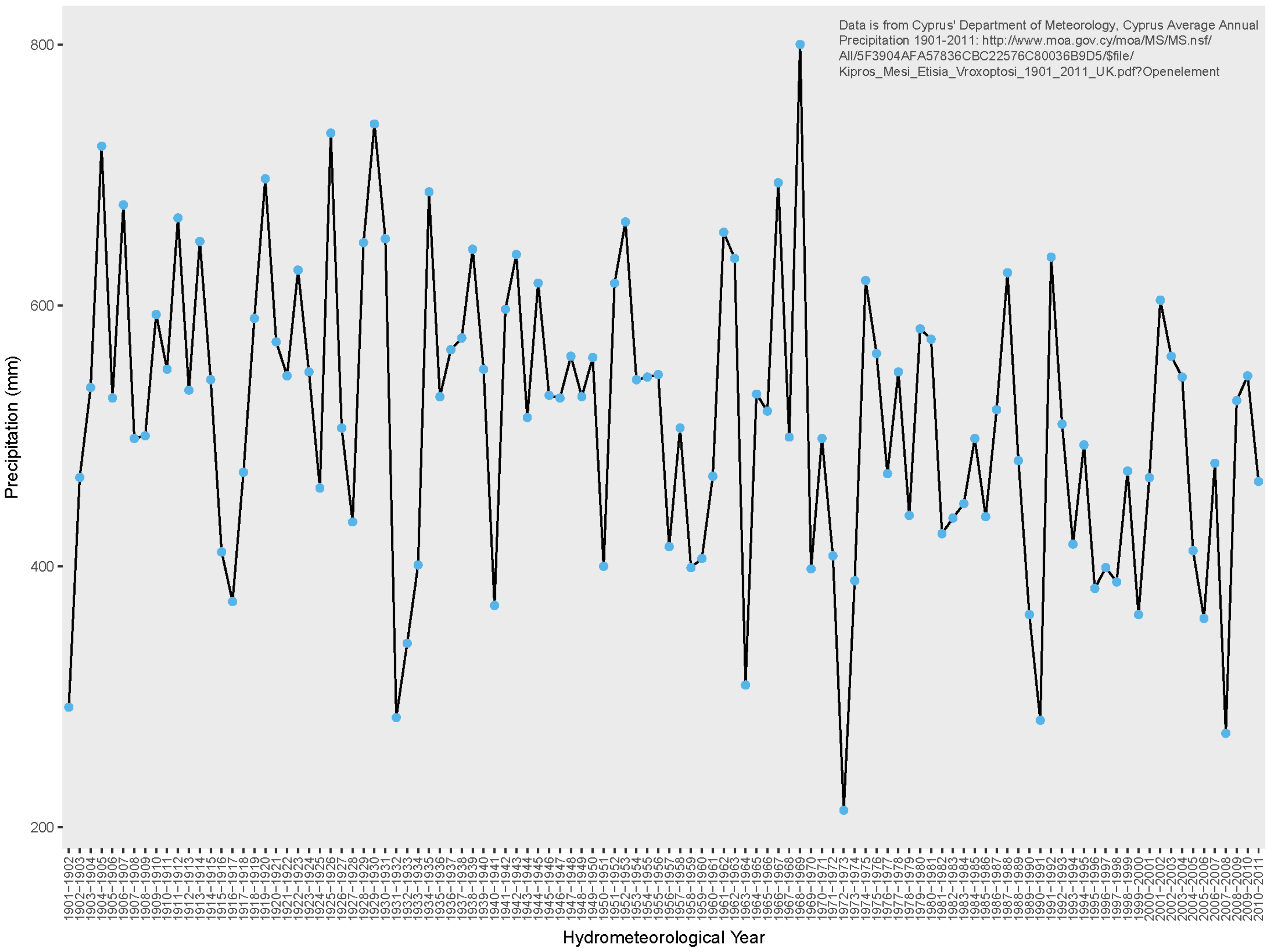
Data courtesy of Levi Keach
Date: 28 March 2018

2.3.2 Climate

As noted above, archaeological data useful for reconstructing local and regional climates and environments on Cyprus are scarce, although there is some evidence that centennial-level climatic fluctuations could have impacted the island’s inhabitants (e.g., Berger et al. 2016). Seasonality still appears to have been important, and was perhaps more extreme than today. Given the limited paleoclimate data, we turn to the modern climate in hopes of providing as accurate of a reconstruction of the ancient climate as possible at this time.

Today, Cyprus has a typical Mediterranean climate (Harding et al. 2009; Pashiardis and Michaelides 2008; Zohary 1973). Summers (June to September) are typically hot and dry, and winters (November to March) are wet and cool (Figure 2.4). High variability and rapid changes in precipitation and temperature characterize the short autumn and spring seasons (October, April, and May) (Christodoulou 1959:21; Pashiardis and Michaelides 2008:58; Price et al. 1999:88). The minimal cloud cover and high temperatures during the summer are influenced by "the combination of subsidence from the northward shift of the subtropical high and the Persian trough, a shallow low-pressure trough extending from the Asian monsoon depressions centered over Pakistan, which leads to summertime northwesterly winds" (Griggs et al. 2014:2702). Summer rain does occasionally occur, contributing less than 5% of the total annual rainfall. It is usually in the form of isolated thunderstorms. Winter weather is influenced by frequent small depressions which cross the Mediterranean from west to east between the continental anticyclone of Eurasia and the persistent low-pressure belt of North Africa (Griggs et al. 2014:2702; Harding et al. 2009:75; Price et al. 1999:88). These depressions, called Cyprus lows, produce the majority of the annual precipitation, with roughly 60% of the total falling during winter (Christodoulou 1959:21; Pashiardis and Michaelides 2008:58; Price et al. 1999:88; Stanley-Price 1979:9; Saaroni et al. 2010).

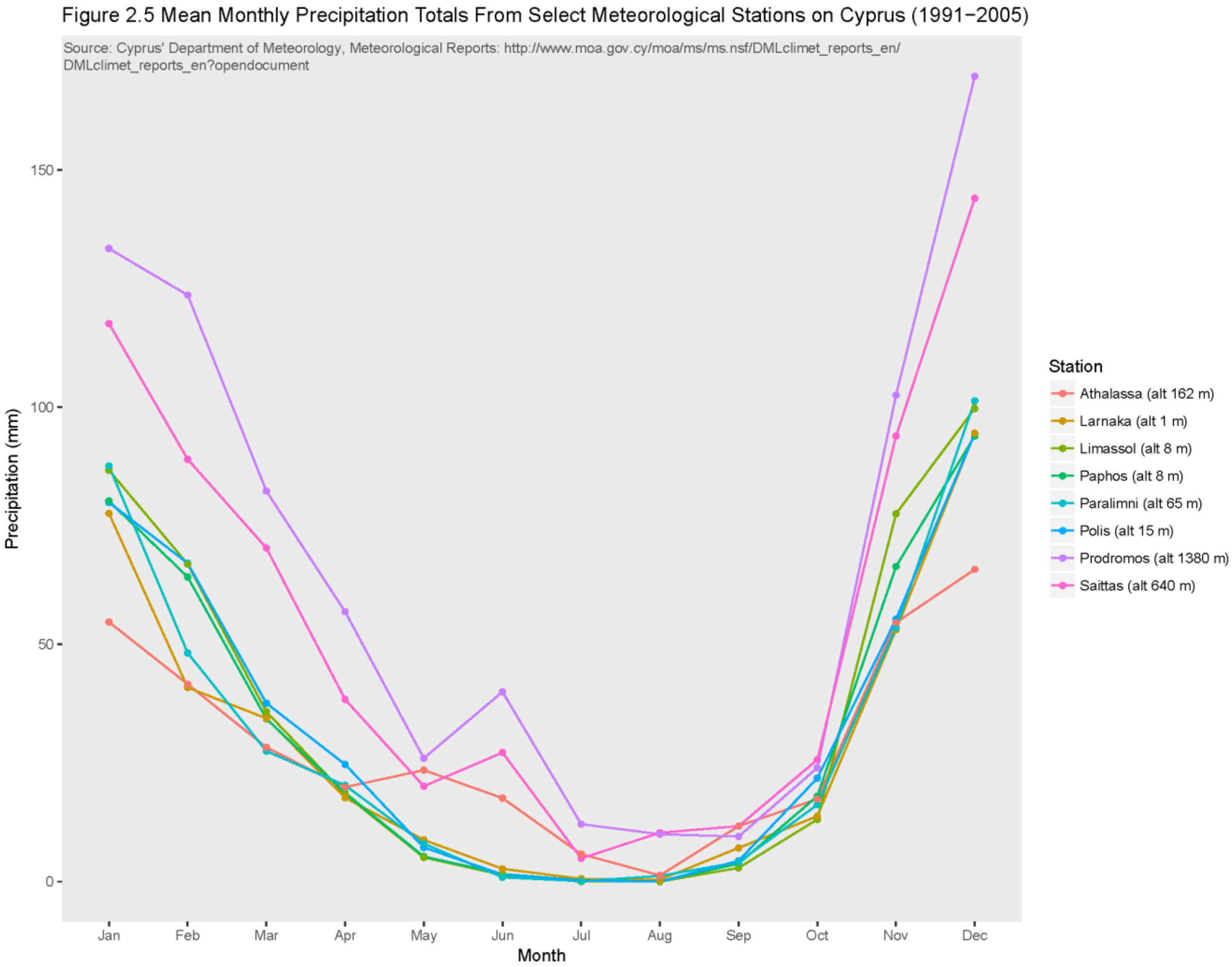
Figure 2.4 Average Annual Precipitation (mm) in Cyprus from 1901-2011



Data is from Cyprus' Department of Meteorology, Cyprus Average Annual Precipitation 1901-2011: http://www.moa.gov.cy/moa/MS/MS.nsf/All/5F3904AFA57836CBC22576C80036B9D5/$file/Kipros_Mesi_Etisia_Vroxoptosi_1901_2011_UK.pdf?Openelement

Rainfall distribution is strongly mediated by the island’s topography (Figure 2.5) (Pashiardis and Michaelides 2008:58; Stanley-Price 1979:9). Inland plain areas receive a mean rainfall average of 30 cm per year, whereas the highest peaks of the Troödos Mountains can receive more than 100 cm (Pashiardis and Michaelides 2008:58). Griggs et al. (2014:2703) note that leeward slopes of the Troödos tend to receive, on average, approximately 10 cm less rainfall, than the windward slopes. In the winter, snow can cover the high northern slopes of the Troödos for several weeks at depths around 1-1.5 m. Snowfall is rare in the Kyrenia range and lowland areas (Griggs et al. 2014:2703; Pashiardis and Michaelides 2008:59). It is noteworthy that up to 80% of the annual precipitation is also lost to the atmosphere by evaporation (Christodoulou 1959:37; Pashiardis and Michaelides 2008:61; Stanley-Price 1979:11; Zohary 1973:28).

Figure 2.5 Mean Monthly Precipitation Totals from Select Meteorological Stations on Cyprus (1991-2005)



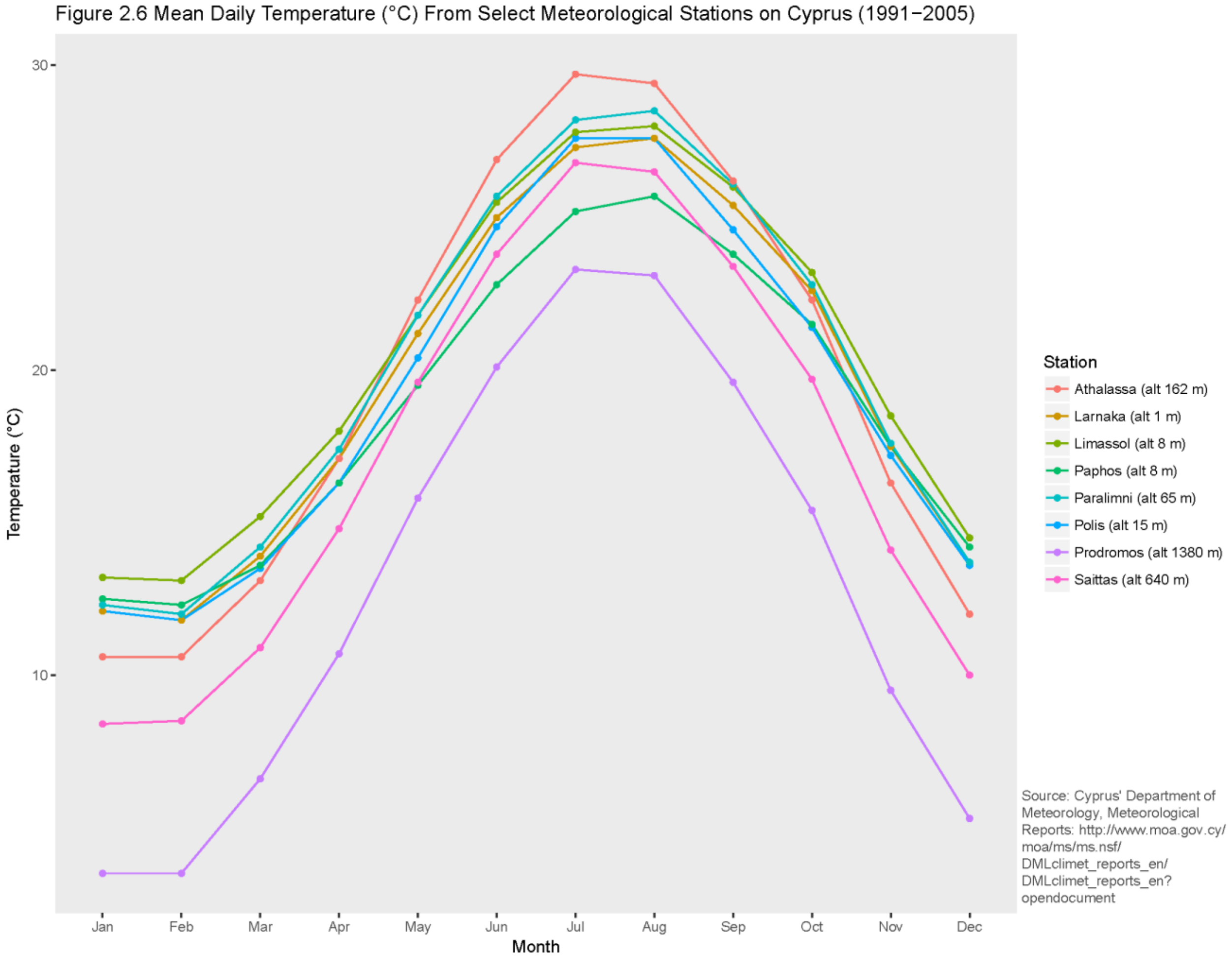
Source: Cyprus' Department of Meteorology, Meteorological Reports: http://www.moa.gov.cy/moa/ms/ms.nsf/DMLclimet_reports_en/DMLclimet_reports_en?opendocument

Precipitation is important because it affects the length of the growing season of annual crops. Pashiardis and Michaelides (2008: 59-60, Table 1) calculated the length of the growing season for a number of locations below 800 m for a period of 15 years using a simple water balance model. They found that the length was highly variable ranging from 65 to 160 days. As Christodoulou (1959:19) noted, “The importance of water for Cyprus cannot be exaggerated,” and this likely held true for the Neolithic inhabitants of the island. While the Early Holocene was likely wetter than today, there were climatic fluctuations that resulted in the climate becoming more arid. Such climatic fluctuations appear to have a long history on Cyprus. A recent study by

Griggs et al. (2014) reconstructed 250 years of precipitation and drought records from *Pinus brutia* Ten. (Calabrian pine) tree rings. The drought reconstructions demonstrate that annual droughts occur about once every 5 years. The one exception is during periods of sustained droughts, which typically last around 20 years, and occur every 70-100 years. It seems highly likely that Neolithic peoples on the island also faced droughts or periods with less than the yearly precipitation average. It is also likely that the differences in precipitation patterns between lowland and upland areas occurred during the Neolithic.

As noted above, Cyprus has hot summers and mild winters, but temperature is influenced by topography, unequal heating of the sea surface and island interior, and changes in humidity across the island (Griggs et al. 2014:2702-2703; Price et al. 1999:88). The island might have been more humid than present, given that the climate was wetter than today. Temperature decreases 5°C for every 1,000 m elevation gain (Figure 2.6). Marine influences can also cause cooler summers and warmer winters near most of the coastlines, and particularly the western coast. The seasonal difference between mid-summer and mid-winter temperatures is quite large at 14°C on the coasts and 18°C inland. During the summer (July and August), mean daily temperatures range from 29°C to 22°C on the central plain and Troödos Mountains, respectively. The average maximum temperature for the summer months ranges between 27°C and 36°C. In January, the mean daily temperature on the central plain and the higher parts of the Troödos Mountains are 10°C and 3°C, respectively. The average minimum temperature during the winter ranges from 0°C (higher elevations in the Troödos) to 5°C (central plain). Frosts occur inland in the winter and spring, but are rarely severe. However, frosts can handicap the production of certain crops (Department of Meteorology, The Climate of Cyprus, 2017).

Figure 2.6 Mean Daily Temperature (°C) From Select Meteorological Stations in Cyprus (1991-2005)



Source: Cyprus' Department of Meteorology, Meteorological Reports: http://www.moa.gov.cy/moa/ms/ms.nsf/DMLclimet_reports_en/DMLclimet_reports_en?opendocument

The relief of Cyprus is sharp, with river valleys that have cut deep into the slopes of the two major mountain ridges. Despite the presence of valleys, permanent, year-round streams and rivers are lacking (Ghilardi et al. 2015:184). Given that rainfall is concentrated in the winter months, the island’s major rivers are active during this season. During the summer many of the rivers and streams subsequently dry up, particularly in the lowland areas and on the Chalk Plateaus (Christodoulou 1959). Travelers’ reports from the 16th century AD on are consistent with the seasonal or episodic nature of river and stream flow on Cyprus (Butzer and Harris

2007:1940, citations therein). It is possible that this trend extends even further back in time to the Neolithic. However, the analysis of alluvial formations of the Dhiarizos River (ca. 15 km east of Paphos), suggests that a braided river system may have been active year-round from ca. 11,000-5,000 BC (Deckers 2002, 2003, 2005; Deckers et al. 2005; Ghilardi et al. 2015:189). Research on the Gialias catchment (Devillers 2008) and Tremithos river (Ghilardi et al. 2015) provide similar conclusions. Thus, perhaps access to consistent water sources was not an issue during the Early Neolithic. However, it is important to note that Ghilardi et al. (2015:199) suggest there was regional climatic control on the dynamics of the Gialias catchment and Tremithos rivers, which are both located in south-central Cyprus. These conclusions, thus, might not be able to be extrapolated to other parts of the island, including western Cyprus which is the primary region of interest in this dissertation.

The extent of standing water (i.e., water found in faults and shatter zones) during the Early Holocene is unknown. Stanley-Price (1979:11) argues that these would not have been main sources of water due to their high salinity, resulting from high evaporation rates. Furthermore, he notes that standing water would have been attractive breeding grounds for malarial mosquitoes. Rather, he argues that river-beds (particularly in winter) and springs were the primary sources of water for the inhabitants. The only exception to this are inhabitants who had access to deep sub-surface storage systems (e.g., aquifers or wells) (Stanley-Price 1979:11)

Leon (2016:207) notes, “The highly seasonal nature of precipitation and inconsistent access to surface water places a premium on water capture and storage of water for use during the dry summer months.” Aquifers are, thus, important for water management strategies on the island. Not all geologic regions across the island are able to capture water. Christodoulou (1959:40) identifies six main geologic areas that are particularly good for storage of subsurface water. These include: the Hilarion Limestone in the Kyrenia Range; the Kythrea silt beds, which surrounds the Kyrenia range; the north-west Alluvial Fan region that flanks Morphou Bay; the Lemesos Lowlands, including the Akrotiri Peninsula; the alluvial deposits of the Kokkinokhoria in the southeastern part of Cyprus; and the alluvial deposits of the Kokkini Trimithia Plateau west of the modern capital Nicosia (Christodoulou 1959:40; Leon 2016:207-208). The Chalk Plateaus store very little subsurface water because this geologic formation is primarily limestone. Limestone does not hold water well (Christodoulou 1959:41).

2.3.3 Vegetation and Fauna of Cyprus

Topography and climate, just discussed above, affect the plant and animal species that develop within them. These species affect land and water management strategies. Plant species are important because they determine available forage for animals, available food for humans, and the location of potentiation areas for grazing and growing crops. Because of the limited pollen core data, it is difficult to reconstruct vegetation during the Early Holocene. Asouti (1998:74-76) examined the wood charcoal macro-remains from the Neolithic and Chalcolithic components of Kissonerga-*Mosphilia* and characterized the prehistoric landscape as typical maquis-type Mediterranean dense woodland/forest vegetation. Specifically, there was a range of deciduous oak and evergreen taxa including oak (*Quercus* sp.), fig (*Ficus* sp.), pine (*Pinus* sp.), lentisk (*Pistacia* sp.), wild carob (*Ceratonia* sp.), and olive (*Olea* sp.). However, this type of research is still rarely conducted on Cyprus. We can, however, turn to the vegetation of late 19th and 20th centuries. These data make the reconstruction of the Early Holocene vegetation tricky because the landscape today (and in the more recent past) is dominated by villages and agricultural land. While both likely occurred during the Early Neolithic, neither was at the scale that they are today. The fauna can provide clues concerning potential predators and natural competition (Leon 2016:224) and will be discussed last.

2.3.3.1 Vegetation of Cyprus. The flora of Cyprus and the Eastern Mediterranean region more broadly is characterized by relatively high biodiversity, with many endemic species. On the island, there are believed to be 1800 indigenous plant taxa, of which 7% are endemics (Tsintides 1998:10).[13] The Mediterranean climate conditions favor the growth of C_3 vegetation on Cyprus (Makarewicz et al. 2016: 4; Meikle 1977; Zohary 1973:151-155). There are also a smaller number of C_4 grasses and chenopods (Collins and Jones 1985; Della et al. 2006; Meikle 1977). It is important to note, however, that there is limited evidence for C_4 plants during the Neolithic.

Similar to most Mediterranean islands, humans have exploited the island's environment for many millennia. As a result, the landscape has been heavily modified. Much of the original pine and oak forests have been changed (Fall 2012:80; Lucas 2014:10-11). The island's phytogeography has been divided in a number of ways by different scholars (e.g., Christodoulou 1959:45-51; Meikle 1977:4-8; Tsintides 1998:11-20; Zohary 1973:151). To follow the geology and topography discussion, I will discuss the vegetation that is found on the mountains, the lowlands, and the Chalk Plateaus.

In the highlands of the Troödos and Kyrenia ranges, forests are prevalent. Two species of *Pinus* dominate the forests: *Pinus nigra pallasiana* (black pine) and *Pinus brutia* (Turkish pine) (Fall 2012:80; Tsintides 1998:11). Black pine are primarily only found in the Troödos. Turkish pine forests are found in the Troödos Mountains and foothills (primarily between 600-1200 m elevation) and in the Kyrenia Range (300-800 m elevation). Individual *Pinus brutia* can also be

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[13] Indigenous plant species may occur in areas other than the one being considered (i.e., in this case Cyprus). Endemic species are exclusively native to the biota of a specific area, and cannot be found anywhere else in the world (Tsintides 1998:10).

found growing at lower elevations. There are a number of understory plants, trees, and shrubs associated with these forests (Fall 2012:80). Cedar (e.g., *Cedrus brevifolia*: Cyprus cedar), oak (e.g., *Quercus alnifolia*: golden oak, *Quercus coccifera*: holly or kermes oak, and *Quercus infectoria*: Aleppo oak), and cypress forests are also present on the island, although in less significant numbers than the pine forests. Today, Cedar have a restricted geographic distribution, and are only found in the Cedar Valley of the Paphos Forest (Fall 2012:80). Cypress are in the Kyrenia Range and along the Karpas Peninsula.

It is thought that forest cover might have been more substantial during the Neolithic, Chalcolithic, and Bronze Age (Lucas 2014:10). The Troödos pine forests have been used for goat grazing since at least the Ottoman period (Given 2000, 2007). In fact, over-grazing by goats was believed to be the cause of deforestation, and the British colonial government (1878-1960) instituted a forest policy that favored conservation and eliminated goat browsing in the forests (Butzer and Harris 2007:Table 1; and see Harris 2012 for a compelling argument that the forests were not degraded). Perhaps this practice reaches much farther back in time, particularly if the forest environment was being exploited for other resources.

The Chalk Plateaus and lowlands are typically unattractive to woody species, because the soil is dry and does not permit deep root penetration. However, there are accounts from antiquity that suggest the central lowlands were once heavily forested. Stanley-Price (1979:13) disputes these accounts, arguing that the descriptions are more suggestive of *maquis* vegetation than true forest. The idea that the island was significantly more forested than today also has been more recently disputed (Harris 2012). Today, there are the occasional lone, dry-tolerant trees on the Chalk Plateaus and lowlands, including hawthorn, terebinth, carob, and wild olive. The flora communities can be divided into three groups: grass, *maquis*, and rock/*garigue* (Leon 2016:224).

Wild grass species that dominate include: wild oak (*Avena barbata*), wild barley (*Hordeum murinum*), wild wheat (*Triticum ovatum*), and other grasses (e.g., *Stipa tortilis* and *Langurus ovatus*).

The *maquis* includes evergreen maquis and forests of Quercetea calliprini (e.g., Quercetalia and Sarcopoterietalia), although both extend from sea level to about 1200 meters elevation. Species that are found within the oak-type *maquis* vegetation of tall shrubs (4-6 meters) include: *Rhamnus alaternus* (Mediterranean buckthorn), *Laurus nobilis* (laurel), *Pistacia terebinthus* (terebinth), *Arbutus andrachme* (Greek strawberry tree), *Olea europaea* (olive), *Styrax offinalis* (styrax), and *Phillyrea media* (broad-leaved phillyrea) (Lucas 2014:11; Meikle 1977:4; Zohary 1973:153-155). The Quercetalia class includes Ceratonieto-Pistacietum lentisci or the carob-lentisk community, which covers much of the dry, lower regions of the island. The community is found in elevations up to around 300 meters. The primary components of this vegetation are the carob tree (*Ceratonia siliqua*) and lentisk (*Pistacia lentiscus*) (Lucas 2014:11).

The heavily grazed and deforested maquis landscape has developed into Sarcopoterietalia class of the Quercetea calliprini, which includes batha and garigue communities such as: *Lavandula stochas* (lavender), *Calycotome spinose* (spiny broom), and *Cistus* spp. (rockrose) (Lucas 2014:11; Zohary 1973:153). These areas are more common and are covered by less dense, garigue communities of small shrubs (less than 3 meters), including rockrose and *Pistacia lentiscus* (mastic tree). Where animal grazing is even more intense, the garigue vegetation is reduced to batha. Species within the batha community include: thorny burnet, sage, thymus, and needle sunrose (Lucas 2014:11; Meikle 1977:4; Zohary 1973:154). Zohary (1973:154) also suggests that batha communities might be part of the original vegetation of some areas in the *Mesaoria*.

Most Early Neolithic sites are near some type of aquatic environment. Thus, aquatic plant communities near rivers and springs were also likely important to Neolithic inhabitants, including those at Kritou Marottou *Ais Giorkis* (see below). Today, Phragmitetea (dominated by Phragmites and sedges) and Potamotea (pondweed) classes dominate aquatic plant communities, and are also likely to have been present in the past (Lucas 2014:11; Meikle 1977; Zohary 1973:153-154).

2.3.3.2 The Fauna of Cyprus. The founder assessment of the terrestrial paleontological record on Cyprus was conducted by Boekschoten and Sondaar (1972). More than forty years later, the composition of the mammal communities remains relatively unchanged. It is characterized by small taxonomic diversity and a high degree of endemism. Both are likely due to the island being an oceanic island.[14] The endemic mammal fauna of Cyprus includes: pygmy hippopotami (*Phanourios minutus*), pygmy elephant (*Elephas cypriotes*), genet (*Genetta plesictoides*), possibly a shrew, the Cypriot mouse (*Mus cypriacus*), and reptiles (tortoise, snake) (Cucchi et al. 2006; Horwitz et al. 2004; Simmons 1999; Vigne et al. 2009, 2013:160). Endemic suids were totally absent from the numerous Cypriot hippo accumulations that date to the Late Pleistocene (Simmons 1999; Vigne et al. 2013:160). In addition, Mesopotamian fallow deer (*Dama dama mesopotamica*) are also not believed to be endemic to Cyprus (Simmons 2009a:3, but see Kassapis 2001). The island is, in fact, devoid of almost all wild progenitors of domesticated species, including: *Bos taurus* (cattle), goats (*Capra hircus*), sheep (*Ovis aries*),

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[14] The island of Cyprus is of marine origin, and likely never connected to any continent. The only exception is during the Messinian Salinity Crisis, which occurred around 5.6 million years ago. During this event, the Mediterranean basin was reduced to desert-like conditions with small pockets of water. Approximately 5 million years ago, the Atlantic waters breached the land barrier that had linked modern-day Morocco with Spain and refilled the basin. This event is known as the Zanclean or post-Messinian flood. Once this occurred, it is believed that the basin filled up with water relatively quickly (Garcia-Castellanos 2009; Schule 1993). The expanse of water that has surrounded Cyprus for millions of years has kept out many eastern Mediterranean animal species found on the mainland (Knapp 2013:57).

and pig (*Sus scrofa*). This means that it is easier to determine when these resources were first introduced. Furthermore, as Vigne (2013b:124) notes, “it is easier to detect phenomena such as feralization or control in the wild, phenomena which are mostly undetectable in osteoarchaeological data from the mainland.” Perhaps, more importantly it means that many of the introduced species did not have natural predators. Rather, there might be natural competition for grazing land and water resources.

2.4 Archaeological Chronology: Late Epipaleolithic to Early Neolithic

Mediterranean islands were once thought to have a relatively late human presence, beginning late in the Neolithic (Simmons 2014). Colonists were believed to have simply imported the complete Neolithic package to these “pristine” islands, breaking connections with their homeland. This resulted in the isolation of these island Neolithic cultures. Specifically, these Neolithic immigrants exhibited few material cultural similarities with their counterparts on the mainland (Held 1990:21; Simmons 2004:1; 2014; Vigne 2013a; 2013b; Vigne et al. 2011b). Recent studies have radically altered that view. We now know that several of the Mediterranean islands, including Cyprus, were being enveloped within the wider pan-Mediterranean and Southwest Asian world by at least the Late Epipaleolithic (11,000-9,000 cal BC) (Simmons 2014, and citations therein). Evidence now also suggests that domesticates arrived on Cyprus at around the same time that we see the earliest evidence for these resources on the mainland (Vigne 2011; Vigne et al. 2012; Zeder 2008). Thus, the earliest periods of human visitation and colonization on the island have much to contribute to our understanding of the dynamic processes that are critical to the Late Epipaleolithic and the Early Neolithic (Table 2.1) (Simmons 2004:1).

Table 2.1 Occupation dates of main sites discussed in this dissertation

Site Name	Cal BC	Culture/Period
Cyprus		
Akrotiri *Aetokremnos*	12181 - 9293	Late Epipaleolithic/Akrotiri Phase
Ayios Tchonas *Klimonas*	9156 - 7746	Cypro-PPNA
Ayia Varvara *Asprokremnos*	9141 - 8569	Cypro-PPNA
Kalavasos *Tenta*	9120 - 4851	Cypro-PPNB
Parekklisha *Shillourokambos*	8751 - 6829	Cypro-PPNB
Kissonerga *Mylouthkia*	8735 - 6696	Cypro-PPNB
Akanthou *Arkosykos*/Tatlısu *Çiftlikdüzü*	8234 - 7748	Cypro-PPNB
Kritou Marottou *Ais Giorkis*	7956 - 7058	Cypro-PPNB
Khirokitia *Vouni*	7175 - 4795	Khirokitia Culture
Kholetria *Ortos*	6560 - 5838	Khirokitia Culture
Kissonerga-*Mosphilia*	4681 - 2215	Chalcolithic
Erimi *Laonin tou Porakou*	2131 - 1316	Bronze Age
Greece		
Kouphovouno	5634 - 4997	middle-late Neolitihic
Israel		
Atlit Yam	7481 - 6256	PPNC
Sha’ar Hagolan	6442 - 5673	Pottery Neolithic/Yarmukian Culture
Jordan		
Ain Ghazal	8528 - 6651	middle PPNB - Pottery Neolithic/Yarmukian Culture
Syria		
Abu Hureyra	11974 - 6534	Natufian - Pottery Neolithic
Turkey		
Göbekli Tepe	9175 - 8559	PPNA
Kömürcü-*Kaletepe*	8250 - 7680	PPNB
Catalhöyük East	7588 - 5768	Neolithic
Catalhöyük West	6007 - 5674	Chalcolithic

Note: See Appendix A for discussion of radiocarbon calibrated dates in this study

2.4.1 Late Epipaleolithic

Currently, the earliest evidence that we have for a human presence on Cyprus dates to the Late Epipaleolithic (Figure 2.7) (Knapp 2013). There is one coastal site that definitively dates to this time frame based on radiocarbon determinants: Akrotiri *Aetokremnos* (hereafter Akrotiri;

Simmons 1999; 2004; 2013; 2014; Simmons and Mandel 2007). There might also be three other contemporary sites, all of which have been excavated to varying degrees: two are coastal (Nissi Beach and Akamas *Aspros*) and the other is inland (Vrestia *Roudias*). In addition, the Elaborating Early Neolithic Cyprus (EENC) survey project has documented other possible inland sites that may date to the Late Epipaleolithic. Excavations have not yet been conducted on these sites to confirm their temporal position (McCartney et al. 2006, 2007, 2008).

Figure 2.7 Late Epipaleolithic sites in Cyprus

All four excavated sites have produced similar types of microlithic, flake-based chipped stone materials. Unfortunately, only Akrotiri has produced radiocarbon determinations, and there are context issues with the other excavated sites as well (Ammerman 2013a; 2013b; Efstratiou et al. 2010; Knapp 2013; Simmons 2014). The problem of a small number of excavated sites is one that does not just afflict the Late Epipaleolithic, but also the succeeding two periods: the Cypro-Pre-Pottery Neolithic A (Cypro-PPNA; 9,000-8,500/8,400 cal BC) and the Cypro-Pre-Pottery Neolithic B (Cypro-PPNB; 8,500/8,400-7,000/6,800 cal BC). As a result, there are limitations to any conclusions that can be made about human alterations to the landscape.

2.4.1.1 Akrotiri. Akrotiri is a collapsed rock shelter located on the southern coast of Cyprus (Table 2.1, Figures 2.7-2.8). It is best-known for the still contentious conclusion that the extinction of pygmy hippopotami was at least partially human-induced (Ammerman 2013a; 2013b; Knapp 2013; Simmons 1999; 2004; 2013; 2014; Simmons and Mandel 2007; Vigne 2015; Zazzo et al. 2015). The majority of the pygmy hippopotami remains were found in Stratum 4, the oldest level at the site. There was also chipped stone (11.8% of the total assemblage) in this stratum, which is partly why the excavators argue for a human role in their extinction (Simmons 1999; 2004; 2014; Simmons and Mandel 2007). In contrast, there are almost no pygmy hippopotami remains in Stratum 2. Rather there seems to be a change in economic activity at the site with a greater emphasis on the exploitation of marine shells and avifauna. The majority (61.5%) of the chipped stone assemblage also occurs in this context. Some of the chipped stone assemblage was made from high quality translucent chert (McCartney 2017:56). In addition, picrolite beads were also recovered (Reese in Simmons 1999:149; 2014:149). Both materials are not found in the Akrotiri Peninsula, indicating that the site's inhabitants had knowledge of the island's landscape (McCartney 2017:56).

Figure 2.8 Overview of Akrotiri Aetokremnos

Interestingly, 18 wild boar bones (*Sus scrofa*) (one incisor and 17 metapodials or phalanges) were also recovered. Most of the bones come from level 2. Direct radiocarbon dating on the bones found that they were dated to around 12,500 cal BP. The bones recovered are exclusively from the limb extremities. Vigne and colleagues (2013) interpret these as the remains of at least two hides that came from animals who were hunted on the island.

Based on evidence from Akrotiri, wild boar were likely introduced by humans to the island by at least the 12th millennium BP. This introduction might have been due to the fact that there were no longer any large game on the island, following the extinction of the pygmy hippopotami and elephant. There is no evidence of wild boar in the Cypriot Pleistocene fauna record. It is unlikely that the animals swam to the island given its distance from the mainland.

Thus, these animals were perhaps brought to Cyprus some 4,000 years prior to the earliest evidence of their morphological domestication on the mainland. This introduction illustrates that humans had significant control over certain animals thousands of years prior to domestication (Vigne 1995; 2015; Vigne et al. 2009; 2011b; 2013). In addition, it should not be surprising that humans were beginning to alter the island's landscape, as this is often something done when humans, past and present, move into a new environment (Hofman and Rick 2017:9).

2.4.1.1 Summary. Akrotiri and the other possible Late Epipaleolithic sites on Cyprus lack permanent forms of year-round occupation. The ephemeral nature of these sites makes them difficult to recognize on the landscape, which partly explains why we have so few sites that currently date to this time period. In addition, there are still few scholars who are interested in documenting and excavating these early sites. Based on limited surveys and excavations, however, there does seem to be sites located on the coast and in the uplands. As such, it appears that over several millennia, seafaring fisher-foragers made seasonal visits to Cyprus to exploit faunal and marine resources, including pygmy hippopotami, pygmy elephants, shellfish, and avifauna (Finlayson 2004:18; Simmons 1999; 2004; 2014). Salt and sea turtles might also have been exploited at these coastal sites (Ammerman 2013b; Ammerman et al. 2008; McCartney et al. 2010:136, Fig. 13.2). In addition, humans might have introduced wild boar to re-stock the island with game following the extinction of the pygmy hippopotami and elephant. This transfer was followed by the introduction of additional plant and animal species during the Neolithic (McCartney 2017:56; Vigne 2015:131; Vigne et al. 2013:167). These lines of evidence point to the idea that these Late Epipaleolithic seafaring fisher-foragers were developing a wealth of knowledge about the island and the surrounding sea, including sea routes, landing places, coastal landmarks, and the availability of marine and terrestrial resources. As McCartney notes (2017:56), seascape exploration appears to go hand in hand with exploration of the island landscape. The discovery of chert and picrolite at Akrotiri, not locally available around the site, supports this notion. Both the sea and landscape exploration suggest that this knowledge was being passed down from generation to generation (Vigne et al. 2013:167). This conclusion has led Vigne and colleagues (2013:167) to support Ammerman's (2010) hypothesis that during the Late Epipaleolithic we see the beginnings of specialized coastal populations or specialized sea voyagers from the mainlands who played a main role in crossings back and forth to Cyprus. This idea will be further discussed below because it pertains to the succeeding early Pre-Pottery Neolithic (PPN). Regardless, these explorations of the island and surrounding sea suggest that it was neither distant nor exotic to mainlanders by at least the Late Epipaleolithic (Finlayson 2004:18).

2.4.2 Cypro-PPNA

The Late Epipaleolithic is followed by the Cypro-PPNA (ca. 9,000 – 8,500 cal BC), which currently has only two excavated sites: Ayia Varvara *Asprokremnos* (hereafter *Asprokremnos*) and Ayios Tychonas *Klimonas* (hereafter *Klimonas*) (Table 2.1, Figure 2.9). An additional site, Ayios Tychonas *Throumbovounos*, near *Klimonas* also possibly dates to the Cypro-PPNA based on similar lithic technology. But, it has not yet been fully investigated and no animal remains have been found (Vigne et al. 2011a, 2011b). The Elaborating Early Neolithic Cyprus (EENC) survey field project has also found other possible Cypro-PPNA sites; however, none of these have yet been excavated (McCartney et al. 2006; 2007). These two excavated sites are important because they helped to fill the so-called 'PPNA hiatus' on Cyprus. This hiatus referred to supposed temporal gap between the Late Epipaleolithic and the Cypro-PPNB, which was supposed to have lasted around 3,000 years. The addition of data from these sites reduces this gap to ca. 500 years, and this will likely disappear as additional sites are excavated (Knapp 2013:83).

Figure 2.9 Select Cypro-PPNA sites in Cyprus

2.4.2.1 Asprokremnos. This site is located on a small saddle between two low hills in central Cyprus. The Yialis River is located to the west of the site and provided the inhabitants with year-round (or nearly year-round) access to water. It also had relatively easy access to the forests of the Troödos Mountains. Basal rocks, which eroded from the mountains were also exploited for ground stone production. There is abundant local cherts, chalks, and ochre surrounding the site, which were used to produce chipped stone, ground stone, and pigments, respectively (Knapp 2013:85; Manning et al. 2010; McCartney 2017). McCartney (2011:187) notes, “Its position at the junction between the open plain (*Mesaoria*) and the forested mountains would have been ideally suited to foragers, while its situation on a riverine terrace with easy access to secure source of water might be seen as more typical of early village societies.”

To date, the site has yielded around 3,000 kg of chipped stone (including over one hundred complete and fragmentary projectile points, which are largely missing from the subsequent Cypro-PPNB), 20 kg of pigments, and more than 1,300 pieces of ground stone. Ochre residue was found on some of the ground stone. Thus, plant and pigment processing were important site activities (Manning et al. 2010; McCartney 2017:48-49). Despite the significant amount of worked material, there are very few built structures and none of them seem to be occupied at the same time, leading McCartney (2017: 50-54) to suggest that the site was not continuously occupied. Rather she believes that there is repeated evidence for abandonments. Other notable finds include a fragmentary baked-clay figurine, decorated shaft straighteners, one bone point, and dentalium shell and picrolite ornaments (Knapp 2013:85; McCartney et al. 2006: 45-47, 2008: 73-75; Manning et al. 2010).[15] The subsistence data are poor compared to that from *Klimonas*. Wild boar dominates the faunal assemblage. Bird, freshwater crab, and turtle were also exploited. No botanical remains have been recovered; however, flotation samples have not yet been analyzed (McCartney 2017:55). Based on the site location, site plan/development, the production of large quantities of chipped stone, and the large amounts of ochre, McCartney

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[15] The fragmentary baked clay figurine is the earliest known on the island (Knapp 2013:85; McCartney et al. 2006: 45-47, 2008: 73-75; Manning et al. 2010).

(2017:57) suggests that "…mineral and stone commodities, not farm land, were the focus of habitation at *Asprokremnos*."

2.4.2.2 Klimonas. This site is located on a naturally terraced slope facing the Mediterranean Sea, which is about 2 km away, within the Limassol District on the south-central coast. It is situated within the Athiaki valley. Preliminary results from a geomorphological study of the Athiaki river's fluvial terraces suggest that, at the time of the site's occupation, there would have been a small alluvial plain near the site. This plain could have been ideal for plant cultivation (Vigne et al. 2011a, 2017). Abundant, high-quality chipped stone is found in this valley, as well as surrounding valleys (Vigne et al. 2011a, 2017). The majority of the lithic assemblage is made of local material. Only three obsidian bladelets and one blade were recovered. Similar to *Asprokremnos*, several decorated stone shaft-straighteners were found, as were numerous projectile points (Vigne et al. 2012: Fig. 2; 2013:162; 2017:23). Ground stone was also abundant, and included polishers, pestles, mortars, hammerstones, querns, and grinders (Vigne et al. 2011a, 2017:23). Abundant marine shells and other stone objects, including local green picrolite, were recovered and have been interpreted as body ornaments. Ochre was also recovered. Conic stone objects made out of local chalky limestones were also documented. The initial interpretation is that they represent either phallic objects or crude figurines, and appear to be similar to objects found in the Levant PPNA (Vigne et al. 2017:25, Fig. 6).

In contrast to *Asprokremnos*, *Klimonas* has substantial structures. In particular, excavations recovered a 10 m circular semi-embedded feature, located in the central sector of the site (St 10). This feature was surrounded by a cob wall set into a circular founding trench. Postholes were found surrounding the building and one was also found in its center, implying that the building was covered by a roof. There is also evidence that it was periodically rebuilt or restored. Within the interior space, there were hearths, pits, and low peripheral benches. The building was reconstructed and renovated several times. It has been interpreted as a communal building, both because of its central location within the site and its similarities with structures discovered in PPNA villages of the Euphrates valley and Southeast Anatolia (Vigne et al. 2012:8445-8446, Fig. 1; 2013:163; 2017:28-32, Figs. 7-11). The only human remains (5 small fragments of human cranial roof and two fragments of jaw) recovered at the site were also found in the benches and in pits of St. 10 (Vigne et al. 2017:25-26).

Excavations also recovered a 6 m circular building, situated at the north-west boundary of the site (St 800). Within the interior, excavators found a plastered floor, post and stake holes, smaller trenches that might have delineated benches or partition walls, and pits. The pits contained artifacts. This building was interpreted as a domestic structure due to its smaller size. In addition, the excavators argue that less labor went into its construction, in comparison with St 10. St 800 also is believed to have had a shorter habitation period than St. 10 (Vigne et al. 2017:32-36, Figs. 12-15). In addition to these two structures, other eroded buildings have been uncovered through extensive mechanical clearing and geophysical surveys. These buildings are primarily circular in shape, ranging in size from 3 m to 8 m, and are terraced on the slope (Vigne et al. 2017:36-37). All structures surround St 10. The site is believed to have covered at least half a hectare, with a minimum of 260 buildings (Vigne et al. 2017:41), although the present author is skeptical of this number. Vigne and colleagues argue, “Its specific organization indicates that *Klimonas* is a village, the earliest not only in Cyprus, but of any Mediterranean island (2017:41).”

Similar to *Asprokremnos*, wild boar are the main faunal component at *Klimonas*. Morphological analyses illustrate that these remains are similar to those from Akrotiri, supporting the notion that a wild boar population was established on the island by the Late Epipaleolithic. There are a wide range of slaughtering ages represented. Coupled with the large number of projectile points, these data imply hunting or herd control, rather than husbandry (Knapp 2013:68, 84; Vigne 2013a; 2013b; Vigne et al. 2011a, 2011b; 2012; 2013). There are also remains of domestic dog, mice, cat, several species of birds, mollusks, lizards, snakes, one fish vertebra, fresh water turtle, and possibly genet. Dog perhaps helped with wild boar hunts and/or management. The remains of cat predate any known interaction with humans from the mainland by 1,500 years and might have been used for controlling pests, possibly supported by the presence of rodent-gnaw marks on some of the bones (Knapp 2013; Vigne et al. 2011a, 2011b, 2012, 2013a:163-164; 2017:40). In addition, despite the site's proximity to the sea, there is no evidence for the exploitation of marine animals. The only exception is a single fish vertebra that the excavators believe is a contaminant from a later period (Vigne et al. 2017:40).

Few botanical remains were recovered, possibly due to intense bioturbation at the site. Those that were recovered include: pistachio (*Pistacia* sp.), plum genus (*Prunus* sp.), oak (*Quercus sp*.), and emmer wheat (*Triticum dicoccum/dicoccoides*). The occurrence of emmer wheat is particularly interesting because both the wild and domestic forms of this species are not endemic to Cyprus. Thus, it likely had to be introduced from the mainland. Analyses of the chaff could not determine if it was domesticated or wild, but it does seem to suggest that *Klimonas* villagers, similar to their PPNA mainland counterparts, were experimenting with plant cultivation. This interpretation is reinforced by the recovery of several sickles and groundstone used for grinding, as well as the possibility of an alluvial plain located adjacent to the site (Vigne et al. 2012:8446-8447, 2013:163, 2017:37-38, 40).

2.4.2.3 Summary. Despite there only being two excavated sites that date to the PPNA, the sites combined provide critical information about some of the earliest people on the island. Based on the lack of evidence for the exploitation of marine resources, Vigne et al. (2013:167) continue to argue that there were specialized groups of seafarers. These seafarers were distinct from the cultivators/villagers found at *Klimonas* and *Asprokremnos*. Galili et al. (2004) were some of the earliest researchers to emphasize this dichotomy:

> The early and mid-PPN sites discovered to date in Cyprus were basically communities engaged in agriculture, with a limited, if any, investment in the exploitation of marine resources. The settlements were established by new immigrants from the mainland (Fertile Crescent) that were attracted by the unpopulated and pristine environmental conditions. There is no doubt that significant navigational skills, as well as an acquaintance with the sea and knowledge of the target, were needed in order to transfer people, animals, and goods to Cyprus. The presence of PPN farmers on the island suggests that sea-going people, possibly local hunter-gathers who utilize marine resources and lived on the shores of the Levant, aided these people. These coastal populations, who possessed the necessary navigation skills may have served as “ferry-men” who transported Neolithic populations living in the hinterland of the Levant to Cyprus (Galili et al. 2004:97).

McCartney (2017:57) disagrees with this dichotomy, because it fails to account for inter-site variability that we see on Cyprus during the PPN. For example, at *Asprokremnos*, it appears unlikely that the site’s inhabitants were experimenting with plant cultivation. Rather, inhabitants appear to be focusing on the mineral and stone resources located at and near the site. In contrast inhabitants of *Klimonas* might have been experimenting with at least plant cultivation, in combination with our resource exploitation. Peltenburg (2004a:19) also suggests that, “Even if there were specialised seafarers, that is ferrymen/fisherfolk who ferried different groups back and forth, island communities probably had their own links with kin, allies, and trading partners on the mainland.”

McCartney adds to this argument, stating, “we should consider whether all groups occupying the island were indeed ‘colonists’ rather than explorers and specialists looking for commodities for exchange with such mainland partners (2017:57).” By this, she means that intense resource exploitation appears to be an integral part of PPNA inhabitant livelihoods, which goes beyond mere settlement of the island during the Neolithic. Often the inhabitants of the Cypro-PPNA and Cypro-PPNB are framed based on their relationship with their mainland counterparts. For example, direct evidence of animal and plant transfers and exotic materials (e.g., obsidian) imply exchanges were pursued via movement across the Mediterranean. However, there is rarely a discussion about what the island’s inhabitants may have been trading with individuals on the mainland. Mineral pigment processing at *Asprokremnos* likely exceeded the need of the people occupying it. Given that only limited quantities of ochre have been recovered from *Klimonas*, this raises the question of where this material was going. Perhaps they were exchanging with other sites on the island that have not yet been excavated. Another real possibility is that the material was being brought back to the mainland. Unfortunately, sourcing pigments is still extremely challenging. However, the intensity of local resource exploitation during the Cypro-PPNA implies that Neolithic groups from Southwest Asia crossed to Cyprus for a variety of reasons besides colonization/settlement. In addition, seafaring does also not have to be the sole profession of these early inhabitants, who likely played a role in exploiting the island’s resources (McCartney 2017:57).

2.4.3 Cypro-PPNB

The transition between the Cypro-PPNA and Cypro-PPNB involves the addition of possibly new types of architecture, different lithic technologies, different material culture, and different plant and animal economies. Many of these elements can be traced to various regions on mainland Southwest Asia, implying that there is still considerable communication between the island and mainland (Knapp 2013). For the Cypro-PPNB (8500/8400 – 7000/6800 cal BC), there are presently five excavated sites: Kalavasos *Tenta* (hereafter *Tenta*), Kissonerga *Mylouthkia* (hereafter *Mylouthkia*), Akanthou *Arkosykos* (hereafter Akanthou)[16], Parekklisha *Shillourokambos* (hereafter *Shillourokambos*) and *Ais Giorkis*. One other site might also date to this time period, that of Prasteio *Mesorotsos* (hereafter Prasteio) (McCarthy et al. 2010). However, there are currently no radiocarbon determinants for this site; thus, it will only be briefly discussed here (Table 2.1, Figure 2.10). Other sites have been proposed, including Kannaviou *Kochina*, Politiko *Kelaïdhoni* and Agrokipia *Paleokamina* (Knapp 2013; McCartney 2004; Simmons 1998). Survey work conducted in the Kyrenia District (North Cyprus) has also located possible Aceramic Neolithic sites. The presence of notable amounts of obsidian at one such site (TCD 96), suggests that it might date to the Cypro-PPNB (Şevketoğlu 2000). Unfortunately, too little information is available for all these sites to confirm their temporal placement.

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[16] The site is also known by its Turkish name Tatlısu-*Çiftlikdüzü* (Şevketoğlu 2002; 2006; Şevketoğlu and Hanson 2015), although it is more commonly referred to by its Greek name in the literature.

Figure 2.10 Select Cypro-PPNB sites in Cyprus

Of the excavated sites, four are coastal or located within five kilometers of the coast. *Ais Giorkis* and *Prasteio*, in contrast, are uniquely located in the uplands (Guilaine et al. 2011; Knapp 2013; Peltenburg 2003; Şevketoğlu 2002; 2006; Şevketoğlu and Hanson 2015; Simmons 2009a; 2009b; 2010; 2012; Todd 1987; Vigne 2011; 2013a; 2013b; Vigne et al. 2011b). *Ais Giorkis* will be discussed in its own section in this chapter. The purpose of this section is to provide context for the Cypro-PPNB.

2.4.3.1 Tenta. This site sits on top of a small natural hill in south-central Cyprus, approximately 3 km from the Mediterranean Sea. It is located within the lower catchment of the Vasilikos River valley. The site is strategically placed on the landscape. Not only is it near the sea, but it offers relatively easy access to the Troödos Mountains to the north and the resources that lie therein (DiBenedetto 2015; Knapp 2013:103; Todd 2003:35; 2005:379). There is only a portion of the site that dates to the Cypro-PPNB, with the main occupation during the subsequent Khirokitia Culture (KC), although the chronology is somewhat unclear. The Cypro-PPNB component is represented by a series of postholes as well as several pits and hearths. The postholes imply use of ephemeral structures made from wood (Todd 2003, 2005). There are several stone-built circular structures, which are believed to date to the late Cypro-PPNB (Knapp 2013:104). Chipped stone and faunal remains are the two major material cultural categories recovered, although ground stone was also found. The chipped stone assemblage shares similarities with other Cypro-PPNB assemblages on both the island and the broader Near Eastern mainland. Specifically, there are blades, Byblos and Amuq-like projectile points, and naviform core technology (McCartney in Todd 2005:177-207, 211-227).

Obsidian was also found at the site, although in relatively small quantities. It has been sourced to the Anatolian Çiftlik source, which reaffirms that at least some Neolithic peoples on Cyprus maintained contact with the mainland and that there was inter-island exchange of this material. Interestingly, a wall painting that possibly depicts two human figures was also recovered (Knapp 2013:106-107, Figure 25; Todd 1987: fig. 39, 1998:64-65, figs. 41-42). Peltenburg (2004b:76-77, figs. 7.5-7.6) argues that this painting falls within the southeast Anatolian, north Syrian ideological tradition, similar to the relief representations of animals and people on pillars at Nevali Çori and Göbekli Tepe (southeastern Anatolia).

The faunal assemblage is dominated by Mesopotamian fallow deer (around 56%) and then sheep/goat. Pig becomes important, but not until the KC (Croft 2002:175, 2005:358; Knapp 2013:104). Mollusca were also recovered in relatively large quantities (McCartney et al.

2010:137). Botanical remains recovered include einkorn and emmer wheat, hulled barley (*Hordeum sativum*), and pulses (pea, horse bean, lentil, and vetch). Wild cereals were rarely recovered; however, wild grasses were found in greater abundance. Thus, the subsistence practices at *Tenta* seem to initially be focused on deer hunting, with some management of domesticated animals. Based on the plant material recovered, it seems the inhabitants were focused on domesticated plant resources, rather than wild resources (Knapp 2013:108).

2.4.3.2 Mylouthkia. This site is located 100 m from the current coastal shoreline, north of Paphos, at the northern end of the Ktimi Lowlands. To the north, it is bordered by the wide Mavrokolymbos Bay. To the south are a series of rocky coves and to the west is a high shoreline cliff (ca. 16 m), a rocky point, and a spring. Occupation overlies an aquiclude. Several possible water sources were nearby, including: the Apis River to the north, the already mentioned spring near the base of the seacliff, and another spring near the modern-day Kissonerga village (DiBenedetto 2013; Knapp 2013:96; Peltenburg 2012:71; Peltenburg et al. 2003:xxxiii-xxxiv).

The Cypro-PPNB component of the site is comprised of a series of seven wells, three pits, and one semi-subterranean structure over an area of some 400 m^2. All features were cut into the havara bedrock (Croft in Peltenburg et al. 2003:3-9; Peltenburg 2012).[17] The wells will be discussed in detail in Chapter 3. The excavators have suggested that the semi-subterranean structure is a possible building. Unfortunately, the structure is poorly preserved. It was thought to have been inhabited towards the end of the site's use. There might have been a plastered floor with an associated hearth; however, no traces of a wall were found, and no building material was identified within the structure (Croft in Peltenburg et al. 2003:8-9). Due to the ambiguous nature

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[17] Three additional wells have also been discovered in the nearby locality of *Skourotos*. These wells have similar fills and upper dimensions as those from *Mylouthkia*; thus, they might also date to the Cypro-PPNB (Peltenburg et al. 2003:88). There are currently no available radiocarbon dates from these wells.

of the structure, many do not believe that it was a building (e.g., Şevketoğlu and Hanson 2015), including the present author.

The material culture recovered was found in either the wells or pits, including: over 800 pieces of chipped stone (McCartney and Gratuze in Peltenburg et al. 2003:11-34; Peltenburg 2012); over 700 pieces of ground stone (Jackson in Peltenburg et al. 2003: 35-40; Peltenburg 2012); faunal remains (Croft in Peltenburg et al. 2003:49-58; Hadjikoumis et al. 2017; Peltenburg 2012); and botanical remains (Murray in Peltenburg et al. 2003:59-72; Peltenburg 2012). For the chipped stone, the majority was manufactured from local chert. Twenty-two pieces of obsidian were also recovered, and provenance studies were conducted on eight. The compositional analyses concluded that they came from obsidian sources in the Gollü Dağ area in Cappadoccia (central Anatolia). Obsidian from *Shillourokambos* has also been sourced to this area as well (McCartney and Gratuze in Peltenburg et al. 2003:30-34, Tables 2.13-2.16b, Figure 2.1; Peltenburg 2012:73). Three possible projectile point tangs were also found in one well, and are similar to Byblos points, which are characteristic of the early PPNB in the Levant (Knapp 2013:99; Peltenburg et al. 2000:848). Projectile points are almost non-existent in the Cypro-PPNB, in contrast to the Cypro-PPNA. Thus, their occurrence at *Mylouthkia* is somewhat surprising.

For the groundstone, types typically used for food processing (e.g., mortars, pestles, and querns) were mostly absent from the assemblage. Rather, the assemblage consisted of a high number of stone vessel fragments and crude limestone hammerstones (Jackson in Peltenburg et al. 2003:40; Peltenburg 2012). The most notable groundstone find was that of a macehead, which the excavators believed was deposited near two human skulls in one of the wells. It was crafted out of a variegated fan conglomerate that was pinkish in color. Maceheads are rarely found at both mainland and Cypriot PPN sites (Jackson in Peltenburg et al. 2003:37-38, Figure 46.9, Plate 7.4; Knapp 2013:99; Peltenburg 2012:73).

The faunal remains included whole carcasses of caprines (some of which have evidence of butchering), pig, microfaunal pit-trap victims (toads, frogs, reptiles, mice, and a shrew), small quantities of deer, and thousands of limpet shells. The limpet shells are particularly interesting because at the Cypro-PPNA sites and at the other Cypro-PPNB sites, there is almost no evidence for consumption of marine resources. The excavators at *Mylouthkia* have suggested that the limpets would have been carried up from the nearby coast and consumed at the site (Croft in Peltenburg et al. 2003:50; Hadjikoumis et al. 2017). There is additional evidence for the consumption of marine resources at *Mylouthkia*, including a few crab claws (typically burnt) and several dozen fish bones scattered throughout the fills of one well. A fish hook made from pig tusk was also recovered (Croft in Peltenburg et al. 2003:50). While sea-levels would still have been about 35 m lower than today, based on local topography (i.e., the coastline is uplifted), it is believed that the coastline near *Mylouthkia* would have been in roughly the same place as today (Croft in Peltenburg et al. 2003:50).

Twelve samples of charred botanical remains were recovered from features at *Mylouthkia*, and include legumes, cereal grains and chaff (emmer wheat, einkorn wheat, hulled barley), wild/weed seeds (wild grasses), fruit and oil plants, nuts, wood charcoal, and roots/tubers (Murray in Peltenburg et al. 2003:63, Figure 7.1, Tables 7.1-7.3; Peltenburg 2012:70; Peltenburg et al. 2000:849-850). All of these taxa are commonly found at other Cypro-PPNB sites. The high ratio of glume bases and weeds to grains coupled with the low number of grains per liter imply that the samples are likely due to cereal crop cleaning. Perhaps the features were used to deliberately dump the cereal processing residues. In fact, none of the samples appear to represent primary deposits (Murray in Peltenburg et al. 2003:67).

Remains of six individuals (2 adult males, 1 adult of an indeterminate sex, 1 adolescent, 1 child, and 1 late fetal/neonatal individual) were also recovered from two of the wells (Fox et al. in Peltenburg et al. 2003:43-47, Table 5.1; Peltenburg 2012:75). Temporal bones were represented the most frequently of other skeletal elements. Several of the bones display evidence of burning post-mortem, because the edges of the bone fragments are also charred. However, none demonstrate more than minimal exposure to fire. The excavators argue that the human remains were purposefully deposited in the wells. Peltenburg et al. (2000:849) suggest that due to the higher frequency of temporal bones, that perhaps this is evidence of skull caching. While this practice is found during the Neolithic on the mainland, there is almost no evidence for it on Cyprus. However, Fox et al. (in Peltenburg et al. 2003:43) note that, "Although temporal bones appear to be represented more frequently than other skeletal elements from Neolithic *Mylouthkia*, this could be due to the relatively greater preservation afforded temporal bones than to any selective interment of this bone in secondary burial."

The excavators believe that the site was occupied year-round. According to them, the fish remains suggest summer occupation. The cereals and legumes would likely have been sown in autumn or early winter and harvested in the spring. Thus, all seasons are represented (Peltenburg 2012:75). While *Mylouthkia* is often described in the literature as representing a year-round sedentary horticultural village (e.g., Knapp 2013:102; Peltenburg 2003, 2012; Peltenburg et al. 2000:852), I am not convinced that this is the case. The economic component has been interpreted as supporting year-round occupation; however, most of the material was in trash contexts. In addition, we do not know where the agricultural fields were located. A mix of ages and sexes are also represented, but these remains also appear to be in trash contexts. There is also no evidence for habitation (i.e., structures) at the site. Compared to other Cypro-PPNB sites, there also are not a large number of animal remains or chipped stone. It is possible that a village was nearby, but currently there is little available information that supports this. Rather than a year-round agricultural village, I believe that the primary purpose of *Mylouthkia* was for Neolithic people to have access to a permanent water source, discussed in Chapter 3.

2.4.3.3 Akanthou/Tatlisu. The site is located on a fifteen-meter-high cliff, which is situated on the north-eastern coast of Cyprus on the edge of the Karpass Peninsula. On a clear day, the area where the site is located can be seen from the Anatolian coast (and vice versa). This feature provides the possibility of direct navigation. At the foot of the cliff, north of the site, there is a perennial freshwater spring, which likely provided the site's inhabitants with water. To the west is a dry riverbed, and rich and fertile soils are located to the south. The site also has easy access to several natural bays. These factors all help to explain why the site was settled during the Early Neolithic (Şevketoğlu 2002:99, 2006: 122; Şevketoğlu and Hanson 2015:226). Given the site's location in Northern Cyprus, very little has been published on it.[18] This summary is based on what Şevketoğlu has published over the last two decades (Şevketoğlu 2002; 2006; Şevketoğlu and Hanson 2015).

Based on geophysical and archaeological investigations, the site is believed to have measured 140 m by 280 m (Şevketoğlu 2006:123; Şevketoğlu and Hanson 2015:226).

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[18] The Department of Antiquities in the Republic of Cyprus forbids excavations in the Turkish-occupied north and condemns conferences and journals that present findings and research on northern sites. Few publications and researchers have been willing to risk their censure (Gannon 2017). Dr. Müge Şevketoğlu, who is Turkish-Cypriot and affiliated with Cyprus International University in Nicosia, is one of the few archaeologists who works in the north and is the excavator of Akanthou. The fact that the north represents a vacuum in terms of research on the earliest inhabitants of the island represents a major issue for Cypriot archaeology, and likely not one that will be resolved in the near future (Simmons 2017).

Excavations have revealed 5 broad phases of archaeological deposits. Due to the types of artifacts recovered and the features recorded, the phases all date to the Cypro-PPNB. Two periods of settlement are represented and are separated by an erosion/collapse phase. The erosion/collapse phase might indicate settlement abandonment or shift (Şevketoğlu and Hanson 2015:229).

One interesting feature that was recovered includes an activity area consistent with the manufacture of quicklime and tempered plaster. These materials were used to line pits and cover the walls and floors at the site. Six buildings have also been identified and are believed to have stood contemporaneously because they abut one another. The majority of the buildings were circular in shape and constructed out of stone and mudbrick. Other features were associated with these buildings, including: postholes, cut features, pits or containers that were plaster-lined, internal occupation layers, floor surfaces, and hearths. There is very little deposit build-up outside and under the buildings, leading the excavators to hypothesize that the spaces between the structures were kept clean and used as work areas (Şevketoğlu 2006:123; Şevketoğlu and Hanson 2015:229-231, 233, Figs. 5, 6, & 8).

A ditch also ran east-west across the southern edge of the excavated area. It is cut into the bedrock and is around 2 m deep and 4.5 m wide. Approximately 90 m^3 of deposits have been excavated and removed from the feature. These deposits include deliberate dumps of waste (some of which might have been from hearths or occupational contexts), which was interspersed with washed-in erosion deposits. Currently, the function of the ditch remains unknown; however, it is not the only ditch on Cyprus. There might also be a ditch at *Ais Giorkis*, and there is one at the *Tenta* (Şevketoğlu and Hanson 2015:233-235; Todd 1981:48, 1987:49-50). These ditches will be discussed in Chapter 3.

More than 4,000 pieces of obsidian – 10 times more than any other site – have been recovered. Provenance studies link the material to the Kömürcü-Kaletepe site in Cappadocia. This source has been identified as a major supplier of obsidian during the Neolithic in Anatolia and the Near East (Gannon 2017; Şevketoğlu 2002:103, Fig. 3, 2006:124-125, Figs. 9-11; Şevketoğlu and Hanson 2015: 235, Fig. 7). Şevketoğlu and Hanson (2015:235) suggest that obsidian was likely imported as bladelets, due to the fact that: 1.) there is limited evidence of cores or reduction debris; 2.) over 95% of the obsidian is in the form of bladelets; and 3.) no raw material or pre-formed cores have been recovered from any Cypro-PPNB sites. The number of obsidian pieces recovered from Akanthou is incredible given that most other Early Neolithic sites on the island have less than several hundred pieces of obsidian! Thus, it seems likely that Akanthou played some role in the obsidian exchange network on the island (Şevketoğlu 2006:125; Şevketoğlu and Hanson 2015: 235).

The chipped stone assemblage was made from local sources in the Kyrenia Mountains, and includes scrapers, blades, and possibly a few projectile points. Around 500 pieces of groundstone were recovered. The assemblage includes polished stone axes, almost complete and several fragmented querns, fragments of stone bowls, and pounding and hammer-stones. A stone that was hollowed out was also recovered from a wall partition. Interestingly, the stone contained pigment. Wall plaster fragments have been recovered with pigment on them. As a result, the excavators suggest that the hollowed stone might have been used for mixing pigment to paint. Small blocks of red ochre were also found at the site, furthering supporting that pigments were used by the site's inhabitants (Şevketoğlu 2002:103-104, 2006:125, Figs. 11-17; Şevketoğlu and Hanson 2015: 235).

Other notable artifacts include: chisels made of picrolite; stone pendants (including possibly a female figure); bone tools (fishhooks, pins, awls, and needles); incised picrolite thimbles, rings, and rounded stone tokens; shell and stone beads; pumice; and worked bone (e.g., fish hooks, needles, and awls). The pumice and picrolite are particularly interesting material. Pumice is commonly found in volcanic areas, including the region where the obsidian at the site originated from. The material can also be collected along the coast of Kormakiti in Cyprus, where it has washed on the beach from a volcanic source in the Mediterranean. Based on the size and abraded surfaces of the two pumice artifacts, they were possibly used to smooth either plaster or bone tool surfaces, or they might have been used to prepare animal skins. Picrolite does not naturally occur in this area of Cyprus. Rather, it is a stone found in the Troödos. Thus, this suggests some type of inter-island exchange system. Furthermore, Şevketoğlu notes that some of the picrolite artifacts are similar to those at *Shillourokambos*, providing additional evidence for inter-island connections (Gannon 2017; Şevketoğlu 2002:103-104; 2006:125, Figs. 18, 20-23; Şevketoğlu and Hanson 2015:235, Fig. 7).

Disarticulated human bones and bone fragments have been recovered from the ditch fills, including cranial and mandibular fragments, teeth, vertebrae, and the smaller bones of the hands and feet. Several of the skeletal elements appear to be from sub-adults. These elements are consistent with what is left after a buried body is moved or collected after the decay of soft tissues is finished. (Şevketoğlu and Hanson 2015:235-236). In addition, in the spring of 2017, a female skeleton was found face down in a ditch near a cluster of mudbrick houses. The women's arms were splayed out and Şevketoğlu argues that she might have met a violent end (Gannon 2017). Human remains have not been found under internal building floors or occupation layers, contrasting mainland sites. The lack of formal graves seems to be a theme for the Cypro-PPNB (Şevketoğlu and Hanson 2015:235-236).

The faunal assemblage from Akanthou is dominated by Mesopotamian fallow deer, followed by sheep/goat. These three species combined total nearly 80% of the mammal bones (Şevketoğlu 2002:105, 2006:125; Şevketoğlu and Hanson 2015: 236, Table 1). Pig, dog, and cattle remains also occur in relatively small quantities. Cattle are quite interesting because they are relatively rare on Cyprus during this period (Frame 2002:236-237, table 2; Knapp 2013:113-114; Şevketoğlu 2006). Evidence for marine resource exploitation was also found at the site, and included deep sea fish (tuna and shark) and small fish from coastal habitats. An almost complete marine turtle carcass was also found. These remains are particularly noteworthy because most of the other Cypro-PPNB sites (as well as the Epipaleolithic and Cypro-PPNA sites) have limited evidence for marine resource exploitation. Currently, it is unknown whether the inhabitants at Akanthou fished from the shore or actually on the open-sea. Analyses of botanical remains have not yet been completed; thus, little can be said about plant exploitation at the site (Şevketoğlu 2006:125, Fig. 24; Şevketoğlu and Hanson 2015: 236).

2.4.3.4 Shillourokambos. The site is located on the coastal plain at the convergence of two small, shallow valleys, approximately 5 km from the coast, northeast of Limassol (Vigne 2013b:118; Vigne et al. 2011b:258, 2017:11). At the site, around 10,000 m^2 has been excavated. It has been assigned four chronological phases, all of which fall within the Cypro-PPNB, based on over 50 radiocarbon dates: Early A (10,400-10,000 BP), Early B (9900-9600 BP), Middle (ca. 9500 BP), and Late phases (9500-9000 BP). It is, in fact, one of the earliest of the securely-dated Cypro-PPNB sites. Current consensus is that the site did not exceed more than 1 hectare in size. Distinct features of the Early A phase include circular dwellings defined by postholes and a few long, narrow enclosures. The latter were remodeled into curvilinear and trapezoidal enclosures, and the excavators hypothesize that they represent livestock pens or domestic activity areas.

A series of deep circular wells were also constructed and used from the earliest phase at the site through the Middle Phase (Guilaine and Briois 2006: 163; Guilaine et al. 2011:143-151; Knapp 2013:88; Vigne 2013b:118; Vigne et al. 2011b:258, 2017:11-12). During the later phases, inhabitants continued to use circular dwellings; however, they were now constructed out of *pisé* (wattle and daub) and/or stones. There are also areas of densely packed cobbles, which might represent dwelling foundations (Guilaine and Briois 2006; Guilaine et al. 2011; Knapp 2013:88; Vigne et al. 2017:11-12). Knapp (2013:88) suggests that at least one of the circular features is similar to the stone structures recovered from *Ais Giorkis*, largely due to the structure being surrounded by pebbles/cobbles.

Similar to the wells at *Mylouthkia*, it appears that when the wells at *Shillourokambos* were no longer used, they were turned into trash areas. Human remains, ground stone, chipped stone, and faunal remains have been recovered from these features (Guilaine et al. 2011:335-399; Knapp 2013:88). In regard to the human remains, one complete skeleton (male in a contracted position) and the crania of 20 other individuals have been recovered. The excavators argue that these remains were placed within pits within the abandoned wells, and thus, are the earliest-known human burials on Cyprus (Knapp 2013:88). However, I am personally skeptical of this conclusion given the trash context of these abandoned wells. There are several human remains that have been found outside of well fill contexts, which lend stronger support to their argument for the earliest-known human burials on Cyprus. One of these human burials (male) is believed to have been buried with a cat. The cat burial was 40 cm away in a small pit. The cat was only eight months old and fully intact (i.e., it did not display any signs of butchering), which suggests that it was killed intentionally for the deceased human (Knapp 2013:93-94, Fig. 19; Vigne et al. 2004:259, Fig. I). The male was interred with grave goods, including polished stones, ochre, chipped stone tools, and greenstone axes. A pit nearby was filled with 24 marine shells and may have been associated with the human burial. Given the grave goods and possible associated cat burial, it seems that this human had some type of community status (Knapp 2013:95)

Numerous pieces of ground stone were recovered, including cooking and serving vessels, pounders, querns, and rubbing stones. It is also thought that stone vessels were used alongside other types of containers which rarely preserve in the archaeological record (e.g., wooden containers, and baskets coated in lime, plaster, or bitumen). A decrease in grinding stones at the transition between the Early and Middle phases has also been documented. This perhaps suggests that plant cultivation played less of an important role in later phases of the site. Unfortunately, this hypothesis is hard to substantiate because botanical remains are not well-preserved at the site (Guilaine and Brios 2006:167; Guilaine et al. 2011:238-241; Knapp 2013:90; Manen 2017; Vigne et al. 2011b:267).

The chipped stone assemblage totals several thousand pieces. There also appear to be clear knapping activity areas, specifically over several of the wells. Thirty-nine thousand waste flakes were recovered from one well alone, and an additional 12,000 flakes came from another well (Guilaine and Brios 2006:167; Guilaine et al. 2011:238-241; Knapp 2013:90). Sickle blades are recovered primarily in the earlier phases at the site. Crescent-shaped sickles are introduced towards the middle phase, perhaps related to the harvesting of crops (Knapp 2013:90). Projectile points, similar to Byblos and Amuq points, have also been found (Knapp 2013:90).

Obsidian makes up 2% of the total assemblage with more than 500 small bladelets. Similar to the other Cypro-PPNB sites, the obsidian has been sourced to Cappadocia. The use of obsidian decreases towards the later phases, with a greater reliance being placed on locally available chert. The limited amounts of obsidian in the later phases of site occupation suggest that there was decreasing contact between the island and mainland (Guilaine and Briois 2006; Knapp 2013:90-91).

Other notable finds include a feline head carved on serpentine, an anthropomorphic lime plaster figurine with a height of 5.5 cm, an anthropomorphic phallus, a small quadruped (species unknown) statuette, grooved pebbles, miniature cups made from picrolite and serpentine, and perhaps a picrolite female micro-statuette (Guilaine 2003a:330-339, Fig. 1c-d, 2a-e; Knapp 2013:95; Vigne et al. 2004). Guilaine (2003a:330) has suggested that the cat figurine might have been a mask with feline traits or a figure that was intended to protrude from a wall, due to its roughly shaped (perhaps unfinished?) neck. The latter notion is similar to what we see on the mainland at the Anatolian Neolithic site of Çatalhöyük, only with plastered bulls' heads (Hodder 2006:157; Knapp 2013:93). The cat figurine is particularly interesting given the cat burial at the site. Both combined suggest that felines played an important role in the inhabitants' lives, but whether this role was ritual in nature and/or practical (e.g., commensal control) remains unknown (Knapp 2013:94).

Of note is the recovery of two species of domestic mouse (*Mus musculus* and *Mus Cypriacus*) remains from this site and other Early Neolithic sites on Cyprus. This line of evidence in combination with the fact that cat remains are found at almost all Early Neolithic sites on Cyprus supports the notion that they, at the very least, were used for pest control. Picrolite is not native to the area around the site. In fact, the closest source is approximately 20 km west of the site (Kouris riverbed) (Manen 2017).

Botanical remains are poorly preserved at the site (Willcox 2003:234). Much of the evidence of plant remains derives from their impression in *pisé*, including impressions of wild barley (*Hordeum spontaneum*), possibly wild wheat, and domesticated hulled barley (Colledge and Conolly 2007:57-59; Knapp 2013:92). Archaeobotanical remains have also been recovered from a single well (Knapp 2013:92.

The faunal assemblage at *Shillourokambos* is particularly interesting given the excavators' ability to document phases. This has allowed them to chronicle the different introductions of the animals, changes in their management through site occupation, and any lineage die-offs and reintroductions. Wild boar, domestic goat, domestic cattle, mice, cat (wild?), and dog are all found in the Early Phase A. There is evidence for wild boar and dog at earlier sites, but perhaps some of these other animals had been already present on the island prior to site occupation. Similar to the Cypro-PPNA sites, wild boar also dominate the assemblage during Early Phase A (Vigne 2013b:119, Figure 6.3; Vigne et al. 2011b, 2013:164, 2017:12). Mesopotamian fallow deer, sheep, possibly a new variety of domesticated pig, and foxes appear during the Early Phase B, around 10,000 B.P. Interestingly, there are very few seashells, fish, or bird at the site (Knapp 2013:92; Vigne 2013b:119, Figure 6.3; Vigne et al. 2013:164, 2017:12). The animal management strategies from this site will be discussed in detail in Chapter 3.

2.4.3.5 Prasteio. The site is located 15 km north of Paphos in the Dhiarizos River Valley. It is a multi-component site, and the excavators believe that the earliest occupation dates to the Cypro-PPNB, if not earlier. This occupation is found around a prominent rocky outcrop, which rises above the western bank of the Dhiarizos River. The site location provides views down to the mouth of the river on the coast and up to Mt. Olympus (McCarthy et al. 2010:53). Currently, there are no radiocarbon dates. Thus, there is no secure Cypro-PPNB component. McCarthy and colleagues (2010) argue for this cultural phase based on similarities in the chipped stone and ground stone assemblages from possibly contemporaneous sites on Cyprus and the mainland.

In addition, they also believe that they have found a 9,000-year-old feasting pit. The pit is 2.5 m wide by 1 m deep. It is stone-lined and covered in ash (Gannon 2015). Preliminary analyses of the faunal assemblage include pig, caprines, deer, fox, bird, fish, and the claws of freshwater crab. It is interesting that, like *Ais Giorkis*, the site is located in a river valley in the uplands (McCarthy 2010). Unfortunately, there are currently no publications to date that include detailed analyses of the hypothesized Cypro-PPNB faunal remains and chipped stone and ground stone assemblages. In combination with the lack of radiocarbon dates, it is difficult to say how this site might fit into the broader Cypro-PPNB context.

2.4.3.6 Summary. Despite there being 5 (and possibly 6 if one counts Prasteio) excavated sites that date to the Cypro-PPNB, we still have a limited understanding of the actual inhabitants' lifeways, including their movement across the landscape, connections with the mainland, and land and water management strategies.

Inter-island and mainland exchange might be attested with obsidian and picrolite during the Cypro-PPNB, both of which are discussed in Chapter 7. Interestingly, contact with the mainland seems to slow by the succeeding Khirokitia Phase, suggested by the disappearance of cattle from faunal assemblages and distinct chipped stone, amongst other lines of evidence. Curiously, cattle disappear by the Late Neolithic, roughly two thousand years after their first introduction. Only a single metapodial fragment has been recovered from the Ceramic Neolithic at Khirokitia, which is primarily an Aceramic Neolithic site that has no evidence for cattle (Davis 2003:263; Simmons 2009a:2). Several cattle bones might also have been recorded from the Ceramic Neolithic site of Philia *Drakos* A, but little information is available about the context

(Knapp 2013:171). This absence of cattle for some four thousand years, until the Early Bronze Age (Croft in Peltenburg 2003), is curious since cattle remain economically and ritually significant on both the mainlands and many of the Mediterranean islands, including Crete, from the time of their introduction onwards. Several hypotheses have been put forward to explain this disappearance including: the island could not sustain a cattle population (Simmons 2009a:6); the inhabitants were tired of maintaining such large creatures and allowed them to die-off (Davis 2003); disease (Davis 2003); and it was part of an island-wide decision to form an identity distinct from the mainland (e.g., Ronen 2000; Simmons 2009a:6). All of these hypotheses still need to be tested, but what these data demonstrate from the Epipaleolithic through the Early Neolithic is that the inhabitants of Cyprus were playing an active role in shaping the island's environment.

While contact perhaps slowed with Anatolia and the Northern Levant, McCartney (2017:56-57) argues that island-mainland interaction did not completely disappear. Rather, there was a to the Southern Levant. She argues that the appearance of engraved stones on the island parallel those in this region, which support this shift (McCartney 2007, 2017:57).

There is limited evidence for ideology on the island. The feline head from *Shillourokambos*, in combination with the possible cat burial and feline mask, represent some of the most poignant evidence to date (Simmons 2007:236). Many of the human remains were recovered from well, pit, or trash contexts. Peltenburg (2003:93) argues that intentionally burying human remains in wells, along with animals and possibly a few grave goods (macehead from *Mylouthkia*), represents an early prehistoric Cypriot custom for depositing the dead. Şevketoğlu and Vigne and colleagues arrive at similar conclusions with their human remains. However, I am not entirely convinced that there was a ritual aspect to the burials. The large quantities of material culture found in the wells at *Shillourokambos* and *Mylouthkia* support the idea that disused wells were turned into trash areas. At this time, I do not feel the evidence is compelling enough to suggest that the human remains were intentionally interred in the wells, rather than simply being thrown out. There is perhaps some evidence of skull-caching at the wells, but it is unknown whether these skulls were deposited at the same time. While skull-caching is an important phenomenon on the mainland tied to social aspects (e.g., ancestry: Kuijt and Goring-Morris 2002), the evidence is not strong enough to invoke a similar conclusion on Cyprus.

Perhaps tied to ideology, is the long-term use of circular domestic structures on Cyprus as compared to the mainland. Their use continues during the 8th-6th millennium cal BC on the island. In contrast, we see the development of multi-roomed rectangular architecture on the mainland (Byrd 1994; Flannery 1972; Peltenburg 2004b). Peltenburg (2004b) ties this difference to divergences in social organization between communities on Cyprus and the mainland. Peltenburg notes (2004b:86):

> A more egalitarian system persisted in Cyprus in spite of contacts with profoundly altered mainland societies because it functioned as a context for stability, an ideology that was regarded as essential for people who had colonized a physically separate world who relied on an intensively managed and recently ‘domesticated’ staples subsistence base and who had no native major alternative subsistence resources

Furthermore, Peltenburg argues that there was a lack of competition between groups on the island, which further explains the persistence of circular architecture. While population was likely relatively low during the Cypro-PPNB, this does not necessarily mean that there was no competition. As noted above, Müge Şevketoğlu and her team found a female skeleton who they suggest met a violent end and tie it back to disagreements over land ownership (Gannon 2017). While this conclusion is speculative, land ownership became increasingly important during the Early Neolithic. Thus, it is likely that there was some tension over land and water rights on the island. Water, in particular, was possibly a scarce resource in parts of the island, given the construction of wells at *Mylouthkia* and *Shillourokambos* (Chapter 3)

Finally, there was diverse subsistence strategies on the island, combining plant cultivation and animal husbandry (specialized practices for milk and meat) with hunting and control of animals in the wild (Knapp 2013:115; Vigne 2013b:125). There is also limited evidence for marine exploitation, particularly from Akanthou and *Mylouthkia*. Currently, it is unknown whether the inhabitants of the island fished from the shore or actually on the open-sea.

Arbuckle (2014:66) notes that there are only a handful of sites in Southwest Asia where the full suite of domesticated animals was managed together by 8,000 cal BC. Several occur on Cyprus. While the major domesticated animals are found in Cyprus, humans continue to rely more heavily on wild Mesopotamian fallow deer. A number of important plant species were also introduced: domestic einkorn, domestic emmer, and domestic hulled barley. As already noted, none of the main domestic animals (cattle, sheep, goat, and pig) as well as deer are endemic fauna. Similarly, the progenitor species of domestic einkorn and emmer have not been found in archaeobotanical assemblages. Wild barley does grow on the island, and was perhaps locally domesticated (Meikle 1985; Knapp 2013:92; Peltenburg 2000:850).

In sum, the Early Neolithic represents the first time that the island is permanently settled. Human groups likely visited the island for at least several hundred years prior to this settlement; however, they only transplanted one wild animal to the island. It appears that by the Neolithic, humans wanted to invest in a livelihood in Cyprus. They might have managed these animals and plants on the mainland, but they had never before managed them on the island. By studying some of the animal and plant management strategies for both the wild and domesticated animals and plants, we can better understand both the mixed economy in Cyprus as well as what these early settlers were doing in the Cypriot landscape.

2.5 Study Site: Kritou Marottou *Ais Giorkis*

The final Cypro-PPNB site discussed is *Ais Giorkis*, which serves as the primary study site in this dissertation (Table 2.1, Figure 2.10). It is located in western Cyprus, some 25 km northeast of the modern town of Paphos in the foothills of the Troödos Mountains. It is situated on a hill between the modern villages of Kritou Marottou and Kannaviou.

2.5.1 Present-day Environment and Climate of Western Cyprus

The present-day environment of Western Cyprus is the result of the interplay of geology, climate, and vegetation. The geology of the area includes: the foothills of the Troödos Mountains, which are underlain by an igneous complex that dates to the Miocene; the deeply divided interior plateau, which was developed from Tertiary marine limestones, gypsum, and marls; Mamonia outcrops; and the low-lying coastal plain, comprised of Holocene alluvial clays. Following the discussion from above, western Cyprus includes all three zones: the mountains (Troödos ranges); the lowlands; and the Chalk Plateaus (Christodoulou 1959:17; King 1987:8-10; Rupp et al. 1984:134-135). The climate of the region is characteristically Mediterranean, with moist winters and hot, dry summers. The amount of precipitation that falls reflects altitudinal variation: highest rainfall amounts occur at the highest elevations. There is intense summer-time soil-moisture deficiency, particularly at lower elevations. The main vegetation type is garrigue, but there is also grass-steppe vegetation. Pine forests can be found at higher elevations and the foothills of the Troödos Mountains. Rivers, streams, and springs are typically seasonal in this area. The two exceptions in the recent past were the major branches of the Ezousas and Xeropotamos rivers, which were fed by summer runoff from the Troödos.[19] However, both rivers are dammed today. Gravelly alluvia can be found in the major river valleys (Rupp et al. 1984:135-136). A number of endemic plants can be found in this region (categorized as Division 2: Meikle 1977:6). Additionally, there are aquatic plant communities near springs and rivers (Lucas 2014:11; Papastergiadou et al. 2016). Wild edible plants were an important dietary addition for rural people in the Paphos region (Della et al. 2006).

2.5.2 Environment and Climate of Ais Giorkis

Ais Giorkis is situated at ca. 480 m above sea level on an east-southeast facing slope of the upper Ezousas River Valley (Fox 1987:20). The hill, even after modern terracing, remains very steep. Keach (2014:55, Figure 16-17) measured the grade in Google Earth, which from the base of the lower terrace to the hilltop is 25.67%, or 22.2% as measured based on kriged 2013 survey points. The site commands impressive views down into the valley, and especially to a number of chert outcrops, which are easily accessible (Stewart 2006:113,). The Ezousas River is around 1.5 km from the site, and a spring is located around 300 m to the south (Simmons 1998b:2). There are also several seasonal streams near the site. Similar to the rest of the region, the climate is Mediterranean. The majority of precipitation falls during the cooler months, with almost no precipitation between June and August.

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[19] The Xeropotamos river is also known as Xeros and Asprokremmos.

The site is located on chalk bedrock; specifically, "a tongue of landslide slumped Lefkara formation" (Fox 1987:20). *Ais Giorkis* is, in fact, located in a geologically rich area, particularly from the standpoint of lithic raw material (Keach 2014:58, Figure 18). The geological zone Ku-Ou is the Lefkara Formation, which is a Paleocene to Miocene aged carbonate deposit. This deposit is formed directly above earlier volcanic deposits while the area was still underwater (Kahler 1994; Keach 2014:58). This formation is the source of both Lefkara and Moni chert (Stewart 2006:113). Immediately northeast of the site is the Upper Pillow Lava (UPL) layer, which is comprised of pillow lava. Basal group (BG) and Diabase (Db) deposits are found northwest of the site. Both of these deposits are composed of diabase, a mafic rock which was used by the inhabitants of *Ais Giorkis* as a raw material for ground stone (Keach 2014:58). Upslope of the site includes a lower white chalky/marly soft rock, locally known as *Harvara*. The *Harvara* is overlain by soil mixed with bedrock fragments (Shahack-Gross 2017).

The surrounding landscape includes Kermes oak (*Quercus coccifera*), Aleppo pine (*Pinus halepensis*), and wild olive (*Olea europaea* var. *sylvestris*) (Figure 2.11) (Held 1992:149; Simmons 1998a:234). Modern land-use in the area includes dry-farmed olives/carobs, cereal

Figure 2.11 Surrounding Landscape

agriculture, and vineyards (Held 1992:149). The phytolith record of a modern surface sample was analyzed by L. Scott Cummings (Paleo Research Institute) and comprises mostly grasses. Few bulliforms were recovered, suggesting that grasses grown in the vicinity of the site were not well-watered, and likely experienced drought stress. A number of grasses grew in the area, including possibly brome grasses and agricultural cereals, both of which are cool season grasses (Scott Cummings 2016).

2.5.3 Archaeological Excavations

Ais Giorkis was originally recorded by the Palaiopaphos Survey as a small KC hamlet, which was possibly related to pig and deer exploitation (Rupp 1987; Fox 1987). Fox (1987) also noted that the chipped stone was characterized by thin, well-made pieces, in contrast to the bulkier technology found in the KC. Limited excavations by the University of Nevada Las Vegas under the direction of Dr. Alan Simmons were first conducted in 1997. A large chipped stone assemblage was recorded, as well as a possible wall and remains of cattle (*Bos sp*.). More extensive summer seasons occurred from 2002 to 2008 with limited ground penetrating radar (GPR) conducted during the summer of 2009. The GPR results were tested during 2011, but they did not reveal much in the way of *in situ* material cultural (Simmons 1998a, 1998b, 2009a, 2009b, 2010, 2012; Simmons et al. in press). Excavations resumed in the summer of 2013 and were carried out in 2014 and 2015. I worked as a crew supervisor at the site from 2013-2015 and I participated in the 2016 study season.

The site is located on two parallel terraces that were created by modern agricultural activities. The upper terrace, however, has not been disturbed in many years. It was initially thought that the majority of the site was located on the lower terrace. As a result, there was concern that *in situ* deposits would not be located due to modern farming activities. It is now known that most of the intact material occurs in the upper terrace. Some material is found in the modern plow zone. There is also substantial *in situ* deposits, in some cases exceeding 2 m, that occur below this zone. The site is well dated by over 30 radiocarbon determinations. Based on the 15 charcoal samples, the main occupation occurred around 7,500 cal BC, with a range from 7,956-7,058, or during the mid-Cypro-PPNB. Specific phasing for the site has currently not been determined, but it has been suggested that primary occupation lasted only a few hundred years (Simmons 1998a, 1998b, 2009a, 2009b, 2010, 2012; Simmons et al. in press).[20]

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[20] I discuss the reason for only using charcoal dates in Appendix A. Four of the thirty dates—three of which are on bone – do suggest dates that there was a KC occupation. This could indicate that *Ais Giorkis* has both Cypro-PPNB and KC phases. If true, however, it is *not* reflected in the artifacts, which all indicate a Cypro-PPNB typology and technology. Thus if occupation of *Ais Giorkis* continued into the KC, it maintained an earlier technology.

Geoarchaeological investigations by Dr. Rolfe Mandel (University of Kansas) identified four stratigraphic units. These units are numbered I through IV from the surface downward. Stratum I consists of colluvium and is generally less than 50 cm thick (and sometimes only a few centimeters thick). Stratum II is of variable thickness (ca. 100-140 cm). It consists of a mixture of colluviums and artifacts that have been transported from up-slope. At the top of Stratum II, a buried soil has developed. Although artifacts in Stratum II have been re-deposited, it is unlikely that they moved a great distance. The edges of chipped stone materials are still very sharp and have not been abraded. Stratum III is also of variable thickness (ca. 50-150 cm). It consists of some colluvium with a dense concentration of *in situ* cultural materials. Stratum IV consists of *havara* (a surficial calcareous deposit), the limestone bedrock that underlies the colluviums. In general, the *havara* is culturally sterile, although some materials have been introduced to this carbonate-rich paleosol through bioturbation (Simmons 2010, 2012; Simmons et al. in press).

In addition, Mandel's analysis has helped in determining the natural slope of the site. Its overall configuration is on a gentle slope. Based primarily on the nature of several features, Simmons et al. (in press) suggest the natural hillside was at least slightly modified for occupational use. They hesitate to suggest that *Ais Giorkis* was terraced during the Neolithic, but argues that the physical configuration of *Ais Giorkis* on a hillside is similar to that of Khirokitia, although smaller in scope.

A total of ca. 500 square meters has now been systematically excavated (Feature 2.12). Site boundaries remain indistinct. However, we estimate that the site covers ca. 3200 m^2, thus we have excavated slightly over 15% (Simmons 2010, 2012; Simmons et al. in press). Excavations have revealed an incredible amount of material culture. Fifty-six features have been identified, most of which are small pits and artifact concentrations. More substantial features have also been found, including deep pits and architectural remnants. The latter, of which 6 have been documented are primarily in the form of cobbled circular “platform” structures. The structures range from ambiguous morphology, to ca. 4-6 m in length. All but one of the features are concentrated at the edge of the upper terrace. Feature 1 is located on the lower terrace (adjacent to the upper terrace). All have been damaged by post-occupational processes. Several of the structures are plastered.[21] However, true lime plaster may not have been used. Shahack-Gross’ (2008) analysis on several “plaster” samples reveals that these samples fall outside of the range of lime plaster and appear to be geogenic. This conclusion is supported by micromorphological examination showing a calcitic mass that still includes microfossils.[22] She suggests that the raw material for the preparation of the plaster surfaces might have been the *Havara* (Shahack-Gross 2017).

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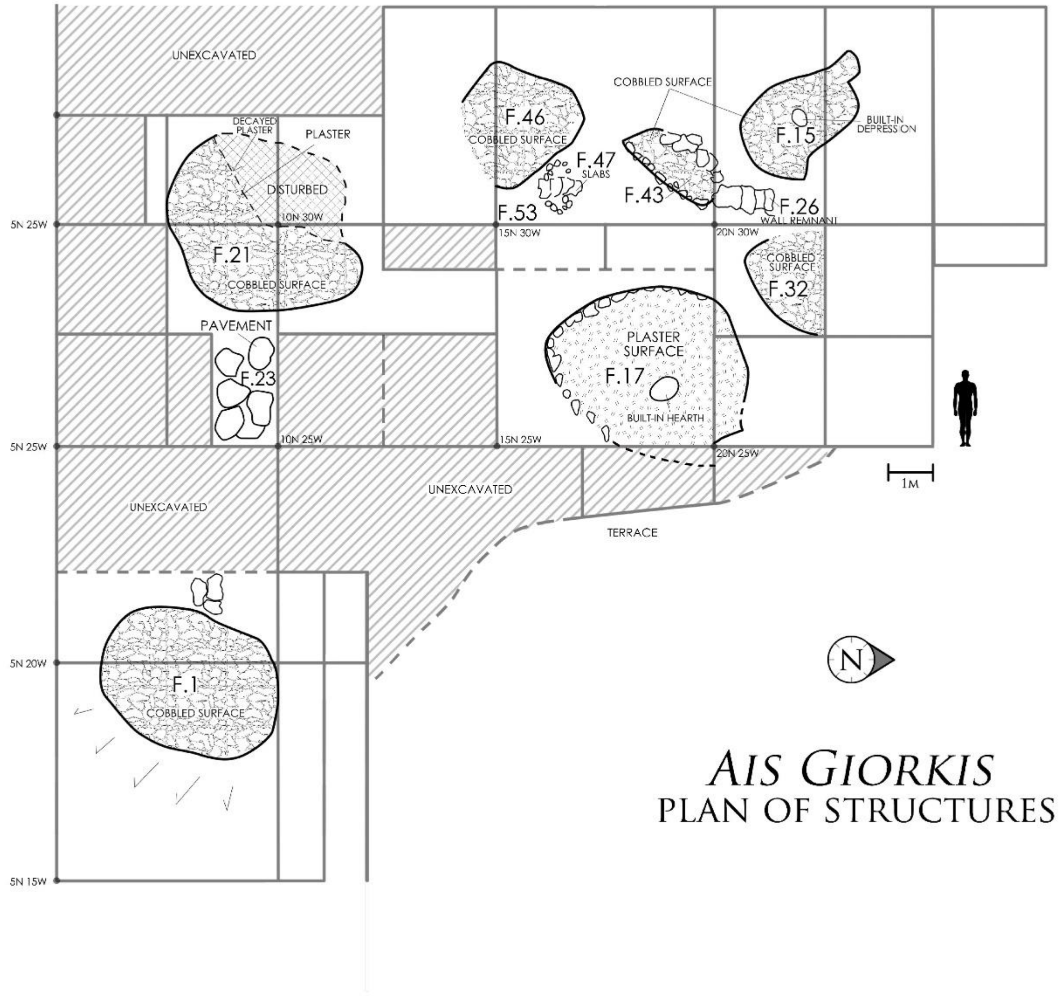
[21] It is also possible that more of the features were covered in plaster. However, it is no longer preserved.

[22] Lime plaster is produced at high temperatures, disintegrating most microfossils. It appears that crushed chalk had been used to cover the platforms. It is possible that the uppermost few centimeters were prepared by working powdered chalk, maybe with some water, into a flat surface, mimicking true plaster (Simmons 2010, 2012; Simmons et al. in press).

Figure 2.12 Plan of Structures at *Ais Giorkis* (Drawing courtesy of Russell Watters)



We sectioned Features 1 and 17 (both "platforms") to determine if there were internal features (e.g., burials, which is often the case on the mainland (Figure 2.13) (Simmons 2007), but none were revealed. However, Feature 1 did have a small cache of blades located near its base. Feature 17 also included a plastered pit incorporated near its presumed center. The pit resembled a hearth; however, there was no indication of burning. It also seems too large to be a post support. The nature and function of these structures remains unclear. It has been hypothesized that they functioned as house bases or, more speculatively, as platforms where communal activity occurred, including dancing (Garfinkel 2003; Simmons 2009b, 2010, 2012; Simmons et al. in press). As discussed above, circular structures are a defining feature of the Cypro-PPNB and continued to be used for several millennia on the island.

Figure 2.13 Feature 17

In addition to these structures, possibly a large ditch or drainage structure was found at the presumed northwestern boundary of the site. It is located upslope from the structures. This feature has not been completely excavated, although it contains some pits within its interior.

Other features include pits, the majority of which are located upslope from the platforms, near where a possible burial was located (see below). Several of the pits contained low artifact densities, and thus might be natural dips. However, there were also pits with substantial chipped stone (Simmons 2010, 2012; Simmons et al. in press). Chipped stone (including blade caches) and ground stone caches were also recovered. Most of the former primarily contained chipped stone, but one had several pieces of ochre, shell, polished stone, ground stone, and a polished axe fragment (Simmons 2010, 2012; Simmons et al. in press).

At the site, a chipped stone assemblage of nearly 300,000 pieces was recovered, based on a general sampling strategy of twenty percent. A comprehensive study of the complete assemblage up to 2004 (n=51,240) was completed (O'Horo 2008) and an analysis of additional materials was done in 2014 (Keach 2014). Keach (2014) also examined spatial distributions of the material, which demonstrated statistically significant density clustering near several features. These data suggest that the distribution of exhausted cores, debris, broken debitage, and burnt chipped stone are not anomalies of excavation, but are instead products of past human activities. These may represent formal trash middens located in or near previous structures, similar to those identified at *Mylouthkia* (Peltenburg 2003) and *Shillourokambos* (Peltenburg 2012). The chipped stone technology throughout the site is similar, with no indication of different cultural periods or phases being represented. Typical for the Cypro-PPNB sites, *Ais Giorkis* shares some mainland typological and technological parallels. These primarily are seen in the form of rudimentary Byblos-like points, finely crafted blades (Figure 2.14), a large array of tool types, and naviform and sub-naviform type cores (Simmons 2010, 2012; Simmons et al. in press). All stages of chipped stone reduction and tool production occurred on-site. This is demonstrated by: 1.) the recovery of several thousand cores; 2.) the huge amount of debris or "shatter," a byproduct of the reduction sequence); and 3.) all stages of reduction are present (Simmons 2010, 2012; Simmons et al. in press).

Figure 2.14 ***In situ*** **blade cache**

The majority of the assemblage is manufactured on locally available Lefkara basal cherts. Blocks of chert can be found within the vicinity of the site. Sixty-seven obsidian bladelets were also recovered. Several samples have been sourced by Robert Tykot to the Göllü Dağ region in central Anatolia (Simmons in 2010, 2012; Simmons et al. press). Although the number is relatively small, especially in comparison to *Shillourokambos* and Akanthou, the presence of this imported material in the uplands suggests that the inhabitants of the site were part of the obsidian exchange network (Melson 2010).

A large ground stone assemblage (over 700 pieces) has also been recovered (Figure 2.15) and is under analysis by R. Kolvet. The assemblage consists of grinding implements, including hand stones and grinding slabs, and a variety of vessels, including small "cupules," and fragments of larger vessels. The cupules are too small to be used in food preparation. As such, they may have been used for mixing either spices, pigments, or medicines. The fragments of larger vessels might have been platters or bowls. Some of the large vessel fragments were also manufactured from picrolite (Simmons 2010, 2012; Simmons et al. in press). This is unusual because most picrolite artifacts in the Cypriot Neolithic and Chalcolithic are restricted to ornaments (Peltenburg 1991). Axes and celts also occur, although they are not overly abundant. They might have been used for agricultural activities (Simmons 2010, 2012; Simmons et al. in press).

Figure 2.15 Groundstone cache

A number of other artifacts are also present and appear to have functioned primarily as ornaments. For example, several picrolite pieces have been recovered, including rings, pendants, thimble-like objects, and/or pieces with cross-hatched patterning (Jarvi 2015). In addition, an imported carnelian bead, some carved bone, and possible figurine fragments (including the bottom half of a limestone female figurine) have been found. Marine shell is abundant and is currently being analyzed by Dr. D. Reese (Simmons 2010, 2012; Simmons et al. in press).

Human remains are extremely limited, and include two interments. Within a larger pit, partial remains of a newborn were recovered within a shallow pit grave. These remains were analyzed by N. Harper. A “vaiselle blanche” vessel and a morphologically similar stone vessel were found adjacent to the burial, suggesting perhaps the vessels were associated (grave goods?) (Simmons 2010, 2012; Simmons et al. in press).

A nearly complete skeleton also was recovered from a pit that was within a larger pit. Assuming that it dates to the Cypro-PPNB, it represents one of the earliest “formal” human burials on the island. These remains are presently under detailed study by Xenia-Paula Kyriakou. There is limited evidence of substantial disturbance; thus, the burial appears to be primary. The adult, likely male, was lying in a crouched position on its right side with a head orientation facing to the west. Bone preservation is good. But there is extensive post-mortem fragmentation, likely related to taphonomic factors. Based on the position of the skeleton, Kyriakou estimates that the individual was buried with both the lower and upper limb tightly flexed into a fetal position, with the hands almost parallel to the head. The mandible also appears to be in a twisted position next to the remainder of the cranium. No clear grave goods were recovered with the male (Simmons et al. in press).

We also have well-preserved botanical and faunal assemblage. The botanical remains were analyzed by Drs. S. Colledge and L. Lucas (Lucas 2014; Lucas et al. 2012). These show a plant assemblage marked by both quantity and quality of plant taxa, including a variety of domesticated cereals and pulses, and wild taxa species. With the exception of lentils, all pulses were too poorly preserved to identify to the genus. Since wild and domesticated varieties of pulses are morphologically similar, a distinction was not made between the two (Lucas 2014:49). Cereals dominate the faunal assemblage and include *Triticum monococcum* (two-grained and one-grained einkorn wheat) and *Hordeum sativum* (hulled barley). Two-grained einkorn is the most abundant species from the sampled contexts. Pulses include cf. *Pisum* sp. (pea), *Vici* asp. or *Lens* sp. (lentil), and *Vicia*/*Lathyrus* sp. (vetch/grass pea). Two tree taxa were also identified: *Pistacia* sp. (pistachio) and *Olea* sp. (olive). Wild herbaceous taxa include *Avena* sp. (oat), *Lolium* sp. (Leguminosae), *Brassica*/*Sinapis* spp. (mustard), *Bromus* sp. (brome grass), *Bolboschoenus* cf. *glaucus* (sea clubrush), *Stipa* sp. (feather grass), *Malva* sp. (mallow), and fragments identified to Leguminosae (legume family). Mallow, brome grass, oat, and ryegrass are weeds associated with cereal cultivation. Feather grass is often associated with fallow and waste lands and is typically found on dry, rocky hillsides and pastures (Lucas 2014:49; Meikle 1985:1790-1793).

The paleobotanical materials recovered from *Ais Giorkis* are extremely significant. They represent some of the earliest directly dated domesticates found in the Near East. In addition, the combination of cereals present at the site suggest a second importation event of two-grained einkorn wheat, likely from the Syrian Middle Euphrates (Lucas 2014:49-50; Lucas et al 2012). The first importation event did not include two-grained einkorn wheat. In fact, prior to *Ais Giorkis*, there is no evidence of this plant species on the island (Lucas 2014:49).

Residue analyses from several ground stone vessels (Scott Cummings 2016) produced phytolith, pollen, and starch records. These support the use of cereals and a variety of wild plant resources (e.g., mustard, goosefoot and/or amaranth seeds, a member of the caper family, a member of the celery family, and a member of the chicory group). Several of the vessels appear to have been used for grinding domesticated cereals. Cereals were also served in several of the vessels. The recovery of mustard is interesting because it might either represent a condiment or medicinal resources. In addition, grapes or possibly wine were mixed with other foods in one of the vessels. A single *Sporormiella* dung fungal spore was also noted and could indicate the presence of grazing animals (e.g., sheep, goat, or cattle) near the site (Scott Cummings 2016). Additional phytoliths and diatoms were analyzed by Dr. R. Shahack-Gross (2008, 2017). These were from sediments and mostly originate from grasses. There is no clear indication they were domestic cereals. The presence of diatoms is possibly due to fresh water ponds in the area or diatoms excreted in human and/or animal feces. Some samples also featured high calcite content, likely the result of the chalky nature of the sediment, but possibly also due to wood ash.

The other paleoeconomic component of *Ais Giorkis* is the huge and well-preserved faunal assemblage. Analysis of this assemblage is underway by Dr. Paul Croft (Lemba Archaeological Research Institute). The amount of material examined is now approaching a ton. Roughly 66% of the assemblage has been analyzed (ca. 642 kg), with more than 33,000 pieces identified. According to numbers of identified specimens (NISP), the assemblage is dominated by Mesopotamian fallow deer, which represent over half of the bones. There are about half as many pigs as deer, followed by moderately abundant caprines. Sheep and goats appear to be fairly evenly represented. Cattle (less than 2%) and fox also occur. Cat and dog are also present, but are uncommon. Non-mammalian animal remains include small amounts of bird and fish bones. Unidentified bone includes 3.4% of fragments that appear sufficiently large or thick that they should come from cattle (Croft 2017; Simmons 2010, 2012, in press). These data demonstrate that deer hunting was a major activity at the site, as was pig husbandry. Caprines were also important. The presence of cat and dogs at the site hint at a level of permanency to the settlement. Cats could have been use to control commensals, such as rats, and cats and dogs could both have been pets.

In summary, *Ais Giorkis* is a larger and more elaborate site than previously thought. Its upland locality in the western region still remains relatively uncommon in the Early Neolithic, although recent systematic survey in upland localities is changing this narrative. As such, the site is helping us to expand our understanding of land and water management strategies in the Neolithic.

2.6 Conclusion

This chapter has summarized the climate and environment of Cyprus in order to draw correct inferences about water and land use. Unfortunately, there is a lack of data that is useful for reconstructing local and regional climates and environments on the island. As such, evidence from the surrounding Eastern Mediterranean was presented. While Early Holocene conditions are thought to generally be wetter, there is still seasonal variation. Thus, I argued that past conditions were similar enough to the present that we could consider aspects of the modern natural environment (geologic/topography, modern climate, and flora and fauna) layered onto one another to recreate the ancient environment. Specifically, the island was still likely semi-arid. I also provided a discussion of the wider pre-Neolithic and Early Neolithic context. This was done to demonstrate that humans have been interacting with the island’s landscape for several thousand years prior to the Cypro-PPNB. I then provided the chronological framework for this dissertation. There are not many excavated sites. However, survey research suggests that there are additional sites that date to the Late Epipaleolithic through Cypro-PPNB. Thus, Cyprus was not totally barren landscape. Finally, the chapter concluded with a discussion of the study site, *Ais Giorkis*.

Ais Giorkis is uniquely located in the uplands for this time period. Site function currently remains unknown. The substantial architecture, the abundance of chipped stone and ground stone, the large and diverse faunal and botanical assemblages, and the presence of exotic artifacts suggests that the site was inhabited for at least a portion of the year.

In addition, feasting activities may have taken place at the site, as evidenced by the constellation of economic resources, exotic artifacts, and large ground stone vessels (Simmons 2012:13). Twiss (2008) cites a number of characteristics of feasting that can be documented in the archaeological record. At *Ais Giorkis*, Simmons (2012:13) argues there is evidence for: the consumption of rarely eaten or symbolic food (possibly cattle), the consumption of large and diverse quantities of food and drink, the consumption of domestic animals and of large animals (cattle and deer), use of special locations (possibly the upland nature of the site), displays of status and wealth and commemorative objects (picrolite, obsidian, and other unique artifacts), use of special serving paraphernalia (elaborate and large ground stone vessels, including ones made of picrolite), and public/ritual performance (perhaps the circular platform features).

Many of the materials at the site also suggest that the inhabitants were engaged in exchange networks; thus, the site was not an isolated community. As such, it might have functioned as a communal gathering, which included the exchange of goods and information, for a number of settlements (perhaps both coastal and upland). Even more speculatively, the site may have served as an elite “resort” (Simmons 2012:13; Simmons and Najjar 2007). The site was located in the uplands, which would have been cooler in the summer than coastal sites. Inhabitants might have moved seasonally to the site to escape the heat as well as to access key resources, including pasture and agriculture land, which is largely the interest of this study. Overall, the presented evidence reinforces the importance of understanding how these Early Neolithic peoples managed their landscape.

CHAPTER 3: ARCHAEOLOGICAL EVIDENCE FOR LAND AND WATER MANAGEMENT STRATEGIES ON CYPRUS

3.1 Introduction

This chapter provides a synthesis of the archaeological evidence of land and water management strategies, primarily during the Cypro-PPNB, in order to place the study in context. These strategies allow us to better understand land use and movement across the landscape by the island's inhabitants. Prior to addressing this issue, I briefly discuss animal biology, particularly for domestic sheep, goat, cattle, and pig, and wild deer and boar, because the basic biology of these animals in some ways constrains human management decisions. The chapter concludes with a discussion of what I think the *Ais Giorkis* inhabitants were doing in the landscape, which is then tested in Chapters 5 and 6.

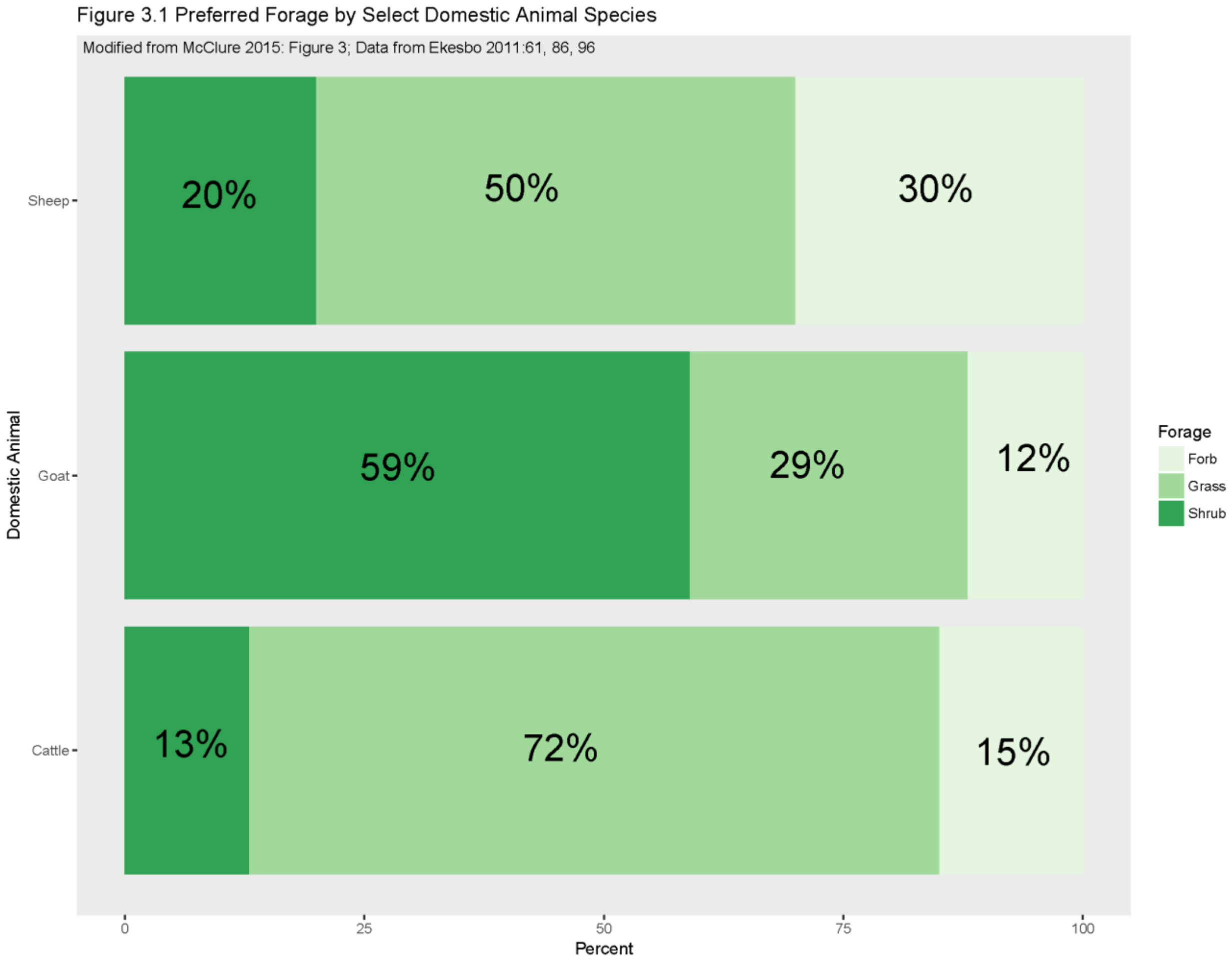
3.2 Animal Biology

Before addressing the archaeological evidence for water and land management strategies, it is important to first discuss the basic biology of the domesticated (sheep, goat, cattle, and pig) and wild (deer and boar) animals of interest in this study. All animals create niches through their basic foraging biology (McClure 2015). Human management decisions also influence the animals' niche constructions. As such, understanding animal biology, which includes foraging biology, enables testable models to be built about possible animal management strategies during the Cypro-PPNB, and what we can infer about land and water management strategies.

3.2.1 Sheep, Goat, and Cattle Biology

Ruminants (cattle, sheep, goat, and deer) are divided into morphological feeding types: 1) grazers (grass-eaters), and 2) browsers (McClure 2015). Sheep and cattle are predominantly grazers, or grass-eaters. During the dry season, when the grass becomes too dry, sheep will also sometimes browse on leaves of dicotyledenous plants (e.g., forbs, bushes, herbs, and trees). Goats, in contrast, are primarily browsers (Figure 3.1). At the beginning of the wet season, they will also consume grass when it is tender and short (Balasse and Ambrose 2005; Ekesbo 2011; McClure 2015:Table 1; Redding 1981:72-75). Cattle require more forage and surface water than sheep and goats (Markwick 2007: Table 2; McClure 2015: Table 2; Miller and Marston 2012:99). Studies have also documented differences in sheep and goat water in-take. Specifically, goats are believed to have a lower water in-take than sheep, making them better adapted to withstand dehydration under dry climatic conditions (Al-Ramamneh et al. 2010).

Figure 3.1 Preferred forage by select domestic animal species



In hot weather all three animals will use more water than in cooler weather for evaporative cooling. In normal conditions (no drought) with good quality water, water consumption in the summer will be around 40% higher than in winter. However, if the water is of marginal quality, the summer intake can be 50-80% greater than in cooler months (Marwick 2007:2). Diet (i.e., green pasture vs. dry pasture) will also influence the amount of water these animals utilize. Green pasture can supply almost all an animal's water needs. In fact, under these conditions, sheep may not need to drink for weeks (Marwick 2007:2). In pastoral areas, sheep and goats normally graze within a radius of about 2.5 km around a water point. Cattle will graze within a radius of 5 km (Marwick 2007:3).

Sheep and goats are relatively tolerant to temperature changes. According to Louca (1981:413):

> The predominant breeds in Cyprus were the local Cyprus Fat-tailed sheep and local goats. In the climatic conditions and extensive farming systems of Cyprus, their milk yields were low and growth rate of their lambs and kids rather poor. They were, however, remarkably hardy animals, capable of enduring extremely unfavorable environmental conditions.

Sheep and goat do have lethal cold and hot temperature tolerance limits, which are dependent on the wind chill, whether animals are shorn, and whether they are wet or dry. In addition, temperature can impact milk production. Sheep and goats can moderate their core temperature through shivering, sweating, and panting (Alexander 1974; Ekesbo 2011; Finocchiaro et al. 2005; Marai et al. 2007; Silanikove 2000). A sheep's fleece can also act as an insulator against external heat. The body temperatures of sheep can also be regulated in response to climatic fluctuations through shearing (Alexander 1974).

While there are species of cattle that are more tolerant of hotter temperatures (e.g., *Bos indicus* and *Bos indicus*-infused breeds), *Bos taurus* is not one (Ekesbo 2011:70; Marwick 2007:3). Similar to sheep and goat, cattle regulate their body temperatures via panting and sweating. At temperatures above 26°C, this breed of cattle will go into heat stress, which results in decreases in food consumption and milk production (Ekesbo 2011:69).

Temperature is also a relevant factor for birth seasonality, which is a key element of pastoralist subsistence economies (Balasse et al. 2003:205). Heat stress and water deprivation are particularly serious in pregnant and lactating ruminants (Ekesbo 2011; Silanikove 2000). On present evidence we do not know the exact season(s) when sheep, goat, and cattle gave birth for the Cypro-PPNB. Studies have demonstrated that the seasonal cycle of day length (photoperiod), which does not vary from year to year, is the most reliable environmental factor to set lambing at the optimal time of year (Balasse and Tresset 2007:73; Balasse et al. 2003:206; Hafez 1952; Karsh et al. 1984; Legan et al. 1977). The neuro-endocrine mechanisms are regulated by seasonal cycle of day length. In turn, these mechanisms underlie the reproductive cycle, setting both the timing and duration of the breeding seasons (Balasse et al. 2003:206; Karsh et al. 1984).

In seasonably arid climates, like Cyprus, mating traditionally occurs for sheep between June and September. Gestation lasts around 5 months (between 142-152 days), putting lambing between November and February. This provides ewes with the opportunity to recover body weight after the winter and before another pregnancy (Leon 2016:221; Redding 1981:85-90). Sheep give birth in the spring at modern-day Çatalhöyük, where traditional management practices still occur. But they are physiologically capable of autumn births, and both wild and domestic sheep occasionally still do give birth during this season (Henton et al. 2010:445).

In contrast to sheep, cattle and goats are less seasonal breeders (Balasse et al. 2003:206; Dahl and Hjort 1976; Goodman and Karsch 1991; Redding 1981:90-92). Cows do not experience seasonal anestrus, meaning they can breed throughout the year. However, their fertility does vary, and is tied to nutritional level (Balasse and Tresset 2007:74; Balasse et al. 2003:206; Ezanno et al. 2005). Primitive breeds that are kept outdoors in extensive conditions where there is no control of breeding, tend to give birth seasonally, at the time of year with greatest food availability (Balasse and Tresset 2007:74; Balasse et al. 2003:206). Traditional subsistence pastoralists in East Africa schedule cattle births during the wet season, because calves born during this season have a higher survival rate than those born during the dry season when milk yields decline (Dyson-Hudson and Dyson-Hudson 1969).

Goats are prolific breeders. Similar to cattle in the Mediterranean, however, the primary factor that influence reproductive efficiency is related to nutritional conditions (Alifakiotis 1992:165). Newborn lambs, kids, and calves are also sensitive to temperature (Alexander 1974; Alexander et al. 1973; Marai et al. 2007; Nardone et al. 2006). Thus, heat stress clearly has negative effects on metabolism, dairy yield, biological processes, and reproduction (Leon 2016:221).

3.2.2 Mesopotamian Fallow Deer Biology

The extant wild population of Mesopotamian fallow deer (*Dama dama mesopotamica*) was rediscovered in the 1960s in a small area of Khuzistan, an Iranian province (Chapman and Chapman 1980; Werner et al. 2015). Today, the population has grown because of conservation programs, and the reintroduction of this species into the wild in several protected areas in Israel and Iran. However, they are currently listed as endangered by the International Union for Conservation of Nature (e.g., Bar-David et al. 2005a, 2005b; Werner et al. 2015, and citations therein). This population is the relict of a significantly larger Early Holocene distribution area that spread from Southern Anatolia to the Levant and from the western Iranian plateau to the Mediterranean (Ekesbo 2011:255; Vigne et al. 2016:853). While these deer were hunted all over this distribution area, Cyprus was one of the rare places, if not sole place, where this species played a major role in human subsistence. This role lasted for over 4,000 years, from the Pre-Pottery Neolithic to the Bronze Age (Croft 1991; Davis 1994; Vigne et al. 2016; Werner et al. 2015).

Due to the rarity of the Mesopotamian fallow deer and the fact that they have been reintroduced into most areas where they are currently found, there are still limited data on their behavior, social structure, and habitat use (Chapman and Chapman 1980; Bar-David et al. 2005a, 2005b; Perelberg et al. 2003:486). As a result, study findings on the reintroduced deer are often compared with other deer species (Perelberg et al. 2003:486). Fallow deer are generalist feeders. They can adapt to a wide variety of ecological niches, with the exception of high mountains. Their preferred habitat is park-like landscape with small woodlands. They may browse forest plants as they move out to grass, and if they are hungry they will also eat leaves that have fallen from the forest canopy (Bonafini et al. 2013; Croft 1991:66; Ekesbo 2011:156). They are also resistant to cold and relatively hardy animals (Ekesbo 2011:156).

Mating traditionally occurs between August and early September. Gestation lasts around 229 days, putting fawning at the end of March to early April (Chapman and Chapman 1975; Werner et al. 2015). In reintroduced populations, fawning season has been documented slightly later, occurring between April and July, with peaks in May (Bar-David et al. 2005b:135). Fallow deer, during the autumn, are relatively ungrouped compared with the rest of the year, when they can form large groups ranging between 12 and 150 individuals. Typically group size is dependent on the availability of their preferred habitat. In winter and spring, mixed-sex groups include females that are joined by young males (Frankel et al. 2013:108).

Home range size and shape are variable (Bar-David et al. 2005a:1843). Perelberg et al. (2003) studied seasonal and circadian attributes of Mesopotamian fallow deer home ranges in northern Israel, mainly to assess the success of their reintroduction in terms of behavioral adjustments to the wild. In a Mediterranean climate, the home ranges of large herbivores are expected to be greatest in mid-summer to autumn, when resources are more limited and when the rut takes place. The study conducted by Perelberg et al. (2003) supported this expected behavior. They found that seasonality in male and female home ranges is tied to the annual reproduction cycle and seasonal food availability. In general, however, annual home ranges for females and males are 2.1 km^2 and 9.75 km^2, respectively (Ekesbo 2011:156).

3.2.3 Wild Boar and Domestic Pig Biology

Wild boars and domestic pigs are omnivores, and thus, able to digest a wide variety of foods. In the zooarchaeological record, pigs are the most difficult major domestic animal to identify as wild or domestic (Balasse et al. 2016; Rowley-Conwy et al. 2012). Wild boar forage for food at night and can cover long distances. Their diet consists of wild foods and cultivars, including beechnuts, grapes, figs, almonds, hazelnuts, and sweet chestnuts. When these resources are not available, they will also consume tubers, grass, root crops, and berries. Around 5-10% of their diet is composed of animals, such as rodents, frogs, fish, shellfish, snakes, insect larvae, and snails (Frémondeau et al. 2012:2025). There is significant size variation amongst wild boar, which has been attributed to climate. Wild boars in colder climates are typically larger than those in warmer climates (Davis 1981: Figure 3, 1987: Figure 3.10; Rowley-Conwy et al. 2012:6-8). Wild boar are encountered from coastal regions to high mountains throughout the Mediterranean. However, they preferentially live in areas under dense canopy and where there is abundant or favored food. On Corsica, wild boar will move up to the subalpine level during the warm seasons, where they will live under tree cover. During the cooler months, particularly when there is snow, they will move back down.

Wild boar mating traditionally occurs between early October to early January and is dependent on food availability. Their preferred food is acorns. Farrowing (i.e. birthing) peaks from late February to mid-March, but can occur from late January to late April. Wild boars typically give birth to three to twelve piglets (Albarella et al. 2011). They also have a higher natural juvenile mortality rate, as compared with other large mammals. Weaning ends in summer. During the summer, groups comprise 2-3 females and their offspring. The females together defend them. Adult males join the females during the autumn (i.e., the mating season). When this occurs, the young males are driven away. They will rejoin the females for a time, but leave in spring when the birth season approaches. Female offspring typically stay longer with their mothers. At 2-4 years of age, males suffer higher mortality rates than females, likely because of separation from their mothers (Rowley-Conwy et al. 2012:25-26, citations therein).

Based on ethnographic studies from Mediterranean islands (e.g., Albarello et al. 2007, 2011; Halstead and Isaakidou 2011; Hadjikoumis 2012), it is common for wild boar to mate with domestic pigs. The hybrids are occasionally kept. However, it is more common to slaughter them early, particularly the males, because they grow slowly and do not grow large enough to produce sufficient meat.

Similar to wild boar, domesticated pigs, when kept in large areas, prefer alternating between wooded and open grounds (Ekesbo 2011:17). Domesticated pigs are also susceptible to lack of water. Their water requirements vary depending on age and weight. At 20°C, pigs weighing between 21-46 kg require around 0.121 water per kg body weight. At higher weights (52-66kg), the amount of water per kg body weight decreases to 0.091. Of note, when temperatures reach 30°C, water requirements for pigs will increase up to 70% (Ekesbo 2011:27). High temperatures, in general, are problematic for pigs, because they cannot cool their skin through transpiration. Because of this, pigs seek places to cool down in water or mud baths (Ekesbo 2011:29-30).

Domestic pigs can eat almost anything. Thus, they are found at all steps of the food web, from strictly herbivore to nearly carnivore (Albarella et al. 2006; Balasse et al. 2016;

Frémondeau et al. 2012). Frémondeau et al. (2012:2024) suggest this foraging behavior partly explains their success as a domestic animal. Depending on food availability, both wild and domestic pigs may farrow once or twice a year, although throughout the year, female pigs are apparently in estrus (Frémondeau et al. 2012:2024). The size of the litter is based on the overall health and nutritional level of the sow. Litter size varies, typically between 5 and 12 piglets (Albarella et al. 2011). This plasticity in dietary and reproductive behaviors was likely exploited by pastoral and agricultural groups. Unfortunately, it has been difficult to assess in the archaeological record (but see Balasse et al. 2016; Frémondeau et al. 2012).

3.2.4 Summary

This section detailed animal biology, and particularly those aspects of foraging biology that would be most relevant for human management decisions. Nutrition (i.e., foraging and water requirements), climate, and temperature all play a role as constraints for base biological parameters in animals. However, these constraints are not absolute limitations when humans are involved. By understanding both animal biology and the landscape that people interacted with, we can better understand the management strategies that were used to mitigate the effects of these biological and physical variables. For example, management strategies might make use of spatial variation in the availability of water and pasture, avoid disease vectors, and/or provide fodder to animals during seasons when there was limited food available (McClure 2015). Next, we turn to the archaeological record to see what evidence there is of land management strategies during the Cypro-PPNB.

3.3 Archaeological Evidence for Land Use

The nature and scale of land use are of interest because of their relevance for the movement of livestock, the proximity of livestock to agricultural fields, the location of cultivation, the short-term economic viability and long-term economic stability of the Neolithic communities, and the potential social and political implications of competition over land. These aspects all shape the cultural landscape where lives were lived (Bogaard et. al 2014:861; David and Thomas 2008:38; Halstead 2017). To date, there are very few publications that examine the nature of Cypro-PPNB land management strategies. Thus, the purpose of this section is to discuss the archaeological evidence for animal and plant management strategies and what they can tell us about land use by the Early Neolithic inhabitants (Table 3.1).

Table 3.1 Major Animal and Plant Species of Early Neolithic Cyprus

Species	**Common English Name**
Capra hircus	Domestic Goat
Ovis aries	Domestic Sheep
Bos taurus	Domestic taurine cattle
Dama dama mesopotamica	Mesopotamian fallow deer
Sus scrofa domesticus	Domestic pig
Triticum dicoccum	Emmer wheat
Triticum monococcum	Einkorn wheat
Hordeum sativum	Hulled barley
Pisum sativum	Pea
Lens culinaris	Lentil
Vicia ervilia	Bitter vetch
Olea europaea	Olive
Pistacia sp.	Pistachio
Lolium sp.	Ryegrass
Avena sp.	Oat
Bolboschoenus cf. *glaucus*	Sea clubrush
Brassica/Sinapis sp.	Mustard
Stipa sp.	Feather grass
Bromus sp.	Brome grass
Malva sp.	Mallow

Note: Plant data from Lucas (2014)

3.3.1 Animal Management Practices

Zooarchaeological (and botanical) remains offer some of the best evidence for past farming and herding practices (Marston 2011:195). Animal bones can be used to produce relative frequencies of types of food consumed by inhabitants at and between sites. The ratio of certain animals to one another can also provide evidence of risk tolerance in herding practices. This is particularly the case with sheep and goats to cattle. As noted above, in comparison to sheep and goat, cattle require more food and water and are more difficult to keep alive during drought periods. A high ratio of sheep and goats to cattle from site assemblages has been interpreted as a more risk-sensitive herding strategy, particularly in semi-arid regions. Evidence for transhumance or mobility might also be illuminated through faunal remains at sites. Culling patterns of animals can reveal if an animal was domesticated or wild. In addition, they can tell us what an animal was utilized for (e.g., meat, milk, and secondary products) (Marston 2011:195-196). Given the wealth of information encoded in animal remains, the archaeological evidence for animal management practices during the Cypro-PPNB focuses on caprine, cattle, pig, and deer, and the limited evidence for livestock pens.

3.3.1.1 Caprine Management Strategies. Currently, the best evidence we have of animal management strategies comes from *Shillourokambos* (Chapter 2). The analyses at Akanthou and *Ais Giorkis* are ongoing. Goats were introduced to the island around the middle of the 11th millennium B.P. in the form of early domesticates. The morphology of the goats (*Capra hircus*) during the earliest phases of occupation imply domestication as they are smaller than wild bezoar goats (*Capra aegagrus*) on the mainland. During the Early B and C phases (and likely Early A), there were no morphological modifications of goat morphotypes, which is in contrast to some sites on the mainland. Specifically, the size of both male and female goats did not decrease until the later phases of site occupation (Vigne 2013b:121, Figure 6.5; Vigne et al. 2011, 2017:13, Fig. 2.1-2.2). Sheep and goat husbandry dominate during the later phases as well (Hadjikoumis et al. forthcoming).

The culling profiles based on tooth eruption and wear demonstrate important changes in the acquisition strategy of goats throughout the site's occupation. During the earlier phases, the weak structure and dominance of adults and old individuals, coupled with the well-balanced sex ratio, implies hunting rather than herding (Vigne 2013b:122; Vigne et al. 2011, 2017:13, Fig. 2.3). This suggests that the introduced goat was released into the wild (feralization) and then exploited via hunting (Vigne et al. 2017:15). The culling profile of the middle phases is much more selective. It is dominated by sub-adults, and particularly sub-adult females. In contrast to the earlier phases, these flocks were likely herded and managed for their meat (Vigne 2013b:123; Vigne et al. 2011, 2017:13, 15). The end of site occupation has a high proportion of adult females, perhaps suggesting specialized milk exploitation or other ante-mortem products (e.g., fibers, prestige, or dung for agriculture) (Vigne 2013b:123; Vigne and Helmer 2007; Vigne et al. 2011, 2017:13). In addition, there is a new type of horn core introduced and the goats are much smaller in size. Vigne and colleagues (Vigne 2013b:123; Vigne et al. 2011, 2017:15) interpret these modifications as a consequence of the intensification of control. They go one step further and suggest that the feralized goats were re-domesticated.

The morphology of the sheep (*Ovis aries*) during the earliest phases of occupation implies domestication. Horn cores were much reduced in size as compared to their wild counterpart (*Ovis orientalis*). The sheep were also slightly smaller or the same size as early and middle PPNB sheep from mainland sites, further supporting their domestic status (Vigne 2013b:119-120, Figure 6.4; Vigne et al. 2011, 2017:15-16). Between Early B and Middle A phases, the sheep significantly decreased in size. However, during the transition between the two sub-phases of the Middle A phase, the sheep were replaced by significantly larger ones. The morphology of the horn cores also changed with these large sheep. These changes remain consistent for the rest of the site occupation and have led the excavators to argue that a new type of sheep was introduced from the mainland. This implies that there is still contact between the inhabitants of Cyprus and the mainland. However, they do also note that the sheep may have come from another part of Cyprus (Vigne 2009; 2013b:121, Figure 6.4; Vigne et al. 2011, 2017:16, Fig. 2.4-2.7).

The sheep culling profiles based on tooth eruption and wear demonstrate important changes in management systems. During the early phases, there is evidence for milk and meat exploitation (Vigne and Helmer 2007; Vigne et al. 2011, 2017:16, Fig. 2.8). During the middle phase, there is selective slaughtering of sub-adult males. Females seemed to have been kept alive until old age. This profile corresponds to specialized meat exploitation with females perhaps being used for their hair, dung, or reproduction (Vigne 2013b:121; Vigne et al. 2011, 2017:19, Fig. 2.8). The transition between the middle and late phases is marked by another change in the management system. Specifically, there is an increased proportion of older animals. The inhabitants might have been exploiting both meat and other ante-mortem products (i.e., hair) (Vigne 2013b:121; Vigne et al. 2017:19).

In sum, the sheep and goat from *Shillourokambos* tell an interesting story. Domesticated sheep were introduced to the site later than domesticated goats. However, they were herded throughout the entirety of site occupation. Local sheep lineages also appear to have been replaced several times. In contrast, goats (feral?) appear to have initially been hunted, and then herded. Furthermore, Vigne and colleagues argue that the feral goats were re-domesticated (rather than a new lineage being introduced). They conclude that, "The only common point with goats is that the strategies of exploitation of sheep have changed several times during the 10th millennium BP: illustrating the relative instability of the status of the system of exploitation of the early Neolithic times" (Vigne et al. 2017:20).

While most of the other Cypro-PPNB sites do not have the level of detail for changes in caprine management strategies over time, sheep and goat remains are present at all Cypro-PPNB sites. At *Ais Giorkis*, it appears that all body parts are at least reasonably well represented. There is at least some slaughter of infant caprines. Goats were slaughtered in roughly equal proportions at the juvenile (~44%) and sub-adult (~45%) stage. For sheep, there is emphasis on the slaughter of juveniles (35%), but the majority survived into adulthood (50%). Thus, it appears that the majority of the sheep and goat at the site were domesticated (personal communication Dr. Paul Croft). In addition, at Akanthou the sheep and goat are mostly juvenile. Thus, they were culled just when they were attaining full size, another indicator of domestic herd assemblages (Şevketoğlu and Hanson 2015:236).

Of interest, anatomical representations at four of the five excavated Cypro-PPNB sites confirmed that entire caprine carcasses were processed at all sites (Hadjikoumis et al. 2017).[23] This result suggests that primarily domestic herds of sheep and goat were exploited at each site, rather than feral or wild populations (although this somewhat contrasts the zooarchaeological data from the early phases at *Shillourokambos*). If hunting had been practiced, then certain

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[23] Hadjikoumis et al (2017) examined butchery marks on six Pre-Pottery Neolithic sheep and goat assemblages in Cyprus. Four sites are from the Cypro-PPNB: Kritou Marottou *Ais Giorkis*, Parekklisha *Shillourokambos*, Kissonerga *Mylouthkia*, and Kalavassos *Tenta*. Akanthou was not included in their study. The other two sites date to the Khirokitia Culture: Khirokitia *Vouni* and Kholetria *Ortos*. Butchery marks can provide insights into a number of aspects of human behavior in the past, including how the carcasses of different age cohorts and animal species were processed, culinary preferences and possible taboos, and cultural affinities (Hadjikoumis et al. 2017:199-200).

anatomical elements, particularly the non-meaty elements, would likely have been absent from the sites.

It is not until the succeeding period, the Khirokitia Culture, that there appears to be increased stress on domestic resources. Specifically, there is an intensification in carcass processing. At Khirokitia there is a high occurrence of dismembering marks on the caprine carcasses. Hadjikoumis et al. (2017) interpret this as an effort to divide the carcass into smaller parcels while the carcass was still fresh. The butchery mark types from *Tenta* appear to be similar to those at Khirokitia. Caution must be given to this interpretation, however, since the assemblage is relatively small and poorly preserved (Hadjikoumis et al. 2017).

There is also a high occurrence of butchery marks at *Shillourokambos*. Both *Shillourokambos* (8th millennium cal. B.C.) and Khirokitia are larger settlements compared to the other sites that date to similar time periods, leading Hadjikoumis et al. (2017:209) to suggest that intensive exploitation of caprine carcasses might have been an inherent characteristic of larger PPN villages. In addition, both sites are located near the coast, leading to the tentative conclusion that there might be geographical patterns in butchery marks as well (the two upland sites—*Ais Giorkis* and *Ortos*—both have fewer butchery marks) (Hadjikoumis et al. 2017:206).

In contrast to Khirokitia, however, butchery marks at *Shillourokambos* (and *Ais Giorkis*) had higher percussion marks and lower dismembering marks. At Khirokitia, the high dismembering marks in combination with archaeological evidence (e.g., increased segregation of household units and higher frequency of hearths within the household units) perhaps can be viewed as increased social segregation during the Late Pre-Pottery Neolithic (Hadjikoumis et al. 2017). In particular, Halstead (2004:153) suggests that these different lines of evidence point towards consumption of smaller parcels of meat at the household or neighborhood level, rather than the communal level. Perhaps, then, meat consumption during the Cypro-PPNB was at the communal level (Hadjikoumis et al. 2017).

3.3.1.2 Cattle Management Strategies. Small amounts of cattle are present at three Cypro-PPNB sites, excluding *Tenta* and *Mylouthkia*. Domestic cattle (*Bos taurus*) were introduced to Cyprus around 10,300 cal B.P. (Vigne et al. 2011), which is around the time they first began to appear on the mainland (Helmer et al. 2005; Hongo et al. 2009). The wild progenitor, *Bos primigenius*, is not endemic to the island. At *Shillourokambos*, cattle bones are rare in the earliest phase (Early A). They become more abundant (around 10% of the faunal assemblage) in the succeeding phase (Early B). However, they decrease in number during the Middle phase and are not found in the final phase. Vigne and colleagues suggest cattle became extinct from the site (and possibly the island) between 9,000 and 8,500 cal B.P. (Croft in Peltenburg 2003:49; Vigne et al. 2011:164). Furthermore, based on changes in morphology, Vigne (2013:123) believes that there was another lineage of cattle brought to Cyprus, which is better documented at *Ais Giorkis*. These newly introduced cattle were larger than those originally brought to the island.

Cattle are found at *Ais Giorkis* (around 2% of the faunal assemblage). This evidence implies that cattle management persisted in some areas for several centuries and even up to a millennium after their disappearance from *Shillourokambos* (Simmons et al. in press; Vigne et al. 2011). This has led Croft to propose, “It was in the west of the island that the cowboys of Aceramic Neolithic Cyprus apparently clung most tenaciously to the tradition of bovine husbandry” (Croft in Peltenburg 2003:50). Nearly all skeletal elements are found at both *Shillourokambos* and *Ais Giorkis*, including limb extremities and vertebrae, which suggests that the animals were killed in or very near the settlements (Simmons 2010:10, 2012:97; Vigne et al.

2011:262). The mortality profile of cattle at *Ais Giorkis* is difficult to interpret because the sample size is incredibly small. However, there does seem to be at least some slaughter of infant cattle and there is considerable emphasis on the slaughter of juveniles, although the majority of cattle appear to have survived into adulthood (personal communication Dr. Paul Croft). Very little has been published on the cattle remains from Akanthou, although preliminary analyses suggest they represent around 2-3% of the total faunal assemblage (Frame 2002; Şevketoğlu and Hanson 2015).

The low percentage of cattle representation at the Cypro-PPNB sites is consistent with mainland evidence. On average, cattle constitute between 1% and 5% total Number of Identified Specimens (NISP) in faunal assemblages dating to the earliest Neolithic (11th and 10th millennium cal. B.P.). It is not until the 9th millennium cal B.P. that cattle remains significantly increase in number, which corresponds to the later part of the Aceramic Neolithic through the Pottery Neolithic. This increase is largely driven by the increase in use of domestic cattle in Anatolia and southeast Europe (Conolly et al. 2012:999, Figure 2), although there is still regional variation in the exploitation of domestic animals (Conolly et al. 2011). For example, up until the late-9th millennium cal. B.P., the arid southern Levant shows, on average, low levels (less than 1%) of domestic taxa. This number increases to more than 10% by the early PN (Conolly et al. 2011:543).

Based on species distribution models, Conolly et al. (2012) found that regional variation in domestic cattle exploitation were related to environmental factors. Particularly important factors were temperature and annual precipitation. Regions where cattle are expected to occur in high probabilities include areas that are characterized by higher annual rainfall with an interquartile range of 450 to 600 mm/yr, but up to 800 mm/yr. Maximum temperatures should be around 32°C (Conolly et al. 2012). Interestingly, data from Cyprus represent outliers in their models. Specifically, they predicted that cattle should be around 10% of faunal assemblages in coastal regions (Conolly et al. 2012), which is not the case based on current archaeological evidence. However, cattle are also not endemic to the island, perhaps explaining the discrepancies with the model. Data from *Shillourokambos* and *Ais Giorkis* indicate that the original cattle lineage may have died off and another lineage may have been introduced (before it also died off). Thus, it appears that the island's inhabitants had trouble keeping cattle alive.

3.3.1.3 Deer Management Strategies. The considerable reliance on Mesopotamian fallow deer exploitation (*Dama dama mesopotamica*), which began during the Cypro-PPNB and continued for several thousand years, represents an adaptation unique to Cyprus with few known parallels on the mainland. Deer bones are totally absent from the earliest phase at *Shillourokambos*. Similarly, they are not present at the *Mylouthkia* well 116, which is contemporary with this phase. During Early Phase B, they appear at the site and dominate the faunal assemblage (occurrence is around 40.9%). The average percentage decreases slightly from the Early C to Middle A phases, although not significantly. During the Middle B phase, the number decreases significantly (28.8%) and does not change during the final phase of site occupation (Vigne et al. 2016).

At *Ais Giorkis*, deer dominate the faunal assemblage (56% of identified bone, 62% by weight of identified bone) (Croft 2017). This is also the case at Akanthou (Şevketoğlu and Hanson 2015) and *Tenta*. At *Tenta* deer consumed did decline through time from around 56% to 42% (Croft 2005:348, Table 106). At *Mylouthkia*, at least twenty-one specimens of deer have been identified. In contrast to the other Cypro-PPNB sites, there are fairly equal proportions of caprine, deer, and pig at *Mylouthkia* (Croft in Peltenburg 2003). Based on estimations from the meat and offal or bone weights, deer provided between 20-40% of the meat supply at *Shillourokambos* (Vigne et al. 2016). This proportion is likely similar (if not slightly higher) at other Cypro-PPNB sites, given that deer occur at similar frequencies.

So far, *D. d. mesopotamica* is the only deer species identified on the island (Croft 1991, 2002; Davis 1994; Vigne et al. 2016). *D. d. mesopotamica* is typically represented in small quantities in mainland zooarchaeological assemblages. They have mainly been found in the Zagros area, Northern Levant, Middle and High Euphrates Valleys, High Tigris Valley, coastal and inland areas of the Central Levant, and the Jordan Valley. Fallow deer were not domesticated on the southwest Asian or European mainland. However, given that they appear to be most abundant and frequent on Cyprus, this prompted early suggestions about whether they were domesticated, tamed or semi-domesticated, or solely hunted on the island (Croft 1991, 2002; Ducos 1965; Frame 2002; Zeuner 1958; Vigne et al. 2016).

Croft (1991, 2002) argues against domestication using remains from Neolithic and Chalcolithic sites. The deer do not appear to have undergone any changes in size through time. In addition, at many sites, meatless extremities are not recovered, suggesting that the deer were killed relatively far from the site. Thus, their size stability and element representation at sites supports the idea that deer were hunted, free-living animals (Croft 1991, 2002).

A recent study by Jean-Denis Vigne and colleagues (2016), using deer remains from *Shillourokambos,* reached a similar conclusion that deer were not domesticated. The deer at the site showed strong sexual dimorphism. Through time, there were no changes in the size differences between males and females. If the animals had been domesticated, this would have led to a decrease in sexual dimorphism. Their size did increase slightly, but significantly, for both females and males. This size increase could be the result of hunting pressures (i.e., selecting larger individuals) or from adaptations to the local environment (e.g., different vegetation, different latitude/climate, increase in population density which reinforces intra-specific competition, and reduction of competition with other ungulates). Males and females were hunted equally, and slaughtering age profiles shows little selection, reinforcing they were exploited via hunting (Vigne et al. 2016). In addition, there was an over representation of meaty parts (e.g., limb bones such as carpal/tarsal bones and scapulae/pelves), suggesting the carcasses were not butchered in the site. Of interest, meaty deer parts were even more strictly selected by the inhabitants of *Shillourokambos* than other species. Vigne and colleagues suggest that this could be due to male deer likely being larger than the largest rams, boars, or billy goats. Distances between kill sites and places of consumption were also probably greater for deer than the other ungulates (Vigne et al. 2016:861).

At *Ais Giorkis*, there is a low level of culling during infancy (around 4% are killed at less than about a year of age). There is a fairly high level during the juvenile stage (ca. 30% between 1 and 2-2.5 years of age). Culling during sub-adulthood was also at a moderate level (ca.14%). The majority of the deer (58%) were culled as adults (about 3.5 years of age and beyond) (Croft 2017). Most deer skeletal elements are found at the site. The greatest inter-taxonomic disparities that are apparent concern head fragments. Head fragments of deer (9.8%) do occur less frequently than caprines (19.4%) and pig (23.3%), but more frequently than cattle (7.0%). Inhabitants might have been less willing to transport the heads of larger animals at the site. Given that deer account for roughly 56% of identified bones, it seems highly plausible that they occurred near the site (Croft 2017, Table 3; personal communication Paul Croft).

3.3.1.4 Pig Management Strategies. In regard to the pig remains from the Cypro-PPNB, there is evidence for both hunting and herding them. Slaughtering profiles and morphological analyses from *Shillourokambos* suggest that approximately half of the suids were wild/feral and obtained via hunting (Vigne 2013b:123; Vigne et al. 2011:260). Some of the suids at *Ais Giorkis* also appear to be wild/feral (personal communication P. Croft). At *Tenta*, domesticated pig represent 30% of the faunal assemblage; their numbers increase to 43% by the Khirokitia Culture (Croft 2005:358, Table II5). Limited information has been published on the pig remains from Akanthou (Frame 2002; Şevketoğlu and Hanson 2015). Frame (2002:236-237) noted that cull patterns show a very high percentage of infants and juveniles, which is typically associated with domesticated animals. The recent publication by Şevketoğlu and Hanson (2015) notes that pig remains were fairly common (~17% of the total assemblage), but they do not comment on their domestication status. The faunal assemblage at *Mylouthkia* is smaller than at the other Cypro-PPNB sites. Around nineteen pig specimens were deposited in the wells. The majority of pig skeletal elements were recovered from *Mylouthkia*. Several pig heads were deposited in at least two wells, leading Croft to suggest that the well shafts might have been foci for ritual activity. Limited information is provided on their domestic status (Croft in Peltenburg 2003:50-56). Thus, the data from Cypro-PPNB seem to suggest that there were both wild/feral and domestic pigs. Pig breeding could have been an important source of fat for the Neolithic peoples (Vigne 2008:199).

3.3.1.5 Archaeological Evidence for Livestock Pens. Only two sites have evidence for livestock pens: *Shillourokambos* and *Ais Giorkis* (Chapter 2). At the former site, there are curvilinear and trapezoidal enclosures cut into bedrock. These enclosures are perhaps direct evidence for livestock pens, although the excavators have also hypothesized that they are domestic areas (Guilaine and Briois 2006:163; Guilaine et al. 2011:143-151; Knapp 2013:88; Vigne 2013b:118; Vigne et al. 2011:258, 2017:11-12).

The evidence is more limited from *Ais Giorkis*. A single *Sporormiella* dung fungal spore was found and could indicate the presence of grazing animals (e.g., sheep, goat, or cattle) near the site (Scott Cummings 2016). In contrast, Shahack-Gross (2017) did not recover fecal spherulites in any of the thin sections analyzed. In addition, micro-laminations were also not found, which serve as indications for degraded enclosure sediments. While these analyses appear to be conflicting, Shahack-Gross (2017) cautions against ruling out that animals were not kept at *Ais Giorkis*. Both did not analyze samples of the site's extent. Thus, evidence further supporting livestock enclosures might have been missed. There is also severe bioturbation, which could have dismantled the micro-laminated structure of enclosure sediments if they were present. Once exposed on the surface, fecal spherulites also dissolve quickly.

3.3.2 Summary of Animal Management Strategies

Three conclusions can be drawn from the zooarchaeological evidence regarding animal management strategies during the Cypro-PPNB. The first is that there is long-distance transportation of both wild and domesticated animals by at least the 11th millennium B.P., attesting to the navigation abilities of these peoples. This transportation phenomenon is much easier to document on an island than it is on the mainland. It is thought that this long-distance transportation and exchange might have increased genetic diversity, because both likely involved the mixing of early domestic lineages from all over the mainland (Vigne 2013b:125). There appears to be sustained contact with at least some people on the mainland, given the fact that new lineages of sheep and cattle were brought to Cyprus when their predecessors possibly died-out.

The second conclusion is that there were diverse subsistence strategies for animals (e.g., hunting, specialized herding for meat, milk, and ante-mortem products) on the island, which varied by site and even regionally. These strategies also did not remain uniform during the Cypro-PPNB. Rather, we see evidence of changes in the relative importance of different components of these strategies (e.g., decrease and ultimate disappearance of cattle exploitation). Evidence from *Shillourokambos* also points to active experimentation and shifts between hunting and herding, particularly for goats and possibly pigs (Vigne 2013b:125).

Finally, there is also experimentation with animal management strategies on the island. This is particularly striking with the goats, where there is evidence for their feralization and then the re-domestication of these feral populations (Vigne 2013b:123). The same situation could have been occurring with pig, although this idea has not yet been fully explored on Cyprus. Management strategies might also have failed on the island, particularly for the sheep and cattle. The original lineages might have died out due to disease, not enough genetic diversity, or perhaps their unsuitability to the island's climate and environment.

3.3.3 Plant Management Practices

The botanical data recovered from each Cypro-PPNB site was discussed in Chapter 2.[24] Site-level plant assemblages are important because they not only provide evidence for the types of food consumed, but also for what agricultural activities took place at the site. Each stage of crop processing leaves a characteristic assemblage of by-products or macro-botanical waste. This is particularly the case for cereals. These products provide information about which stage in the

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[24] Glume wheat over free-threshing wheat (i.e., naked wheats) are the preferred choice until the late Bronze Age, although there is limited botanical data for the early and middle Bronze Age. Lucas (2014:74) suggests that this choice might be due to limited storage, low population density, and the level of social complexity.

process the assemblages came from. Analyses of weed assemblages and cereal chaff remains also provide evidence for post-harvest activities, including crop-processing and storage. The process of taking a crop from the field to the quern for grinding is represented by nine stages (Fuller et al. 2014; Lucas 2017). These nine stages are: 1.) threshing; 2.) raking; 3.) winnowing; 4.) coarse sieving; 5.) first medium-coarse sieving; 6.) pounding; 7.) second winnowing/medium-coarse sieving; 8.) fine sieving; and 9.) sorting. Two main items occur as a crop goes through these stages: the proportion of weed seeds to grain decreases and the proportion of small weed seeds to larger weed seeds decreases (Fuller et al. 2014; Lucas 2017).

At *Ais Giorkis* there is limited evidence of crop processing at the site itself. This conclusion is based on: the low occurrence of cereal chaff (glume bases, spikelet forks); high proportion of cereal grains; low chaff to cereal grain ratio; low weed to cereal grain ratio; the low number of arable weed specimens and weed taxa; and the fact that the weed taxa include weed species that are large (Lucas 2014:50). Lucas suggests that crop processing (winnowing and sieving) might have occurred offsite. In addition, she also notes that the remains may have been carried away from the site, deposited in a context that was not sampled, or the material did not survive due to depositional or post-depositional destructive processes (Lucas 2014:50). The cereal grains and weeds were also similar in size. Thus, the *Ais Giorkis* crop assemblage is either the product of fine-sieving or final sorting of clean cereal grains (Lucas 2017).

In contrast to *Ais Giorkis*, the botanical assemblage from *Mylouthkia* appears to be the result of later stages of crop process (winnowing, sieving, and hand sorting) and the by-products of fine-sieving. The chaff to grain and weed to grain ratios are both high. The percentage of weed taxa represented at the site (52% of the total assemblage) is also far higher than at *Ais Giorkis* (0.02% of the total assemblage) (Lucas 2014:50).

In addition to providing information about site-level crop-processing strategies, weed compositions also enables inferences to be made about the sowing and harvesting times (Lucas 2014). This is because in archaeobotanical assemblages weeds are typically included due to being harvested with cereal or pulse crops. Thus, based on the flowering/fruiting times of the weed taxa, harvesting times can be surmised (Lucas 2014:68). Lucas (2014:50, Figures 5.2-5.3) found that the highest percentage of weed taxa flowering occurs between March and June for the Cypro-PPNB. The evidence for flowering times implies autumn-sowing, with spring and early-summer harvesting of crops. Cereal crops sown in the autumn tend to yield more grain (Lucas 2014:68).

Weed composition can also be used as an indicator of soil composition, specifically soil fertility and manuring (Jones 1992:133; Lucas 2014:59). In particular, two plant groups have been used as indicators for soil fertility: Chenopodietea (summer crop and ruderal weeds) and Secaliatea (winter crop weeds) (Jones 1992:137; Lucas 2014:59). The presence of species of Chenopodietea weeds are used as indicators of wetter, richer, and more nitrogenous (well-manured) soil. In contrast, the occurrence of species of Secaliatea, which are typically grasses and perennials, have been used to indicate winter-sown crops that are grown with little or no irrigation, with little manure, and on less fertile soil. These grasses and perennial weeds are typically associated with nitrogen deficiency and minimal field maintenance, meaning there is no crop rotation or soil disturbance (Jones 1992:140; Lucas 2014:59-60). Based on the occurrence of these plant groups and several plant families, Lucas (2014:60) found that Cypro-PPNB sites in Cyprus (and western Syria) have poorer, less nitrogenous soils than samples from other Neolithic sites in Turkey and the Euphrates Valley.

Variation in crop species between sites might also hint at differences in preferences. For example, emmer wheat is the most common species of wheat across sites dated to the Cypriot Neolithic. However, this species is absent from *Ais Giorkis*. Rather, two-grained einkorn wheat is found at the site, representing the earliest evidence for this wheat species on the island (Lucas 2017). Two-grained einkorn wheat is currently not found at any other Cypro-PPNB site. There is also limited evidence of this wheat species in the succeeding Khirokitian period and Ceramic Neolithic. One-grained einkorn wheat is found at a much higher prevalence at sites than two-grained einkorn wheat (Lucas 2014:49).

3.3.4 Evidence of Terracing at Ais Giorkis

As noted in Chapter 2, Simmons speculates that the inhabitants of *Ais Giorkis* slightly terraced the natural hillside of the site for occupational use. Specifically, terracing helped them to stabilize the structures (Simmons et al. in press). It is important to note that this landscape modification was not for agricultural activities. Starting in the PN, there is evidence of terrace walls, particularly on the mainland (e.g., Kuijt et al. 2007). These walls would have helped limit soil erosion and maximize water use for field systems. The inhabitants of Cyprus do have a long history of terracing the landscape for extensive exploitation of the available cultivable land (Papayannis and Sorotou 2008:85), but this occurs after the Cypro-PPNB. This evidence of landscape modification from *Ais Giorkis* is still important because it demonstrates human impact on the landscape. Furthermore, it still would have required time, labor, and resources.

3.3.5 Summary of Land Management Strategies During the Cypro-PPNB

Based on the archaeological evidence, it is clear that inhabitants of the island modified and interacted with the local landscape. While this chapter focused on the Cypro-PPNB, human actions have impacted the island's landscape since humans first began exploring it. The possible introduction of wild boar during the Late Epipaleolithic, perhaps because of human-induced extinction of pygmy hippopotami, likely led to changes in vegetation and the ecology of the island (Papayannis and Sorotou 2008:85). Similarly, the introduction of the domesticated animals and plants also must have modified these aspects, although the scale and extent of this modification remains unknown.

Once humans settled the island during the Early Neolithic, their primary activities did have direct impacts on the land (Papayannis and Sorotou 2008:85). Although speculative, the terracing at *Ais Giorkis* for occupational use provides support of this. Zooarchaeological data has provided modest on-site herding practices, including the possible existence of animal enclosures from *Shillourokambos* and *Ais Giorkis*. We also know that animals were exploited for a variety of reasons, including as hunted animals and for meat, milk, and ante-mortem products. However, there are far more limited data on off-site herding strategies, specifically the existence of transhumance modes of pasturing. Given that we have animal butchering and carcass processing of sheep, goat, and cattle at both lowland and upland Cypro-PPNB sites, this hints that mobility was a key characteristic of at least certain members of these settlements. This idea will be discussed below.

The botanical data from the Cypro-PPNB provide evidence for possible land management strategies. Modification of, and interaction with, the local landscape includes the construction of fields. Unfortunately, we currently do not know where the agricultural fields were located. In fact, the Cypro-PPNB sites with preserved botanical remains do not have evidence for the early stages of crop-processing. The data from *Ais Giorkis* implies that inhabitants were not participating in most stages of crop processing at the site. Rather, it appears that only the final stage, hand sorting, occurred. The cleaned crop also was possibly hulled and likely separated from the arable weeds off-site. Lucas (2014, 2017), who conducted the botanical analyses, argues that the remains were brought to the site to be processed as flour. The opposite occurs at *Mylouthkia*. The evidence from this site demonstrates that the earlier stages of crop processing occurred off-site, but later stages of sieving on-site (Lucas 2017).

Furthermore, autumn-sowing seems to have occurred during the Cypro-PPNB, but again we do not know where these agricultural plots were located. Based on proportions of certain plant families/groups, crops during the Cypro-PPNB appear to have been grown in poorer, less nitrogenous soils. Thus, crop fields were perhaps not well-maintained, and there does not appear to be crop rotation.

Finally, there seems to be variation in plant species at certain sites; however, we do not know if this is tied to differences in preferences or environmental factors (or a combination of the two). Studies from botanical assemblages on the mainland have tied differences in water management strategies between crops (e.g., some are more well-watered than others) to human preferences (Wallace et al. 2015).

While the current archaeological data allow us to begin to shed light on land management strategies, much remains unknown about how people interacted with the landscape. I believe that a number of important questions still need to be addressed, including: 1.) Is there evidence of transhumance modes of pasturing?; 2.) Where were the agricultural fields located; 3.) Is there integration of crop cultivation and livestock herding; 4.) Are variations in plant species at certain sites tied to differences in crop preferences; and 5.) What was the soil nitrogen composition of crop fields? This study seeks to address some of these issues, allowing for a better understanding of human land use strategies during the Cypro-PPNB.

3.4 Archaeological Evidence of Water Management Strategies

A reliable source of drinking water is one of the most fundamental requirements for human and animal physical survival. Given its importance, water is argued to have been domesticated, meaning its natural properties have been manipulated and consolidated for human need (Garfinkel et al. 2006; Mithen 2010, 2012). The timing of this domestication is debated. Mithen (2010, 2012) argues that it began as a "few drops of water being carried within a cupped-leaf by *Homo habilis* two million years ago" (Mithen 2010:5250). Others believe (e.g., Garfinkel et al. 2006) that its domestication was an additional and unexpected aspect of human activity resulting from the Neolithic. Ultimately, I believe that the scale and nature of water management strategies intensifies during the Neolithic and has done so for the last 10-12,000 years.

Similar to land use, human water use provides a window into livestock mobility, crop water management strategies, the economic viability and stability of Neolithic communities, and evidence of possible competition over water resources. To date, there are very few publications (e.g., Peltenburg 2012) that examine the nature of Cypro-PPNB water management strategies. Thus, the purpose of this section is to discuss the archaeological evidence for these strategies. Wells from *Shillourokambos* and *Mylouthkia* serve as the primary evidence of water management strategies during the Cypro-PPNB. In addition, there are possible ditch/drainage features at *Ais Giorkis* and Akanthou.

3.4.1 Cypro-PPNB Wells

Wells have been found at the Cypro-PPNB sites of *Mylouthkia* and *Shillourokambos* (Chapter 2). Specifically, a total of 7 wells have been identified and excavated from the first site, and up to 12 from the second site. These wells are some of the earliest known in the world, ranging from the second half of the 9th to the mid-7th millennium BC (Croft in Peltenburg 2003:3-9; Dawson 2014:17; Garfinkel et al. 2006:686; Guilaine et al. 2011; Peltenburg 2012:77-78; Peltenburg et al. 2003). Other wells have been found on the mainland, but date to later time periods. For example, three wells have also been reported from the now underwater Pre-Pottery Neolithic C site of 'Atlit Yam (c. 7000 B.C.), off the coast of modern Haifa, Israel (Galili and Sharvit 1998; Galili et al. 2002; Garfinkel et al. 2006:687). In addition, one well has also recently been discovered at Sha'ar Hagolan, a Pottery Neolithic site of the Yarmukian Culture (6400-5800 B.C.) (Garfinkel et al. 2006).[25] In contrast to the wells from Cyprus and 'Atlit Yam, which are coastal, this well was located some 60 km inland in the Jordan Valley. Sha'ar Hagolan is also located on the bank of the Yarmuk river, which has one of the strongest currents in the Levant (Garfinkel et al. 2006). Other mainland examples can be found in North Mesopotamia, the Negev, North Arabia, and Anatolia. These occur later in time than the Cyprus examples, but before 2,000 B.C. when wells became widespread on the mainland (Peltenburg 2012:77).

The wells at *Shillourokambos* utilized an aquifer that was closer to the surface than at *Mylouthkia*. As a result, the wells at *Shillourokambos* are shallower, varying between 4.5 to 6 m in depth (Guilaine et al. 2011; Peltenburg et al. 2001:46-48; Peltenburg 2012:76). At *Mylouthkia*, wells were placed above the low cliffs and tapped subsurface water of the aquiclude. "Aquicludes often consist of a sheet flowing on top of an impervious bed. The existence of channels at the bottoms of the excavated wells, however, suggests that water flowed in

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[25] The well itself has been radiometrically dated to around 6400-6200 B.C. (Garfinkel et al. 2006).

underground streams as part of a dendritic or braided system" (Peltenburg 2003:89). Preserved depths are between 7-13 m. Substantial erosion occurred at the site. As a result, some of the wells are thought to have been deeper.

The wells at *Mylouthkia* were clearly dug with precision. Since the ground water occurred in discrete stream channels at their bases, rather than expansive sheets, well-diggers could not just start digging and assume they would find sub-surface water (Peltenburg 2003:89, 2012:72, Fig. 6). Peltenburg and colleagues (Croft in Peltenburg 2003; Peltenburg 2003:89, 2012; Peltenburg et al. 2001:46-48) suggest that the Neolithic peoples might have used hydrophilic plants with long, straight roots as underground water markers. P. Croft also proposes that people deployed water dowsing or divining to determine suitable spots for well-digging (Croft in Peltenburg 2003). However, Galili et al. (2004) do not believe that water-divining was necessary for detecting water sources at the site because of the aquiclude. The aquiclude is visible from seepages in seaside cliffs that are adjacent to the site (Galili et al. 2004:98-99). In fact, the wells are located approximately 75 m inland from visible water seepages along these cliffs (Peltenburg 2012:71).

Substantial labor went into the wells' construction at both sites. At *Mylouthkia*, between 5-6 m^3 of soil was removed for each well, likely with antler picks or wooden sticks and lifting devices, when the marl was wet. Cylindrical wells shafts had a diameter of between 0.90-1.20 m. Shafts often belled out towards their base, where the stream(s) could be tapped. At the very bottom of the well, there was a circular, dished basin. This basin allowed water to be collected to a sufficient depth, which made drawing it easier. In several of the wells, there were also distinctive hand/footholds (Figure 3.2) (Peltenburg 2003:89, 2012:72). "The clearest arrangement of these climbing holes consists of a regular distribution in two fairly vertically aligned, approximately opposed, major ranges" (Peltenburg 2012:72). Most of the wells are located along the 22-26 m contour, but the recently discovered wells are located about the 34 m contour line (Peltenburg 2012:72, Figure 4). Many objects were found in the basal fills (Chapter 2), below and at the water table, but still allowed water inflow. Once the fills block the water inflow, then the wells were likely abandoned (Peltenburg 2012:73). Peltenburg (2012) suggests that the wells could still have been functioning units, even with the objects in them, although I am skeptical of this. I am not sure why people would contaminate their water source.

Figure 3.2 Well from Mylouthkia with visible hand/footholds

The well openings or apertures at *Shillourokambos* were less than 1 m in diameter. A stone well head appears to protect some of the apertures. This feature was not found at *Mylouthkia*. There is also no evidence of the hand/footholds or shaft linings. Some of the wells were expanded during the Middle Phase of the occupation to serve as cisterns. At least one well from both sites are thought to have ritual significance, because a number of human remains were buried (deposited?) within (Peltenburg 2012:76).

Near at least *Mylouthkia* there were more easily accessible, but seasonal, sources of nearby water (Peltenburg 2003:89, 2012:71). Wells might have been intended to supplement both sites' water sources, particularly since it is thought that the sites were inhabited year-round by at least some people. This suggests that their construction might have been a risk aversion or buffering measure in the face of unpredictable access to fresh water (Peltenburg et al. 2001:47; Peltenburg 2003:89). Christodoulou (1959:40, 62) notes that well-digging was ubiquitous on the island until relatively recently when piped water began to replace wells, starting at the end of WWII. Thus, wells at *Mylouthkia* and *Shillourokambos* might represent the beginning of this Cypriot tradition of well-digging.[26]

However, Peltenburg (2012:78) cautions against assuming wells were used as a buffering mechanism during the Cypro-PPNB. *Mylouthkia* and *Shillourokambos* were both settled during the warmer and wetter phase of the Early Holocene, when the water table was likely higher. Thus, perhaps scarcity was not an issue for these earliest inhabitants. Rather, Peltenburg (2012) suggests that networking might have played an important role, at least for the inhabitants of *Mylouthkia*. Specifically, the island's inhabitants might have wanted to stay near the coast to maintain contact with both other islanders and people from the mainland. Peltenburg also does not believe that this case applies to *Shillourokambos* because it is located farther from the coast.

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[26] Wells have currently not been recovered from settlements during the later Aceramic Neolithic (Khirokitia Culture), perhaps because settlements are located near springs and rivers. In fact, wells do not reappear until some 4,000 years later, during the Late Bronze Age, when large urban centers come into existence (Peltenburg 2003:89, 2012:80).

The economic situation on the island was also very different from the mainland. All major plant and animal resources had to be brought to the island, whereas on the mainland (especially northwest Syria and southeast Anatolia) people had been engaging and experimenting with these resources for several thousand years. As Peltenburg notes (2012:79):

> With the possible exception of barley, none of these was native to the island hence the experience and lifeways of the islanders was profoundly at odds with those of the mainlanders. They were dealing with a host of varied, imported stocks that required care since they could not be so easily replenished. The introduction and exploitation of so any kinds of managed plants and animals in the mid-9th millennium (pigs even earlier) was a fragile experiment. Just how uncertain it was is evident from the ultimate failure to establish cattle successfully.

It seems that people on the island had to pay more attention to maintaining subsistence resources than their mainland counterparts. As a result, they had to sustain this new way of life, in part by taking more unusual measurements, such as well-digging. Support for this can be found with the possible animal pens recovered at *Shillourokambos* (Chapter 2). Penned animals in a settlement suggest that the inhabitants needed a dependable and nearby water supply. This need could have been satisfied through the construction of wells (Peltenburg 2012:79).

Well construction might have also served as a status symbol. It involved significant labor inputs and was often dangerous. Communities or individuals who had access to wells could have had greater power over those who did not (Garfinkel et al. 2006:695). Those able to locate water underground might have also been held in high regard. The excavation process itself may have also formed part of a well-ritual (Koutrafouri 2013). Koutrafouri (2009, 2013) argues that a ritual practice known as ‘the well ritual’ can also be identified for the Cypro-PNB. Accordingly, the series of ritual practices relating to the wells can be summarized as staged and structured depositions: 1.) the dismemberment of human corpses, and their transport and final deposition in the well shafts; 2.) the accumulation of fragmented artifacts and their final deposition in the wells interior; 3.) the deposition of animal remains, possibly in a votive manner; and 4.) non-worked stone boulders that were structurally deposited inside the well (Koutrafouri 2013:93).

While Koutrafouri's hypothesis is interesting, I do not think that one based on strictly the symbolic/ritual role of wells gives the inhabitants of the Cypro-PPNB due credit. Well-digging clearly addressed some issue that the people were facing. It seems unfathomable that labor and time would be invested into well construction if they were truly not needed as a stable water for humans and animals. Well-water might also have been more convenient than traveling to the nearest spring. Garfinkel et al. (2006:694-695) propose this idea as one reason for the well construction at Sha'ar Hagolan. In addition, quality of water might have been an important consideration. Water in an open body source, such as a river or stream, is open to pollution from both humans and animals. In contrast, well-water is isolated and controlled (Garfinkel et al. 2006:694-695).

The number of wells at each site raises the question of whether their usage was for public or private. At both *Mylouthkia* and *Shillourokambos,* two wells occur adjacent to one another. Furthermore, as noted above, the wells at *Mylouthkia* seem to generally cluster together. In addition, based on radiocarbon dates, it appears that at least some of the wells were used contemporaneously, although this is difficult to determine given their error range. Peltenburg (2012:73, 76) proposes that this is evidence for the wells possibly belonging to discrete groups, such as households, rather than to the whole community. As noted in Chapter 2, Peltenburg and colleagues (see Peltenburg 2003) argue for at least one structure being present at the site.

However, not all (e.g. Galili et al. 2016:182), including the present author, agree that this feature represents a structure (Chapter 2). The absence of structures, however, does not necessarily negate household ownership. J. Guilaine and F. Brios also caution about connecting specific wells to households at *Shillourokambos* because of the site size, which is only 2 ha in extent. They also do not believe the entire site was occupied at one time (Guilaine and Briois 2006). At this time, we do not have enough evidence to determine whether wells belonged to families or entire communities. At the very least, these structures required a tremendous investment in labor, wealth, and resources to construct.

3.4.2 Ditch Features

Ditches have been recovered from both *Ais Giorkis*, Akanthou, and *Tenta*. Excavators have hypothesized that the ditch at *Ais Giorkis* might have served as a drainage structure or water channeling system, site boundary, or a "foundation" for several pits (Figure 3.3). The ditch appears to have been recut several times. At least three pits were built into the feature or occur next to it (Simmons 2012; Simmons et al. in press). At Akanthou, there is evidence that rain-water formed gullies within some parts of the ditch. There is evidence that the structure might have been cleaned out at least once, before it was filled with rubbish and other deposits (Şevketoğlu and Hanson 2015). The ditch at Tenta is argued to date to the Cypro-PPNB, although its use might also extend to the Khirokitia Culture. The ditch was deep and near the outer wall of the settlement; thus, it has been tied to defensive measures. It eventually went out of use when the village expanded past the original outer wall during the Khirokitia Culture (Knapp 2013:104; Todd 1981:48, 1987:49-50).

Figure 3.3 Ditch feature from *Ais Giorkis*

The ditch features were all dug into bedrock and appear to have been maintained to some degree, which likely required substantial labor from the sites' inhabitants. Unfortunately, all of their functions remain ambiguous. It seems that these features might have served different purposes at the three sites, including as drainage features and for defensive purposes. Regardless, these features do add a dimension to the alteration of the natural landscape during the Cypro-PPNB.

3.4.3 Summary of Water Management Strategies

In sum, the clearest archaeological evidence that we have for water management during the Cypro-PPNB are wells. Because two of the three ditch features have not been excavated in full, it is difficult to say whether they functioned as water management structures. In addition, the feature at *Tenta* appears to have served as a defense mechanism for its community.

The well constructions demonstrate that the island's inhabitants had both the technological capacity and the geological and hydrological knowledge to dig the wells. This engineering ability adds another component to the domestication of their landscape, perhaps enabling group identity to be consolidated through place attachment (Dawson 2014:23; Garfinkel et al. 2006; Peltenburg 2012).

Well-water was likely intended for human and animal use, rather than for irrigation. In fact, there is no evidence of irrigation during the Neolithic in Southwest Asia. On an island plagued by inconsistent precipitation from year to year, well-digging removed a major ecological barrier of water shortages. In turn, this opened new areas for habitation and agricultural activities. *Shillourokambos* and *Mylouthkia* appear to have been inhabited (at least by some groups) year-round. Thus, the sites' inhabitants clearly had strategic access to important resources, including a consistent supply of water.

There is still the question of who had access to the well-water. The labor that went into the construction and maintenance of the wells suggests, irrespective of the presence or absence of structures or their contemporaneity with the wells, that some group(s) had ownership over them. This idea will be further explored in Chapter 6. Besides wells, there is almost no other archaeological evidence for water management strategies during the Cypro-PPNB.

3.5 Conclusion

Archaeological data useful for reconstructing local and regional climates and environments on Cyprus are limited (Chapter 2). There is some evidence that centennial-level climatic fluctuations could have impacted the island's inhabitants. While the overall Early Holocene had wetter conditions, summer drought conditions are still believed to have persisted. Increased precipitation is believed to have only occurred in the winter (and possibly autumn and spring). Thus, seasonality was likely more pronounced during the Early Holocene. Researchers, including Peltenburg (2012), have cautioned against assuming the paleoenvironment and paleoclimate conditions were similar to the present on the island. However, I believe that the presence of wells at two Cypro-PPNB sites indicates that access to a year-round, consistent supply of water was challenging for people, particularly in the lowlands/coastal areas during the summer. During the hot summer months, temperature routinely approaches, and can surpass, 28-30°C in the Paphos region today. Issues related to access to water would not just impact human and animal drinking water, but also both crop fields, grazeland, and other physiological needs of the herd animals.

The current evidence suggests that crops during the Cypro-PPNB were grown in poorer, less nitrogenous soils than samples from other Neolithic sites in Turkey and the Euphrates Valley. There was likely minimal field maintenance, meaning there is no crop rotation or soil disturbance (Jones 1992:140; Lucas 2014:59-60). This seems to suggest that there was no integration of livestock keeping and crop cultivation. Pasturing herds near villages would have enabled this integration. Herd animals could have grazed crop fields after the harvest, and their manure could have been used to increase fertility of the soil (Bogaard 2005, Bogaard et al. 2014).

There are also very limited data that allow us to discuss whether crops were grown in well-watered soils, although the current botanical evidence suggests otherwise. This is important because it has been demonstrated on the mainland that there were differences in water management strategies for crop species (e.g., Wallace et al. 2015). These differences were tied to preferences for certain crops.

Given what we know about both past and modern Cypriot climate data, in combination with the temperature prescriptions on sheep, goat, and cattle, I argue that settlement at *Ais Giorkis* was tied to seasonal mobility by people in the western region of the island. This pastoral regime is well-documented throughout the Mediterranean and Southwest Asia from prehistory through modern times, including on Cyprus (e.g., Christodoulou 1959; Given 2000; Makarewicz 2013; McClure 2015). Hot summer temperatures in the coastal regions of western Cyprus could have put animal herds under stress, making breeding challenging. Scarce water and forage resources in coastal/lowland areas during the summer might also have made diversification of land use for at least some groups desirable. Moving to the uplands during the late spring/early summer might have helped mitigate the above challenges, given the milder temperatures and greater amount of available surface water. In early fall, returning to the lowlands would reduce the impact of cold temperatures on adult animals. In addition, birthing would also be made easier (Leon 2016:223).

The late winter, spring, and early summer in the uplands would also have provided hunters with suitable weather conditions and the greatest access to mixed-sex groups of deer (Frankel et al. 2013:108). The data from *Ais Giorkis* suggests that people were hunting the animals near the site. Thus, seasonal movement to the uplands was also likely tied to deer hunting. Deer hunting was also likely a highly esteemed activity (Croft 2012; Vigne et al. 2016).

It is difficult to determine how pigs might fit into this overall seasonal mobility regime during the Cypro-PPNB. There are a number of ethnoarchaeological studies on traditional pig husbandry from Europe, particularly from the Iberian Peninsula/Spain (Hadjikoumis 2012, and citations therein), Sardinia and Corsica (Albarella et al. 2007, 2011), and Greece (Halstead and Isaakidou 2011). These studies all emphasize that scale of husbandry coupled with closeness of control affects a number of important aspects of domestic pig herds, including: morphology, castration strategies, level of interbreeding with wild pigs, and seasonality (Hadjikoumis 2012:363). The scale of pig husbandry can vary widely, including household keeping to specialized extensive management of large herds. The former typically comprises only a few individuals. The latter is adapted to a variety of landscapes (e.g., woodlands and open areas) in both the lowlands and highlands. It can also follow either transhumant or sedentary life-styles. There can also be seasonal foraging in cultivated areas.

Seasonal movement of pigs can occur for different reasons and follow separate routes than for sheep, goat, and cattle. On Sardinia, for example, pigs would spend the winters in the mountains and the summers on the plains. In terms of food availability, this was the most efficient strategy (Albarella et al. 2007, 2011; Balasse et al. 2016:28; Hadjikoumis 2012; Halstead and Isaakidou 2011). Domestic pigs that are herded extensively would be expected to have diets similar to wild boars. This diet is composed mainly of plant resources, but includes seasonal animal components. Pigs kept around or near the household would, in contrast, include in their diet human consumption waste, including the by-products of plant cultivation and animal exploitation (Balasse et al. 2016:28). On Sardinia and Corsica, some pigs live far from their owners, who only visit them a few times a year. Often, these individuals interbreed with wild or feral animals (Albarello et al. 2011; Rowley-Conwy et al. 2012:10).

We have both feral/wild and domestic pigs at *Ais Giorkis*. Groups might have brought domestic pigs with them from the lowlands and left at least some of them at the site, resulting in them becoming feral/wild. In this case, scale of husbandry (e.g., part of an extensive managed herd vs household pig) is really intriguing. Groups might have also hunted the wild boar, which probably found the habitat around the site suitable.

We know that people at *Ais Giorkis* were exploiting a number of different resources, including chert for chipped stone production, diabase for ground stone production, and picrolite. The substantial architecture, abundance of chipped stone and ground stone, the large and diverse botanical and faunal assemblages, and presence of exotic artifacts all indicate that the site was inhabited for a portion of the year. Thus, I believe it makes sense to tie habitation to seasonal mobility during at least the early spring and summer.

Scientific advances in the field of archaeology, including zooarchaeology and paleobotany, have allowed for a more fine-grained view of the relationship of Neolithic peoples with their landscape. As discussed, zooarchaeological studies of faunal remains have long been utilized on Cyprus to understand animal consumption and husbandry practices. Similarly, archaeobotanical research has enabled us to understand plant consumption as well as to infer what agricultural activities took place at the site and to some extent the growing conditions of crops. However, aspects of animal and plant management strategies are less visible through traditional methods, including animal diet, seasonal movement, crop water status, and soil nitrogen composition. Recently, innovative ways for examining past landscape usage in early prehistoric southwest Asia have been developed using stable isotope analyses on archaeological faunal and botanical remains (e.g. Bogaard et al. 2014; Henton 2012; Henton et al. 2010; Makarewicz 2014; Makarewicz and Sealy 2015; Makarewicz and Tuross 2006, 2012; Makarewicz et al. 2016; Pearson et al. 2007, 2015; Wallace et al. 2015), but there are few published studies to date on Cyprus (see Scirè Calabrisotto 2017; Leon 2016). To better understand Early Neolithic land and water management strategies, stable isotopic analyses were conducted on the botanical and faunal remains from *Ais Giorkis*. The results are discussed in Chapter 5.

CHAPTER 4: METHODS AND MATERIALS

4.1 Introduction

The primary goal of this research is to understand land use by the inhabitants in western Cyprus during the Cypro-PPNB. To begin to understand this issue, I integrate the stable isotope analysis of faunal and ancient crop remains from *Ais Giorkis* to explore plant and animal management strategies. This chapter begins with a discussion of foundational concepts of stable isotope geochemistry, including: what are stable isotopes?; how have stable isotopes been utilized in problems of anthropological/archaeological interest?; what are the types of archaeological materials that can be used?; and what are the key properties/features of the stable isotopes (i.e., $\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$) of interest in this study? Next, I discuss studies of Cypriot archaeological material that have incorporated stable isotope analyses to address human and animal paleodiet and animal management strategies. I also discuss carbon and nitrogen and oxygen baseline data on the island. I attempted to build a carbon baseline using living land snails, which ran into challenges. Finally, I discuss the specific materials and methods used in this study.

4.2 What are Stable Isotopes?

At the simplest level, atoms consist of protons, neutrons, and electrons. Protons are positively charged particles, neutrons have no charge, and electrons are negatively charged. Electrons are present as a negatively charged cloud around the nucleus. The mass of a neutron is about equal to that of the proton. Compared to both the proton and the neutron, the mass of electrons in an atom is negligible (Fry 2006:4-5; Sharp 2007:5).

An element, such as carbon, is determined by the number of protons in its nucleus. In an atom, the gross chemical properties are determined by the configuration of the electron cloud. For a given element, the number of protons (the atomic number Z) is always the same. However, the number of neutrons (the neutron number N) can differ (Sharp 2007:5). The mass (the mass number A) is equal to the sum $Z + N$. The number of neutrons in an element's nucleus does not affect the gross chemical properties of an element and its compounds. Differences in the overall mass of the element due to differences in the number of neutrons cause subtle chemical and physical differences between compounds that contain elements of varying N. These small differences make up the subject of stable isotope geochemistry (Sharp 2007:5).

An isotope of any given element differs from another isotope of that same element by the number of neutrons in the nucleus. Some of these isotopes of the same element may be stable (i.e., they do not decay); whereas other isotopes of the same element may be radioactive, meaning they decay (Fry 2006:7-8; Sharp 2007:5). For example, carbon has three isotopes: C^{12}, C^{13}, and C^{14}. The first two are stable isotopes, whereas the final one is a radioisotope. Different isotopes of an element have different kinetic and thermodynamic properties. During physical and chemical processes (i.e., fractionation), these differences can lead to measurable isotopic partitioning between substances. These substances are labeled with distinct isotope ratios (Koch 1998:574).

What does δ mean? The delta (δ) notation is used to report the relative differences in isotopic ratios for all materials except interstellar dust (Sharp 2007:17). The delta value is given by the following equation: $\delta X = \frac{R_{sample} - R_{standard}}{R_{standard}} x\, 1000$

R is the ratio of the heavy (and rare) to light (and more abundant) isotope (Table 4.1), x refers to the sample, and *std* is the abbreviation for standard (Fry 2006:9; Sharp 2007:7, 17,

Table 1.3-1.4). For the elements of carbon, oxygen, and nitrogen, R is given by $^{13}C/^{12}C$, $^{18}O/^{16}O$, and $^{15}N/^{14}N$. Natural fractionations are small. As a result, delta values are reported in per mil, or parts per thousand (hence why the equation above is multiplied by 1000). The delta notation provides a way to report the small relative differences in isotopic ratios between the sample and standard that are measured by the isotope ratio mass spectrometer. The symbol for per mil is ‰. A positive δ value means that the ratio of the heavy to the light isotope is higher in the sample than it is in the standard. A negative δ values means the opposite. For example, a $\delta^{18}O$ value of +19.7‰ has an $^{18}O/^{16}O$ ratio that is 19.7 per mil (1.97% higher) than that of the standard. In the isotope ratio mass spectrometer, it is the intensities of the ion signal that are reported as the δ value (Koch 1998:574; Sharp 2007:17-18).

Table 4.1 Isotopic abundance and relative atomic masses of the pertinent elements in this study

Atomic number	Element name	Symbol	Abundance (%)[1]	Atomic weight (u)
1	Hydrogen	1H	99.985	1.007825
	Deuterium	2H	0.0015	2.014102
	Tritium	3H	*1	3.016049
6	Carbon	12C	98.89	12.000000
		13C	1.11	13.00335
		14C	*1	14.003242
7	Nitrogen	N	99.63	14.003074
			0.37	15.000109
8	Oxygen	16O	99.759	15.994915
		17O	0.037	16.999132
		18O	0.204	17.99916
38	Strontium	84Sr	0.56	83.913425
		86Sr	9.86	85.909262
		87Sr	7.00	86.908879
		88Sr	82.58	87.905614

[1] In the abundance column, nuclides marked with an asterisk (*) indicate that it is not present in nature or that a meaningful natural abundance cannot be provided.

Note: Table 4.1 is modified from Sharp (2007:Table 1.4, 8). Data are from: Sharp (2007:Table 1.4, 8), Vocke (1999).

Precise comparisons of isotopic compositions of materials can be determined in a given laboratory using working standards. However, to compare data obtained in different laboratories, the working standard needs to be calibrated with an internationally accepted set of reference standards. Carbon isotope ratios are reported relative to the PeeDee Belemnite (PDB) standard.[27] The $\delta^{13}C$ value of PDB is zero. Oxygen isotope ratios are reported on the PDB and SMOW (Standard Mean Ocean Water) scales. These scales are very different and cannot be mixed when presenting the data. There are equations for converting back and forth between the two scales. By definition the $\delta^{18}O$ values of PDB and SMOW are both zero (Sharp 2007:24-29). The reference standard for nitrogen isotope analyses is atmospheric nitrogen and is called AIR. The $\delta^{15}N$ value of atmospheric nitrogen is nearly constant everywhere on Earth. Its value is 0‰ (Sharp 2007:28-29).

For this study, I have chosen to use light stable isotopes ($\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$) because of the relatively inexpensive analysis cost of these isotopes compared to using heavier isotopes (e.g., $^{87}Sr/^{86}Sr$). Furthermore, Cyprus, in general, lacks published baseline data for any stable isotope (see below), which is necessary for all stable isotopes, but in particular the heavy isotopes.

4.3 Stable Isotopes and Archaeology

This section first outlines the history of the application of stable isotopes to archaeological remains. I highlight a few key points that laid the foundation for current archaeological research that employs stable isotopes. Makarewicz and Sealy (2015) and Lee-Thorp (2008) provide an excellent and in-depth review of this issue. I then discuss the primary types of tissue that are used in isotope archaeology, but ultimately focus on bone collagen,

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[27] It is a calcite sample of a specimen of *Belemnitella americana* from the Upper Cretaceous Peedee formation of South Carolina. The original supply of PDB is exhausted; however, it remains the standard used in reporting carbon isotope analyses (V-PDB) (Sharp 2007).

enamel, and charred plant material, because these are the tissues utilized in this study. Finally, the section concludes with a discussion on the foundational concepts behind carbon, nitrogen, and oxygen stable isotopes.

4.3.1 History of the Application of Stable Isotopes to Problems of Archaeological and Anthropological Interest

Stable isotopes provide a means to investigate human and animal diet and mobility and how people exploited wild and domesticated plant and animal resources largely because stable isotopes record environmental and dietary inputs in the plant and animal tissues. The application of stable isotopic studies to problems of archaeological and anthropological interest began around the mid-1960s.

Much of the research that uses stable isotope analyses in archaeological contexts draws on the field of isotope geochemistry in the earth and plant sciences (Makarewicz and Sealy 2015:145). Geochemist Cesare Emiliani is thought to have been one of the earliest researchers to perform stable isotope analyses on archaeological materials. He applied oxygen isotope analyses to marine molluscs remains from prehistoric Mediterranean sites. This study was important because it found that oxygen isotope ratios in the shell carbonates from prehistoric sites were noticeably different than those of modern topshells and limpets from the Mediterranean. This finding indicated that sea surface temperature during the Late Pleistocene was several degrees colder than today (Emilani et al. 1964; Mannino et al. 2016:193). Paleoceanographer and paleoclimatologist Shackleton (1973), nearly a decade later, expanded on this initial study to examine how oxygen stable isotopes can inform on the season of collection of marine molluscs.

Following Emilani's study, carbon isotope analysis began to be applied on mammalian skeletal tissues in order to reconstruct past human diets. This application can be traced to two scientific discoveries: radiocarbon dating and the chemical pathways that plants take during photosynthesis. Both discoveries are credited to two American scientists who were awarded the Nobel Prize in Chemistry for their research on the chemistry of carbon in 1960 and 1961, respectively. The 1960 laureate, William F. Libby, discovered the natural radioactive isotope of carbon, ^{14}C, and developed the radiocarbon dating method for determining the age of organic material up to around 50,000 years of age (Libby 1955; Libby et al. 1949). The 1961 Nobel Prize in Chemistry went to Melvin Calvin for his description of the chemical pathway followed by carbon during photosynthesis in plants (Calvin and Bassham 1962; Calvin and Benson 1948).

It was recognized that radiocarbon determinants derived from C_4 plants yielded dates that were consistently too young compared to those plants that fix carbon through the C_3 pathway. This meant that the carbon isotope ratios in consumer tissues (i.e., bone) would also be impacted. Thus, the measurement of carbon isotope ratios could be used to indicate the importance of maize in human diets. Succeeding research benefited from this observation and began to use stable isotopes as a natural tracer of the flow of carbon isotopes through foodwebs (e.g., Makarewicz and Sealy 2015; Tykot 2004:433; van der Merwe 1982; van der Merwe and Vogel 1978; Vogel and van der Merwe 1977). For example, in North America, one of the earliest applications of this method was in examining when maize was first incorporated into the diet of North American Woodland Native Americans in New York. Maize is a C_4 plant, whereas the archaeological sites were primarily in C_3 environments. C_4 and C_3 plants, discussed below, have very distinct isotopic signatures. A change in the $\delta^{13}C$ values was detected in the human remains with maize consumption (van der Merwe 1982; van der Merwe and Vogel 1978; Vogel and van der Merwe 1977). The use of nitrogen isotopes in exploring trophic level relationships between marine and terrestrial ecosystems followed these studies (Deniro and Epstein 1981; Makarewicz and Sealy 2015:147; Mannino et al. 2016:193; Schoeninger and Deniro 1984). Research on oxygen isotope ratios of meteoric water (Craig 1961; Dansgaard 1964) enabled relationships between drinking water, body water, and mammalian mineralized tissues to also be investigated. This provided a means to reconstruct climate (Longinelli 1984; Luz et al. 1984). The first study relating strontium isotope values of human skeletons to geologically sourced strontium was published in 1985. The purpose of this study was to establish mobility of archaeological individuals during their lifetime (Ericson 1985).

The expansion of isotope archaeology, however, did not occur until the development of continuous-flow mass spectrometer during the 1990s. This technological advance greatly reduced the cost of analyses, making them more affordable for archaeological budgets. In turn, this led to increasing numbers of isotopic studies on archaeological material. Bogaard and Outram (2013:333) argue that stable isotope analysis "constitutes a third 'isotopic revolution' comparable in impact to the advent of radiocarbon dating and of calibration curves in archaeology (cf. Renfrew 1973)."

4.3.2 Archaeological Material Used for Stable Isotope Analyses

Archaeological material used for stable isotope analyses includes bone, teeth (enamel and dentin), hair, otoliths, egg shell, hair and charred plant material (Koch 2007). The first two are particularly important since they are typically the most common vertebrate tissues that are recovered during excavations (Scirè Calabrisotto 2017:301). I will first discuss bones and teeth and then charred plant material.

4.3.2.1 Bones and Teeth. Body tissues are comprised of biomolecules. These biomolecules are made up of elements, including carbon, nitrogen, and oxygen, that are taken from food and water consumed over the organism's lifetime. Isotopic composition of consumer tissues depends on both the isotope ratios of the nutrients consumed and on metabolic fractionation during their synthesis into tissue (Makarewicz and Sealy 2015:152).[28] Experimental data have demonstrated that different consumer tissues reflect different dietary components (Ambrose and Norr 1993; Bryant et al. 1996; Lee-Thorp et al. 1989). Bone, enamel, and dentine are all inorganic/organic composites. These tissues are primarily comprised of the inorganic (mineral) component, although proportions and types of organic and inorganic component vary between the different tissues. Most of the inorganic component is in the form of calcium phosphate bioapatite, with the chemical formula $Ca_{10}[PO_4,CO_3]_6[OH,CO_3]_2$, and is also known as bioapatite. The organic component is in the form of fibrous protein (collagen) (Hedges et al. 2005; Koch 1998:576, 2007; Pearson et al. 2015:70; Wang and Cerling 1994:282).

Bone is comprised of tiny apatite crystals (65-70%) which are intergrown with an organic matrix. This matrix is mainly collagen, and makes up approximately 25-26% of its dry weight (Hedges et al. 2005; Koch 1998:576, 2007; Wang and Cerling 1994:282). Dental enamel is far less porous than bone and it is almost entirely inorganic. It has larger crystals with fewer substitutions and defects. The organic composition, organic content, and crystal size of tooth dentin resembles that of bone. Its porosity is between enamel and bone (Hedges et al. 2005; Koch 1998:576, 2007:101-102; Wang and Cerling 1994:282). In this dissertation, I only use bone collagen and enamel (as well as charred plant materials).

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[28] Once consumed, major macronutrients (carbohydrates, fats, and protein) are metabolized in different ways. In fact, they enter different metabolic pathways, including amino acid synthesis, glycolysis, gluconeogenesis, and fatty acid β-oxidation. These biochemical reactions each involve isotopic fractionation (Makarewicz and Sealy 2015:152).

Stable isotope values from bone collagen provide information about dietary protein.[29] This is because dietary protein consumed by an organism is used to build body protein. Depending on the age of the individual, it remains for several years or decades until it is replaced through the process of bone turnover. This means that differences detected in stable isotope values between individuals or groups of individuals is the result of food that is repeatedly consumed on a regular basis, rather than one-off meals consumed (Ambrose and Norr 1993; Deniro and Epstein 1978; Hedges et al. 2005; Jim et al. 2004; Pearson et al. 2007, 2015:70).

Based on radiocarbon dating experiments, it has been shown that collagen is the portion of the bone that is less susceptible to contamination in the burial environment relative to the inorganic component. The majority of collagen in archaeological remains is lost due to microbial activity. Bacteria and fungi in the surrounding soils produce collagenases, which breaks down bone collagen and liberates the organic nitrogen and carbon to the microorganisms. Even without microbial activity, collagen tends to decompose over time. Decomposition can also occur faster in hotter climates, a point that is returned to below. Thus, while most isotopic paleodietary studies focus on bone collagen, it is important to determine first that the intact collagen is well-preserved (Ambrose 1990; Berna et al. 2004; Hare 1980; Hedges 2002; Hedges et al. 2006; Leatherdale 2013; Lee-Thorp and Sponheimer 2006:7; Richards 2015:15-16; Tuross 2002; Weiner and Bar-Yosef 1990).

Enamel bioapatite is among the most useful of tissues to use in stable isotope analysis for three primary reasons. First, it has been shown to be less susceptible to diagenetic alteration than

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[29] In contrast, stable isotope analysis of the mineral component of tissues, including bone and enamel, provides information that reflects the contribution from carbohydrates, fats, and protein to the diet. These minerals contain a limited range of elements that can be analyzed. Carbon and oxygen are the two primary elements (Pearson et al. 2015).

dentine or bone. Specifically, it does not incorporate the isotopes from the surrounding soil (Hedges et al. 2005; Kohn et al. 1999; Lee-Thorp 1989; Lee-Thorp and van der Merwe 1991). The second is that once formed, enamel does not remodel. This means that isotopes incorporated into the enamel directly reflect dietary and climatic factors at the time of its formation (Balasse 2002; Fricke and O'Neil 1996). Finally, enamel also keeps a chronological record of isotopic changes during the time of tooth growth. Ungulates (e.g., sheep, cattle, and goats) have hypsodont (i.e., high-crowned) teeth. Enamel formation in these teeth proceeds down the crown in a sequential manner as the tooth is formed. This preserves a record of the body water isotopic composition throughout tooth growth (Fricke and O'Neill 1996). The length of growth depends on the species and the molar type (Britton et al. 2009). For sheep and goats, molars develop over the first two years of life. For the first molar (M_1), enamel begins to form right before birth, and continues to develop until around nine months. In the second mandibular molar (M_2), enamel forms over approximately one year, beginning at birth (Henton et al. 2010:435). The third mandibular molar (M_3) begins to form around one year. Growth is completed after around two years (Hillson 2005:230-232). Thus, sequential samples taken down the column of these teeth provide a way to track the incorporation of specific isotopes into the tooth enamel matrix with time depth. The isotopic ratios that are present in the body at the time of tooth formation reflect the isotopes of the ingested diet and water intake (Henton et al. 2010:435; Leon 2016:339).

4.3.2.2 Charred Plant Material. Investigations into the field of stable isotopic analyses have only recently begun incorporating archaeobotanical remains (Araus et al. 1997, 1999, 2014; Bogaard et al. 2007, 2013, 2016a, 2016b; Fraser et al. 2011, 2013a, 2013b; Lightfoot and Stevens 2012; Vaiglova et al. 2014; Wallace et al. 2013, 2015). Some of this literature (Bogaard et al. 2007, 2013; Fraser et al. 2011, 2013; Lightfoot and Stevens 2012; Vaiglova et al. 2014) have also emphasized that, where preserved, the isotopes of plants should also be measured alongside those of humans and animal remains to better understand diet in the archaeological record. All botanical samples in this study represent domesticated crops. Experimental studies have been conducted on crops, whereas wild plant species have not yet been studied experimentally. Thus, it is known how domesticated plants respond to soil ^{15}N enrichment and charring (e.g., Nitsch et al. 2015; Vaiglova et al. 2014:204; Wallace et al. 2013).

4.3.3 Carbon and Nitrogen Stable Isotopes

Metabolic processes, including digestion, breathing, and photosynthesis, are the primary ways in which plants and animals obtain carbon and nitrogen. These processes are governed by principles of biochemical fractionation. These principles determine the proportions in which the different isotopes of each element are assimilated into the organisms' tissues (Vaiglova et al. 2014:202). Consumption of these tissues by another organism is important because it impacts the isotope chemistry of the consumer, which now includes the food source signature plus an enrichment factor. Thus, compared to the plants they consume, herbivores have higher $\delta^{15}N$ values and to a lesser extent $\delta^{13}C$ values. Carnivores have higher values than herbivores (DeNiro and Epstein 1978; Hedges and Reynard 2007; Lee-Thorp et al. 1989; Vogel and van der Merwe 1977).

The $\delta^{13}C$ values of plants are determined by carbon isotopic value of atmospheric CO_2 during the time of the plant's growth and the degree of fractionation that occurs during photosynthesis.[30] The former is particularly important because its $\delta^{13}C$ value (also known as $\delta^{13}C_{air}$) has varied over time. In particular, values have dramatically changed since the Industrial Revolution due to fossil fuels. This variation needs to be considered when comparing the $^{13}C/^{12}C$ ratio for plants grown in different time periods as well as when comparing archaeological remains with modern crops grown under known watering conditions. As a result, the $\delta^{13}C$ value from the plants must be converted into $\Delta^{13}C$, which reflects only the carbon isotope discrimination (Farquhar et al. 1982; Ferrio et al. 2005; Nitsch et al. 2017; Wallace et al. 2013). This enables the $\Delta^{13}C$ is calculated using the following equation (Farquhar et al. 1982, 1989):

$$\Delta 13\mathrm{C} = \frac{\delta 13\mathrm{C}_{air} - \delta 13\mathrm{C}_{plant}}{1 + \delta 13\mathrm{C}_{plant}}$$

In the above equation, $\delta^{13}C_{air}$ refers to the isotopic composition of atmospheric CO_2 at the time of plant growth. These values have been preserved in sequence in ice-cores from Antarctica and they can be estimated using the AIRCO2_LOESS data calibrator for time periods between 16,100 B.C.E. and 2003 C.E. (e.g., Ferrio et al. 2005).[31] The conversion of $\delta^{13}C$ into $\Delta^{13}C$ results in a change in the direction of the effect, where $\delta^{13}C$ values that are higher equate to lower $\Delta^{13}C$ values, and the sign is also changed (i.e., negative $\delta^{13}C$ values become positive $\Delta^{13}C$ values) (Vaiglova et al. 2014:203).

There are three photosynthetic categories used by terrestrial plants: Calvin cycle (C_3), Hatch-Slack pathway (C_4), and Crassulacean Acid Metabolism (CAM).[32] C_3 plants are the most

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[30] The modern-day $\delta^{13}C$ value of atmospheric CO_2 is -7 to -8‰. As discussed, this value has changed over the last 10,000 years. Plants assimilate carbon from atmospheric carbon dioxide (CO_2), where the lighter carbon isotope (^{12}C) is preferentially taken up relative to the heavier isotope (^{13}C). During photosynthesis, the ^{13}C isotope is discriminated against, meaning the carbon isotope value of plants is ^{13}C-depleted compared to atmospheric CO_2 (Richards 2015; Wallace et al. 2013:389). Thus, the $\delta^{13}C$ value of plant tissue is lower than the value of atmospheric CO_2.

[31] The AIRCO2_LOESS data calibrator is found here: http://web.udl.es/usuaris/x3845331/AIRCO2_LOESS.xls (Ferrio et al. 2005).

[32] C_3 plants include temperate grasses, trees (thus most fruit and nuts), legumes, and most major food crops (e.g., wheat, barley, rice, and rye); C_4 plants typically are from arid and/or saline environments and include sub-tropical

common on Cyprus. There are also some wild herbaceous taxa that are C_4, including a small minority of Chenopodiaceae, Cyperacea, and Graminea families (Elmore and Paul 1983; Pyankov et al. 2010). Unfortunately, their use as animal or human food has not yet been demonstrated in prehistoric Cyprus (Lucas 2014), including with Scirè Calabrisotto's (2017a, 2017b) investigation of diet and subsistence economy during the Chalcolithic and Early to Middle Bronze Age (ca. 3900 – 1650 BC) through stable isotope analysis of human and animal bone and teeth.

The crops (two-grained einkorn, hulled barley, and lentil) analyzed in this study are C_3 plants. The degree of ^{13}C discrimination during photosynthesis for this photosynthetic pathway is linked to the opening and closing of the stomata (pores on the surface of plants). A closed stomata means that the plant is conserving water and restricting the availability of CO_2. Thus, the discrimination of ^{13}C is at a minimum, resulting in less negative plant $\delta^{13}C$ values. Water availability is one of the major determinants of stomatal conductance, and this is particularly true for dry regions, such as Cyprus. In these regions, the water status of crops is related to both climate and the agricultural strategies used to minimize risk caused by arid conditions. Thus, $\Delta^{13}C$ serves as a proxy for water availability and can allow researchers to begin to infer about crop water management strategies (Araus et al. 1997; Farquhar et al. 1982, 1989; Farquhar and Richards 1984; Styring et al. 2016; Wallace et al. 2013). The archaeobotanical stable carbon isotope data are interpreted based on Wallace et al. (2013) crop water status $\Delta^{13}C$ bands. They proposed three broad levels of water status for wheat grain, barley grain, and lentil seed: poorly watered crops, where water availability would impose a significant limitation on plant growth;

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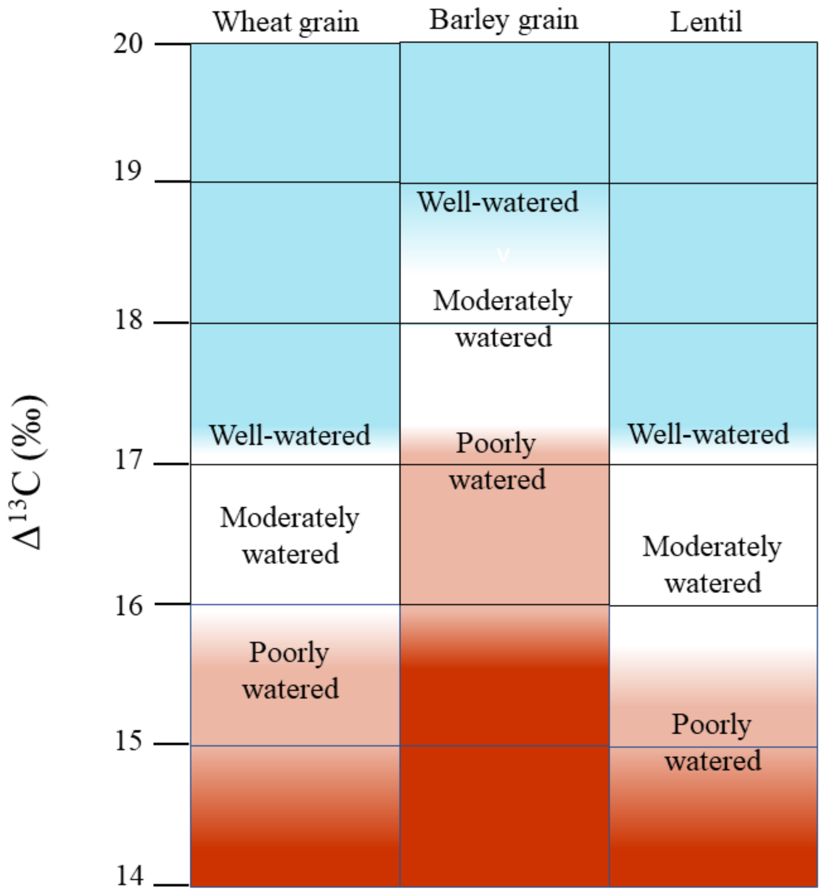
grasses, chenopods, and food crops (some millet, maize, sugarcane, and sorghum); and CAM are typically cacti and other succulents and bromeliads (e.g., pineapple, agave, yucca, and prickly pear (DeNiro 1987; O'Leary 1981).

moderately watered crops; and well-watered crops, where water does not serve as a limitation on plant growth (Figure 4.1). These are discussed in more detail in Chapter 5.

Figure 4.1 Crop water status Δ^{13}C bands



Modified from Wallace et al. (2013:Figure 5, 404)

C_3 and C_4 photosynthetic pathway plants have distinct δ^{13}C values. C_3 photosynthetic pathway plants discriminate the most against ^{13}C. As a result, they have the most negative δ^{13}C values. The mean isotopic value of C_3 plants is around -26‰, with a range of -37 to -22‰. C_4 photosynthetic plants discriminate less against the heavier carbon isotope and therefore have more positive δ^{13}C values compared to C_3 plants. For C_4 plants, the mean isotopic value is around -14‰, with a range of -20 to -7‰ (Deniro 1987; Koch 1998, 2007; Kohn 2010; O'Leary 1981; Richards 2015:19; van der Merwe 1982; Smith and Epstein 1971). There can be subtle differences in $\delta^{13}C$ values within terrestrial C_3-dominated ecosystems, which correspond to the position within and density of the forest canopy. In dense forests, $\delta^{13}C$ values have been observed to range from around -29‰ to -30.5‰ (Ambrose 1986; Drucker et al. 2008; Kohn 2010; Tieszen 1991; van der Merwe and Medina 1981).

Carbon isotopes can also be used to distinguish between marine and terrestrial environments. The $\delta^{13}C$ values of marine organisms is between C_3 and C_4 plants, with an average of -19‰. In this environment, carbon is derived from dissolved bicarbonate, which has a $\delta^{13}C$ value of around 0‰ (Smith 1972; Smith and Epstein 1971).

For herbivores, the carbon isotope composition of both bone collagen and enamel provide an indication of the relative contribution of C_3 and C_4 plants in their diet as well as the types of vegetation available to support them when a number of different animals are analyzed (Koch 1998; Lee-Thorp et al. 1989). The carbon isotopic signature of the plant consumed passes up the food chain and their $\delta^{13}C$ values are reflected in the herbivore's tissues. Due to metabolic fractionation effects, the $\delta^{13}C$ values of bone collagen is depleted by around -5‰ compared to dietary (plant) $\delta^{13}C$ values (Koch, Fogel, and Tuross 1994). Similarly, studies of animals of known diet have demonstrated that there is around a 14.1‰ carbon isotope fractionation between enamel and dietary plant $\delta^{13}C$ values (Cerling and Harris 1999; Cerling et al. 1997; Lee-Thorp and van der Merwe 1987; Lee-Thorp et al. 1989; Wang et al. 1994).

The $\delta^{15}N$ value of crops reflects the isotopic composition of their nitrogen source. In general, there are two nitrogen sources that are of importance for domesticated crops in the Near East: N_2-fixers and non-N_2 fixers. N_2 fixers include pulses, such as lentils. In the nodules of their roots, they host *Rhizobium* bacteria. These bacteria convert atmospheric nitrogen to ammonium ions and pass them to the surrounding soil and plant. This process does not involve substantial isotopic fractionation, and because of this, the δ^{15}N values of N_2-fixers are closer to that of atmospheric nitrogen (i.e., 0‰) (Bernhard 2010; Fraser et al. 2011:2792; Marshall et al. 2007; Vaiglova et al. 2014:202).

Non-N_2 fixers include cereals and they obtain their nitrogen directly from soil nitrates. Factors that affect the δ^{15}N values include soil salinity, soil age, soil depth, sea-spray of nitrates, aridity, climate (temperature and rainfall), and denitrification (Brenner et al. 2001; Fiorentino et al. 2015; Fraser et al. 2011; Heaton 1987; Styring et al. 2016; Vaiglova et al. 2014:202, and citations therein). Denitrification typically occurs in water-logged environments such as marshlands, which is likely not the case for this study. Anthropogenic factors can also cause soil ^{15}N enrichment. These factors are clear-cutting of forests (Pardo et al. 2002), fossil fuel burning (Templer et al. 2007), middening (Bogaard 2012), and manuring (Bogaard et al. 2007; Fraser et al. 2011; Kanstrup et al. 2012, 2014). Fraser et al. (2011) have recently demonstrated that the δ^{15}N values of non-N_2-fixers are more greatly affected by factors that cause soil ^{15}N enrichment, such as manuring, compared with N_2-fixers in traditional farming contexts. The reason for this could be that these plant types directly uptake the amino acids that are present in the soil (Vaiglova et al. 2014:202).

Stable nitrogen isotope values from human and animal collagen are used to determine the trophic level of the individual, or where they are situated in the food web (Deniro and Epstein 1981; Hedges and Reynard 2007). As noted above, plants are the primary way that nitrogen enters the food web. With each step-up the food web (i.e., from plant to herbivore and herbivore to carnivore), there is an enrichment factor. For many years, it was widely believed that this enrichment factor (or isotopic spacing) between diet and consumer tissue was between 3 and 5‰ (Deniro and Epstein 1981; Hedges and Reynard 2007; Schoeninger and Deniro 1984). Recent work, however, by O’Connell et al. (2012) on humans suggests that this value might be higher, between 4.6 and 6‰. As discussed above, nitrogen values in the food web can be influenced by a number of environmental factors, most of which increase the nitrogen isotope values. For animals, these factors include conservation of water in urine in warmer climates, ruminating, and starvation from urea salvaging (Pearson et al. 2015: 71, citations therein). These aspects of animal physiology have been insufficiently resolved (Pearson et al. 2007:2173). Thus, I will follow other published studies that examine nitrogen stable isotope values from animal bone collagen to help with interpretation of this study’s results (e.g., Pearson et al. 2007, 2015; Vaiglova et al. 2014).

4.3.4 Oxygen Stable Isotopes

Oxygen isotopes signature of meteoric water (i.e., water derived from precipitation) vary according to different environmental factors. This property is particularly useful in archaeology for identifying elevation changes and mobility. Oxygen atoms are a main component in the water (H_2O) molecule. Throughout the environment, the ratio of ^{18}O and ^{16}O varies. This is because water molecules that contain the lighter isotope (^{16}O) will evaporate more readily than those that contain the heavier (^{18}O) isotope. On the other hand, ^{18}O condenses and precipitates out more readily than ^{16}O (Dansgaard 1964).

The oxygen isotope ratio in water is primarily influenced by temperature. In the hydrology cycle, temperature acts on precipitation and evaporation rates. In the liquid phase, the heavier ^{18}O is preferentially retained (Gat 1996). Precipitation also becomes isotopically lighter as the parent air mass moves farther from its source (often oceanic water) inland. This is particularly the case as progressive rain out of ^{18}O occurs over mountain ranges, from oceanic sources, to more continental locations. This results in depleted $\delta^{18}O$ values of precipitation as distance from the ocean increases. In addition, at higher elevations cooler temperatures result in lower $\delta^{18}O$ values (Dansgaard 1964; Sharp 2007:82-83). Furthermore, in seasons that are dryer and warmer, such as Mediterranean summers, where the hydrologic cycle is characterized by greater evaporation, the $\delta^{18}O$ value is enriched, as compared with seasons of lower temperature and greater precipitation (Dansgaard 1964; Gat and Gonfiantini 1981). Thus, seasonal surface waters (e.g., perennial streams and puddles), water on leaf surfaces, and groundwater, have higher $\delta^{18}O$ values during the hot, dry season (Gat and Gonfiantini 1981). Empirical studies have determined the relationship between $\delta^{18}O$ values and temperature (Rozanski et al. 1992) and $\delta^{18}O$ values and altitude (Poage and Chamberlain 2001), as follows:

1°C rise in temperature = 0.6‰ increase in the $\delta^{18}O$ value

100 m rise in altitude = 0.3‰ decrease in the $\delta^{18}O$ value.

Oxygen isotopes, in animal tissue, primarily comes from body water, which is influenced by the oxygen isotopic composition of ingested water, atmospheric water, and organic compounds in plants (Makarewicz et al. 2017; Henton 2012; Henton et al. 2010; Longinelli 1984; Luz and Kolodny 1985; Koch 1998, 2007; Koch et al. 1989). The contribution each of these sources make to body water depends on animal energy expenditure and drinking and feeding behaviors (Bryant and Froelich 1995; Levin et al. 2006; Luz et al. 1984). However, the $\delta^{18}O$ values of mineralized hard tissues in herbivores, including enamel, primarily reflects the oxygen isotopic composition of isotopically diverse ingested water sources (e.g., open water, ground water, and/or leaf waters) (Bryant et al. 1996; Levin et al. 2006). Herbivores in arid environments primarily receive their water intake from the plants they consume or via seasonal water sources (e.g., streams and springs) (Silanikove 1989). This means that the $\delta^{18}O$ values from sheep/goat tooth enamel track water derived from the atmosphere (Longinelli 1984; Luz et al. 1984).

As discussed above, tooth enamel in sheep and goats is laid down in sequential layers. Thus, a sequence of samples taken down the tooth contain isotopes that reflect the environment the animal lived in at the time of tooth formation. The samples yield a curve of $\delta^{18}O$ values that show an annual cycle of ingested water (Fricke and O'Neil 1996). A key challenge with sequential sampling, however, is the inability to truly isolate discrete amounts of time. Hence, each enamel sample is associated with a range of formation times, resulting in the temporal signature for a set of enamel samples to be delayed by a few months (Balasse and Tresset 2002). As a result, the $\delta^{18}O$ values are not exact proxies for the local environment. Rather, the $\delta^{18}O$ values reflect changes in elevation and temperature that the animal experiences at the time of tooth formation (Leon 2016).

In semi-arid environments, like the Mediterranean, water availability (i.e., water available for ingestion or water that is incorporated into food sources for herbivores) is tied directly to rainfall due to the seasonal nature of precipitation. Furthermore, the Mediterranean, including Cyprus, lack year-round ice-packs and large water reservoirs (e.g., deep lakes). The sharp relief of Cyprus and its seasonal climate variation should allow good discrimination between $\delta^{18}O$ values in different seasons and altitudes. Thus, the oxygen isotope ratios in sheep and goat tooth enamel can be used to detect birth seasonality and elevation changes. The latter could indicate seasonal movement between lowland and upland pastures.

4.3.5 Summary

To summarize, stable isotope studies have been incorporated into archaeological research designs since the 1960s. However, the application of this technique has greatly expanded since the 1990s with the invention of the mass spectrometer, which helped to substantially decrease the cost of analyses. This study utilizes nitrogen, carbon, and oxygen stable isotopes on botanical and faunal remains from *Ais Giorkis* in order to investigate plant and animal management strategies, which will in turn allow us to infer land use. The $\delta^{15}N$ and $\delta^{13}C$ values from the ancient crops themselves will provide direct information on crop growing and watering practices. The $\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$ values from the bone collagen and tooth enamel will shed light on animal diet, seasonal movement between the lowlands and uplands, and animal birth seasonality.

4.4 Stable Isotope Investigations on Cyprus

The use of stable isotope ratio analysis in archaeology on Cyprus is practically absent in the current literature. However, there are some exceptions. This section summarizes these studies and their major findings. It then concludes with a discussion on the carbon and nitrogen and oxygen baseline data for the island, including contributions that I make to these data.

4.4.1 Stable Isotope Analysis on Cypriot Archaeological Remains

There are currently around 5 publications or dissertations that incorporate stable isotope analyses on Cypriot archaeological remains. The majority of these are from the last few years. However, there is one study that I know of from the 1990s. Lange-Badré and Le Mort (1998) carried out stable isotope analysis on some faunal and human remains from the Neolithic site of Khirokitia to attempt paleodietary reconstruction. Most of their samples did not yield enough collagen to be able to conduct stable isotope analysis on them (i.e., 5 of the 28 individuals had well-preserved collagen). However, the preliminary results suggested a diet dominated by the consumption of animal meat herbivores and cereals for adults and children at the site. These herbivores were primarily feeding on C_3 plants. There was almost no evidence of consumption of marine resources.

Since 2015, several publications and dissertations have also incorporated stable isotopes. Scirè Calabrisotto (2017a, 2017b) used carbon and nitrogen isotope analysis of human and faunal bone and teeth to explore issues of diet and subsistence economy during the Chalcolithic and Early to Middle Bronze Age (ca. 3900-1650 BC). Her dissertation currently remains largely unpublished (Scirè Calabrisotto 2017b). Thus, I summarize the results from her published pilot study (Scirè Calabrisotto 2017a) on paleodiet reconstruction of people at the site of Erimi *Laonin tou Porakou* (Middle Bronze Age). The $\delta^{13}C$ values span from -20.2‰ to -18‰, with a mean value of -19.6‰. The $\delta^{15}N$ values range from 8.1‰ to 10.2‰, with a mean of 9.4‰. These values suggest that the people at the site had a predominantly terrestrial-based diet characterized by C_3 feeding animals. Of note, there is some evidence that people had differential access to certain resources. Specifically, some individuals appear to have consumed less animal proteins. Rather, they were consuming a higher quantity of pulses. It could also be that they were consuming animals that were fed with legumes, which, as noted above, are nitrogenous-fixing plants and have lower $\delta^{15}N$ values than other plants (Scirè Calabrisotto 2017a:Table 11.2-11.3). Scirè Calabrisotto also notes that she did not find evidence for the consumption of marine food or C_4 plant resources in the human and animal isotope data. There is perhaps one exception to this, where an individual yielded an anomalous $\delta^{13}C$ value of -18‰. However, Scirè Calabrisotto notes that the reason for this ^{13}C-enrichment cannot be determined at this time with the limited available isotopic evidence (2017a, 2017b).

In addition to Scirè Calabrisotto (2017a, 2017b), Jeffrey Leon (2016) also recently completed a dissertation that utilized oxygen and strontium isotopes of ovicaprid tooth enamel to examine shepherding and livestock management during the Late Bronze Age. As part of his study, he began to establish a biologically available strontium baseline for the south-central and south-eastern regions, which has not previously been done before on the island. The strontium and oxygen values from the ovicaprid molar enamel suggest three distinct livestock management patterns: localized herding strategy (i.e., animals were kept near the site throughout the entirety of the tooth growth); a regional, coastal strategy (animals were herded along the coast); and a regional strategy that moved some individuals from the lowlands to the uplands.

Finally, for stable isotopes in a Neolithic archaeological context, there is only one study by Dr. Angelos Hadjikoumis and colleagues, which has recently been submitted to the *Journal of Anthropological Archaeology*. The study involves analyzing carbon and oxygen stable isotope values of mandibular third molars of sheep and goat from the sites of *Ais Giorkis* and *Shillourokambos* to investigate birth seasonality. They found that there is an extended period of births for Cypro-PPNB caprines, which deviates from wild populations (mouflons) who have restricted periods of births. Late autumn and early winter births were demonstrated with the data, reflecting results from their ethnoarchaeological survey of traditional caprine husbandry on the island. There were also occurrences of late summer to autumn births, suggesting either summers were milder, or herders were providing fodder. The $\delta^{13}C$ values also shed light on the environmental settings of the caprine husbandry systems, including that caprines from Shillourokambos were likely foraging in higher altitude pastures and that there was a presence of closed canopy in some areas where the caprines were being herded (Hadjikoumis et al. forthcoming).

In sum, while there are less than a handful of studies that have incorporated stable isotope analyses on Cyprus, all studies demonstrate the usefulness of this geochemical technique to research problems that are of anthropological and archaeological interest. In addition, the data from this study can be compared to the results from these other studies to better understand past peoples on the island.

4.4.2. Carbon and Nitrogen Baseline Data

For studies of paleodiet and local environmental conditions using nitrogen and carbon isotopic analyses, it is important to have a thorough knowledge of the range and variation of foods that may have been consumed by past peoples and their animals. Baseline isotopic values from local flora and fauna are often used to help interpret isotope values of prehistoric human remains (e.g., Szpak et al. 2009). These values are typically regionally specific, in part because animals' foraging behaviors can exhibit geographical variability (Szpak et al. 2009). Ultimately, the carbon and nitrogen data produced from this study can be used to help researchers begin to better interpret isotope values of prehistoric human and animal remains on Cyprus.

In terms of animal diet, it is also important to understand the proportions of plant type in a landscape. Studies of aragonitic shell material of land snails have demonstrated their use in tracking isotopic signatures of both fossil and living plant materials (e.g., Goodfriend 1990; Goodfriend and Ellis 2000, 2002; Yanes et al. 2013; ZongXiu et al. 2007). The majority of land snails are primary consumers and feed on living and decayed vascular plants. Thus, $\delta^{13}C$ values of their shell mainly reflect the carbon isotope values of the consumed plants (ZongXiu et al. 2007).

In order to have an idea of the proportions of plant types in western Cyprus, and thus a baseline of regional carbon values, I collected snails from a variety of elevations and geological contexts within the western region.[33] Specifically, I collected land snails from 45 locations (23 locations were collected in summer of 2015 and 22 locations were collected in Spring 2016). This attempt at producing a carbon baseline ran into several major setbacks. The first was that land snails were not always found in the different geological contexts or elevations, especially in the summer of 2015. This is part of the reason why I went back to Cyprus in spring of 2016; however, I ran into a slightly different issue. I used Garmin Glo (program was shapefile over map) on a Dragon Touch Model E-70 in the field to determine elevation and geological context, which did not always work very well in the field. Thus, it made collecting samples from specific areas very challenging. The second issue, which in part relates to the first, is that snails were not collected in a systematic manner across the western region. It likely would have taken far great resources than I had to do this. These limitations leave considerable room for additional researchers to develop carbon (and nitrogen) baseline standards; a point that will be discussed in greater detail in Chapter 8.

The $\delta^{13}C$ values of land snails range from -9.13‰ to -12.29‰, with a mean value of -10.72‰. Based on published literature (e.g., Balakrishnan et al. 2005; Prendergast et al. 2015), these values are consistent with C_3-plant based diets. While there are C_4 plants on the island, these are the minority plant type. It appears that the areas that I sampled are dominated by C_3 plants. While these results are not necessarily as useful as I had hoped for, they do reinforce the idea that far greater research needs to be done to establish baseline standards for stable isotopes on the island. For example, in regard to land snails, a number of studies (e.g., Prendergast et al.

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[33] Appendix B provides a detailed explanation of the preparation and laboratory methodology that was used to analyze these samples.

2015; Yanes et al. 2013) collect living samples from both known C_3 and C_4 plants. In addition, many also collect the C_3 and C_4 plants as samples. They conduct stable isotope analysis of the plant samples, snail shells, and even snail tissues. These data allow for a more informed discussion of the how land snail carbon isotopes can reflect the $\delta^{13}C$ value of local vegetation.

We can still examine carbon and nitrogen isotopes of animal and botanical remains because there is now some comparative data from the island. In addition, there is a substantial amount of published literature from the Southwest Asian mainland which we can also use to help with interpretation of the isotopic results. Finally, the isotope data from this study is also contributing to the carbon and nitrogen baselines on Cyprus.

4.4.3 Oxygen Baseline Data

Studies that investigate animal mobility using oxygen isotopic analyses also require an understanding of the spatial variation in isotopic compositions of precipitation and surface water (Szpak et al. 2013). There are data that provide details on oxygen isotopes on the island. In the late 1950s/early 1960s, the International Atomic Energy Agency (IAEA) and World Meteorological Organization (WMO) began the Global Network of Isotopes in Precipitation (GNIP) database. The primary objective of this project was to systematically collect basic spatial data on the isotope content of precipitation across the world to determine spatial and temporal differences of both environmental stable isotopes (including oxygen isotopes) and tritium (^3H) in precipitation (Global Networks of Isotopes in Precipitation 2015).[34]

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[34] One of the initial drivers of the GNIP initiative was to monitor atmospheric thermonuclear test fall-out. This was measured through the determination of Tritium, the radioactive hydrogen isotope. However, since the 1970s, the focus has shifted and GNIP is the observation network of stable oxygen and hydrogen isotope data for hydrologic studies (Global Network of Isotopes in Precipitation, 2015).

Data for GNIP was collected in Cyprus between 1964 and 1972 (Table 4.2, Figure 4.2). Precipitation samples were taken from: Prodhromos which is located in the central Troödos at 1378 masl; Halefka along the north-western edge of the Troödos at 640 masl; and Nicosia which is located near the center of the *Mesaoria* plain at 224 masl. Unfortunately, the samples were not collected systematically over the study years. This is particularly the case for Prodhromos, where most of the precipitation samples are from the winter months. Because of the inconsistency in data collection, it is difficult to produce a consistent measure of oxygen isotopes in precipitation at various areas across the island. For example, we do not have monthly oxygen isotope data from precipitation for these study years, which would allow for annual weighted mean $\delta^{18}O$ values and mean seasonal $\delta^{18}O$ ranges (as is the case for Anatolia/Turkey). However, the data indicate a broad correlation between elevation and $\delta^{18}O$ values. Prodhromos has the lowest $\delta^{18}O$ values, which makes sense since it is the highest elevation of the surveyed sites (IAEA/WMO 2018).

Figure 4.2 Locations of GNIP Precipitation Samples

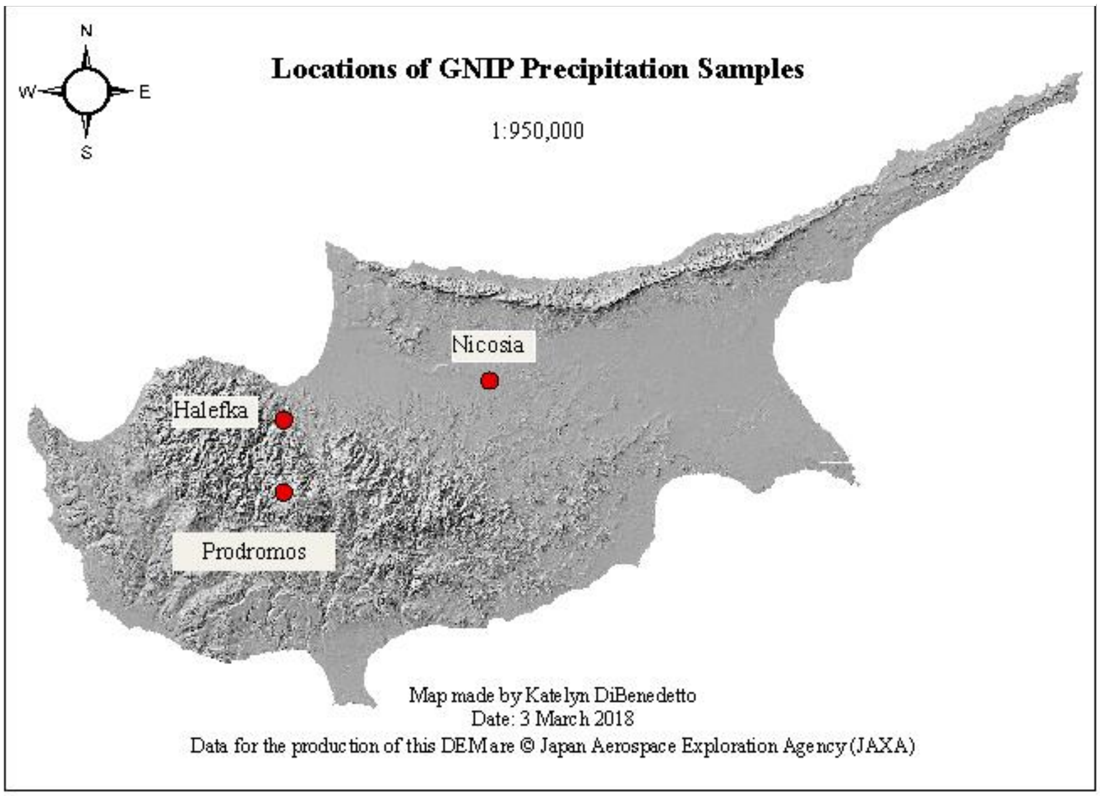

Table 4.2. Global Network of Isotopes in Precipitation (GNIP) δ18O Values from Cyprus

Site	Altitude (masl)	Precipitation Type	Date Samples Collected	$\delta^{18}O$
Nicosia	224	Precipitation	1964-03-15	-2.52
Nicosia	224	Precipitation	1964-12-15	-9.46
Nicosia	224	Precipitation	1965-01-15	-8
Nicosia	224	Precipitation	1965-12-15	-5.15
Nicosia	224	Precipitation	1966-12-15	-4.21
Nicosia	224	Rain	1967-12-15	-4.6
Nicosia	224	Rain	1968-01-15	-5.85
Nicosia	224	Rain	1972-01-15	-6.1
Nicosia	224	Rain	1972-02-15	-4.2
Nicosia	224	Precipitation	1972-05-15	-4.6
Nicosia	224	Precipitation	1972-07-15	-3.5
Halefka	640	Rain	1971-11-15	-4.24
Halefka	640	Rain	1971-12-15	-6.68
Halefka	640	Rain	1972-02-15	-7.1
Halefka	640	Precipitation	1972-03-15	-7.1
Halefka	640	Precipitation	1972-04-15	-7.3
Halefka	640	Precipitation	1972-05-15	-5.2
Halefka	640	Precipitation	1972-06-15	-5.3
Halefka	640	Precipitation	1972-07-15	-8.1
Prodromos	1378	Precipitation	1964-03-15	-6.04
Prodromos	1378	Precipitation	1965-01-15	-8.11
Prodromos	1378	Precipitation	1965-12-15	-7.03
Prodromos	1378	Precipitation	1966-01-15	-6.87
Prodromos	1378	Precipitation	1966-03-15	-7.1
Prodromos	1378	Precipitation	1966-10-15	-5.69
Prodromos	1378	Precipitation	1966-12-15	-6.16

Data are from: IAEA/WMO (2018).

The term *Precipitation* is used when the specific precipitation type was not specified (unreported).

In addition to the GNIP data, Jacovides (1979), with the assistance of the IAEA and Water Development Department (WDD) of Cyprus, conducted an environmental isotope survey across parts of the Troödos Mountains between 1976 and 1978. Water samples were collected from boreholes, springs, and river baseflows originating from the Troödos. In addition, snow and rainfall samples were analyzed for ^3H. For the oxygen data, there was a strong correlation between $\delta^{18}O$ values and elevation. Boronina et al. (2005a) also studied oxygen and hydrogen stable isotopes in the precipitation and groundwater from the Kouris catchment, which is located in south-central Cyprus.[35] They found that there are significant variations in isotopic values between precipitation events. However, they also note that there was a correlation between elevation and oxygen isotopes. Specifically, the altitude gradient for $\delta^{18}O$ was: -0.27 ± 0.26‰ per 100 m. Furthermore, Boronina et al. (2005a) also noted that higher $\delta^{18}O$ values corresponded to the warm, summer months and that lower $\delta^{18}O$ values corresponded to the cool, winter months. This trend matches the expected sinusoidal oxygen isotope curve.

There are important limitations that need to be considered when using modern oxygen isotope values to model values during the Neolithic. The first is that oceanic waters had a different isotopic value than today. They were approximately 2‰ isotopically lighter during the Neolithic due to the evaporative effects of global insolation, which was greater during this time period (Henton et al. 2010:434; Rossignol-Strick 1999). In addition, the changes in the seasonal distribution of humidity and temperature are not entirely understood because of conflicting sapropel, lake core, and pollen evidence (Chapter 2; e.g., Brayshaw et al. 2011a, 2011b; Peyron et al. 2011; Rossignol-Strick 1995, 1999; Turner et al. 2010). As a result, seasonal evaporative effects on oxygen isotope values might differ between the Neolithic and present. Absolute oxygen isotopic values are likely not similar; however, the overall seasonal patterns can be expected to be similar. While there are limitations to using modern data, we can still use these data to look at overall trends in the oxygen isotope values during the Neolithic.

To summarize, these oxygen isotope data from studies on the island show general trends that can be helpful with interpreting the stable oxygen isotope values from the ovicaprid molars, including that there are correlations between $\delta^{18}O$ values and elevation and $\delta^{18}O$ values and seasons. Specifically, there are lower $\delta^{18}O$ values at higher elevations and lower $\delta^{18}O$ values

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[35] Boronina et al. (2005b) also collected groundwater and precipitation samples from the Kouris catchment and analyzed their ^{3}H contents to better understand groundwater hydrology.

during winter months. As noted above, the $\delta^{18}O$ values of the teeth cannot be directly compared to any of the above data. This is because the $\delta^{18}O$ value from the carbonate component of the enamel reflects body water, which is influenced by the oxygen isotopic composition of ingested water, atmospheric water, and organic compounds in plants.

4.5 Materials and Methods

This section provides information on the sample choice, pretreatment of the samples, isotope measurements and precision, and the charring correction. Appendix C provides additional context information for the samples (e.g., level, FN/SFN, year, etc.). The section outline primarily follows that of Vaiglova et al. (2014), who similarly integrated stable isotope analyses of ancient botanical and faunal remains to explore the nature of agricultural economy at the middle-late Neolithic site of Kouphovouno on mainland Greece (5634 - 4997 cal BC; Table 2.1); although the authors did not include oxygen stable isotope analyses on sheep and goat tooth enamel.

4.5.1 Choice of Samples

Five bulk samples of charred archaeobotanical material were analyzed in this study, along with three individual lentil (*Lens* sp.) seeds. The botanical remains had been previously studied by the project paleobotanist, Dr. Leilani Lucas. The bulk samples include 3 samples of hulled barley grain (*Hordeum sativum*) and 2 samples of two-grained einkorn wheat (*Triticum monococcum*). The bulk samples had at least two grains each (Table 4.3). The small sample size is not ideal. Researchers have found it beneficial to analyze bulk samples of at least 5+ grains per analysis since there is a lot of natural variability between individual seeds that is difficult to relate to growing conditions unless many samples are analyzed (pers. communication Dr. Amy Bogaard). On Cyprus, however, there is often poor preservation of charred plant material, although part of this may be due to sampling strategies (Hansen 1991; Lucas 2014). As Fuller and Weber (2005:103) note for botanical remains in general, "Only a small portion of the seeds from a site became carbonized, an even smaller number were preserved, and an even small number retrieved in excavation." While the sample size is small, I demonstrate that stable isotope analyses can be conducted on botanical remains from Cyprus, in hopes that other researchers will continue to utilize effective sampling strategies to recover botanical remains and conduct stable isotopic analyses on at least some of the remains to add to this study's dataset.

Table 4.3 Archaeological Context of Crop Samples

Lab Sample Number	Area/Context	Species	Weight (g)
PL-1	20N 45W	*Lens* sp.	0.013
PL-4	20N 45W	*Lens* sp.	0.007
PL-7	20N 30W	*Lens* sp.	0.013
PL-2	20N 40W	*Hordeum sativum*	0.012 0.015 0.012 0.013
PL-5	20N 40W	*Hordeum sativum*	0.019 0.017 0.012
PL-8	20N 40W	*Hordeum sativum*	0.012 0.012
PL-3	20N 50W	*Triticum monococcum*	0.016 0.02 0.013 0.012 0.019
PL-6	20N 40W	*Triticum monococcum*	0.014 0.014 0.006 0.009 0.007

One hundred samples of animal bone were analyzed in this study (Tables 4.4 – 4.6). These include 34 samples of Mesopotamian fallow deer (*Dama dama mesopotamica)*, 34 caprine, 21 pig (identified as domestic-*Sus Scrofa*), and 11 cattle (*Bos taurus*). Of the 34 caprine bones, 7 were confidently assigned as sheep (*Ovis aries*) and 13 as goat (*Capra hircus*). The sample size in this study is based on: 1.) preservation (i.e., sampling preference for bone material was given to well-preserved long bone shafts with good cortical integrity); 2.) archaeological provenience (i.e., where possible I chose *in-situ* material, and not surface finds); 3.) cost and time; and 4.) published literature.[36] Pearson and Grove (2013) found that eight samples are a sufficient minimum to establish an accurate estimate of the mean $\delta^{13}C$ and $\delta^{15}N$ isotope ratios for a single archaeological site population of herbivores and that more than forty samples would be unnecessary in most cases. Reynard and Tuross (2015) reach similar conclusions as Pearson and Grove (2013) about the minimum number of samples needed to get a reliable estimate of the mean $\delta^{13}C$ and $\delta^{15}N$ values.

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[36] The only species that it was difficult to find well-preserved long bone shafts was with *Bos Taurus*. Most of these samples were from shaft fragments (i.e., less than half of the shaft was preserved).

Table 4.4 Archaeological Context of *Sus* and *Bos* Bones

Lab ID	Identification Number	Species	Area/Context	Element	Initial Weight (g)
Lab ID 31	105-Sus	*Sus Scrofa*	15n30w	radius R	9
Lab ID 32	107-Sus	*Sus Scrofa*	15n30w	radius R	24
Lab ID 33	111-Sus	*Sus Scrofa*	15n30w	radius R	16
Lab ID 34	112-Sus	*Sus Scrofa*	15n30w	radius R	7
Lab ID 35	113-Sus	*Sus Scrofa*	15n30w	radius R	20
Lab ID 36	117-Sus	*Sus Scrofa*	20n25w	tibia R	17
Lab ID 37	119-Sus	*Sus Scrofa*	20n45w	tibia R	12
Lab ID 38	127-Sus	*Sus Scrofa*	30n45w	radius R	19
Lab ID 39	128-Sus	*Sus Scrofa*	30n45w	tibia R	23
Lab ID 40	131-Sus	*Sus Scrofa*	30n45w	tibia R	14
Lab ID 41	135-Sus	*Sus Scrofa*	5n30w	tibia R	26
Lab ID 42	136-Sus	*Sus Scrofa*	5n30w	tibia R	22
AY0058	121-Sus	*Sus Scrofa*	30n40w	humerus L	21
AY0059	122-Sus	*Sus Scrofa*	30n40w	tibia L	34
AY0060	124-Sus	*Sus Scrofa*	30n40w	humerus L	16
AY0061	125-Sus	*Sus Scrofa*	30n45w	humerus L	38
AY0062	115-Sus	*Sus Scrofa*	20n25w	humerus R	22
AY0063	102-Sus	*Sus Scrofa*	15n20w	tibia L	14
AY0064	101-Sus	*Sus Scrofa*	10n25w	humerus L	50
AY0065	108-Sus	*Sus Scrofa*	15n30w	humerus L	63
AY0066	109-Sus	*Sus Scrofa*	15n30w	humerus R	21
Lab ID 43	139-Bos	*Bos taurus*	10n30w	humerus R	123
Lab ID 44	143-Bos	*Bos taurus*	15n20w	tibia R	181
Lab ID 45	149-Bos	*Bos taurus*	20n25w	tibia R	32
Lab ID 46	150-Bos	*Bos taurus*	20n25w	humerus R	15
AY0051	148-Bos	*Bos taurus*	20n25w	radius L	138
AY0052	147-Bos	*Bos taurus*	15n30w	femur L	29
AY0053	152-Bos	*Bos taurus*	5n30w	humerus L	51
AY0054	146-Bos	*Bos taurus*	15n20w	humerus L	40
AY0055	137-Bos	*Bos taurus*	10n25w	radius L	78
AY0056	140-Bos	*Bos taurus*	10n30w	femur L	107
AY0057	151-Bos	*Bos taurus*	30n40w	radius R	77

Table 4.5 Archaeological Context of *Dama* Bones

Lab ID	Identification Number	Species	Area/Context	Element	Initial Weight (g)
Lab ID 1	11-Dama	*Dama dama mesopotamica*	15n20w	tibia R	41
Lab ID 2	13-Dama	*Dama dama mesopotamica*	15n20w	tibia R	29
Lab ID 3	15-Dama	*Dama dama mesopotamica*	15n25w	tibia R	25
Lab ID 4	19-Dama	*Dama dama mesopotamica*	15n30w	tibia R	41
Lab ID 5	23-Dama	*Dama dama mesopotamica*	15n30w	tibia R	23
Lab ID 6	29-Dama	*Dama dama mesopotamica*	20n45w	tibia R	18
Lab ID 7	2-Dama	*Dama dama mesopotamica*	5n30w	tibia R	24
Lab ID 8	32-Dama	*Dama dama mesopotamica*	20n45w	tibia R	24
Lab ID 9	40-Dama	*Dama dama mesopotamica*	30n40w	tibia R	12
Lab ID 10	42-Dama	*Dama dama mesopotamica*	30n40w	tibia R	16
Lab ID 11	44-Dama	*Dama dama mesopotamica*	30n45w	tibia R	31
Lab ID 12	47-Dama	*Dama dama mesopotamica*	30n45w	tibia R	33
Lab ID 13	5-Dama	*Dama dama mesopotamica*	5n30w	tibia R	17
Lab ID 14	48-Dama	*Dama dama mesopotamica*	30n45w	radius R	14
Lab ID 15	50-Dama	*Dama dama mesopotamica*	30n45w	radius R	22
Lab ID 49	3-Dama	*Dama dama mesopotamica*	5n30w	humerus R	50
Lab ID 50	4-Dama	*Dama dama mesopotamica*	5n30w	humerus R	49
AY0084	9-Dama	*Dama dama mesopotamica*	10n30w	tibia L	21
AY0085	7-Dama	*Dama dama mesopotamica*	10n30w	tibia L	37
AY0086	10-Dama	*Dama dama mesopotamica*	15n20w	tibia L	16
AY0087	14-Dama	*Dama dama mesopotamica*	15n25w	tibia L	18
AY0088	16-Dama	*Dama dama mesopotamica*	15n25w	tibia L	43
AY0089	18-Dama	*Dama dama mesopotamica*	15n25w	tibia L	27
AY0090	20-Dama	*Dama dama mesopotamica*	15n30w	radius R	23
AY0091	31-Dama	*Dama dama mesopotamica*	20n45w	tibia L	20
AY0092	34-Dama	*Dama dama mesopotamica*	25n25w	radius L	56
AY0093	38-Dama	*Dama dama mesopotamica*	25n45w	tibia L	28
AY0094	39-Dama	*Dama dama mesopotamica*	30n40w	radius L	14
AY0095	33-Dama	*Dama dama mesopotamica*	20n45w	radius R	26
AY0096	41-Dama	*Dama dama mesopotamica*	30n40w	radius L	28
AY0097	45-Dama	*Dama dama mesopotamica*	30n45w	radius L	50
AY0098	49-Dama	*Dama dama mesopotamica*	30n45w	tibia L	26
AY0099	26-Dama	*Dama dama mesopotamica*	20n25w	radius L	24
AY0100	27-Dama	*Dama dama mesopotamica*	20n25w	radius L	23

Table 4.6 Archaeological Context of Caprine Bones

Lab ID	**Identification Number**	**Species**	**Area/Context**	**Element**	**Initial Weight (g)**
Lab ID 16	55-Caprine	Caprine	15n20w	tibia R	12
Lab ID 17	59-Caprine	Caprine	15n25w	tibia R	10
Lab ID 18	65-Caprine	Caprine	15n30w	tibia R	24
Lab ID 19	68-Caprine	Caprine	20n25w	tibia R	11
Lab ID 20	70-Caprine	Caprine	20n25w	tibia R	18
Lab ID 21	72-Caprine	Caprine	20n25w	tibia R	7
Lab ID 22	80-Caprine	Caprine	20n25w	tibia R	28
Lab ID 23	96-Caprine	Caprine	5n30w	tibia R	7
Lab ID 24	82-Caprine	*Ovis aries*	20n45w	radius R	15
Lab ID 25	92-Caprine	*Capra hircus*	30n45w	humerus R	16
Lab ID 26	56-Caprine	*Ovis aries*	15n25w	radius R	12
Lab ID 27	57-Caprine	*Capra hircus*	15n25w	humerus R	28
Lab ID 28	78-Caprine	*Capra hircus*	20n25w	humerus R	24
Lab ID 29	58-Caprine	*Capra hircus*	15n25w	humerus L	20
Lab ID 30	64-Caprine	*Ovis aries*	15n30w	humerus L	27
Lab ID 47	81-Caprine	*Capra hircus*	20n45w	humerus R	25
Lab ID 48	83-Caprine	*Capra hircus*	20n45w	humerus R	16
AY0067	73-Caprine	*Capra hircus*	20n25w	humerus L	35
AY0068	75-Caprine	*Capra hircus*	20n25w	humerus L	24
AY0069	79-Caprine	Caprine	20n25w	tibia L	15
AY0070	54-Caprine	*Capra hircus*	15n20w	humerus L	43
AY0071	60-Caprine	*Ovis aries*	15n30w	radius R	11
AY0072	52-Caprine	Caprine	15n20w	tibia L	23
AY0073	85-Caprine	*Ovis aries*	20n45w	humerus L	44
AY0074	89-Caprine	*Ovis aries*	25n30w	humerus L	25
AY0075	87-Caprine	*Ovis aries*	20n45w	radius R	12
AY0076	88-Caprine	*Capra hircus*	20n45w	humerus R	18
AY0077	69-Caprine	*Capra hircus*	20n25w	humerus R	18
AY0078	62-Caprine	*Capra hircus*	15n30w	radius L	14
AY0079	67-Caprine	*Capra hircus*	15n35w	radius L	16
AY0080	93-Caprine	Caprine	30n45w	tibia L	10
AY0081	94-Caprine	Caprine	30n45w	humerus L	16
AY0082	95-Caprine	Caprine	35n50w	humerus L	7
AY0083	98-Caprine	Caprine	5n30w	humerus L	9

All individuals are adults and have been analyzed by the project zooarchaeologist, Dr. Paul Croft. Collagen samples were taken from the compact midshaft of skeletal elements (discussed in greater detail below). For the most part, I did not differentiate between skeletal element or body part. Some studies have done this to avoid double measurements of the same individuals (e.g., Balasse et al. 2013; Doppler et al. 2017). However, I discussed this issue with Dr. Croft, and he believed that since I took samples from different contexts across the site as well as the fact that the site was likely occupied for several hundred years, that it would be unlikely for the bones to have come from the same individual.

Seven ovicaprid mandibular molars were analyzed in this study (3 M_3 molars and 4 M_2 molars) (Table 4.7). All are from the right side. Two M_2 molars were confidently assigned to goat and sheep, based on where the accepted morphological criteria in M_3s or P_4s in the same-tooth row could be established (Halstead et al. 2002; Payne 1973, 1985). The rest could not be confidently identified to the species.

Table 4.7 Archaeological Context of Ovicaprid Mandibular Molars

Lab ID	Identification Number	Species	Area/Context	Molar	Payne's (1973) stage
AY0101	159-Molar	Caprine	20n45w	M3	E
AY0102	160-Molar	Caprine	20n45w	M3	G
AY0103	161-Molar	Caprine	20n45w	M3	J
AY0104	156-Molar	*Capra hircus*	20n25w	M2	H
AY0105	158-Molar	Caprine	20n25w	M2	H
AY0106	162-Molar	Caprine	20n45w	M2	H
AY0107	167-Molar	*Ovis aries*	5n30w	M2	F

Note: The sampled molars were attributed to age classes according to Payne's (1973) system.

4.5.2 Wild vs. Domestic Species

The majority of the animal species analyzed in this study are domestic species (sheep, goat, cattle and pig). Wild deer are included because their stable isotope values will help to characterize the environmental surrounding of the site, including whether the wild and domestic animals were feeding in areas with similar stable isotope ecology (Balasse et al. 2013).

All plant species analyzed in this study represent domestic forms. This is largely because most of the experimental studies have focused on crops. Thus, we know how these plants respond to charring (Fraser et al. 2013a; Nitsch et al. 2015), soil ^{15}N enrichment (Bogaard et al. 2016a, 2016b; Fraser et al. 2011; Styring et al. 2016), and water availability (Bogaard et al. 2016a, 2016b; Styring et al. 2016; Wallace et al. 2013). In contrast, experimental studies involving stable isotopes of wild plant species have not been conducted. The interpretations made in this study are based primarily on relative differences between the domestic species.

In addition, the crop stable isotope values are compared with forage values estimated from the collagen of local herbivores. The local herbivores (wild and domestic) represent a local unmanured baseline, due to the fact that their diet is mostly composed of a mixture of wild plants.[37] As noted above the trophic shift between plants and herbivores is between 3-5‰ (Hedges and Reynard 2007). We can subtract 4‰, which is an average of the 3-5‰ range, from the average herbivore nitrogen isotope values to get the unmanured baseline. By comparing these values, it provides another way of inferring ^{15}N enrichment in cultivated crops (Bogaard et al. 2013).

4.5.3 Preparation and Analysis

Pretreatment of the plant material was conducted by Beta Analytic and follows an acid-base-acid protocol. The samples are first crushed then dispersed in deionized water. They are then placed in 10 ml test-tubes and soaked in 2-4 ml of 10% HCI acid between 70-90 °C for two

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[37] By unmanured, I mean natural vegetation. Humans have not added anything, like manure, to enrich soil fertility.

hours and subsequently rinsed in distilled water until the blue litmus paper demonstrates neutrality (3 to 4 rinses). This part of the process helps to eliminate carbonates. Next, there is an alkali wash (NaOH) to remove secondary organic acids. Finally, the samples are treated to another acid rinse to neutralize the solution and then dried in an oven set at 110 °C (Beta Analytic Standard Pretreatment Protocols 2018; personal communication Carlos Barroso and Darden Hood, Beta Analytic). Measurements of plant δ^{15}N and δ^{13}C were performed at Beta Analytic. The elemental analyzer and mass spectrometer are Costech ECS and Thermo Electron DeltPlus IRMS. The standard utilized for δ^{15}N and δ^{13}C isotope analysis was acetanilide, which is an in-house standard that is traceable to NIST 8541, 8573, 8542, RM 8539, 8540, 8547, 8548, and 8550. The expected value of the acetanilide for δ^{13}C is -27.90‰ and the expected value for δ^{15}N is -0.50‰. The standard used for %C, %N, and C:N analysis is Sulphanilamide, which is traceable to the same NIST standards mentioned above. Sulphanilamide should give the following results: %C = 41.85, %N = 16.26, and C:N = 3.00 (personal communication Zeneida Cernada, Beta Analytic).

Samples for collagen extraction were taken from the compact midshaft of skeletal elements.[38] The bone samples (around 300-500 mg) were then cleaned with a diamond-studded Dremel bit to remove the outer layer of cortical bone. This was followed by the samples being cleaned through washes of distilled/deionized water, 95% ethanol (EtOH), and 100% EtOH. Next, samples were treated with a 0.25 M hydrochloric acid solution until the sample was completely demineralized to isolate the collage portion (Ambrose 1990; Schwarcz and

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[38] Pre-treatment of all faunal material was conducted at California State University, Chico. Sarah Hall (M.A. Anthropology student) supervised all sample preparation, with help from Sam Mijal (M.A. Anthropology student), Vanessa Reeves (M.A. Anthropology student), Farah Yousif (B.S., Biochemistry student), Cassie Havens (B.S., Microbiology student), and Tara Burns (B.S., Microbiology student). Dr. Eric Bartelink (California State University, Chico) graciously provided me with the information on the pretreatment process, helped set-up the isotope work with both his lab, the Stable Isotope Facility at UC Davis, and the Stable Isotope Facilty at the University of Wyoming, and answered all my istope questions since fall of 2016.

Schoeninger 1991). In order to eliminate contamination from the burial environment, collagen pseudomorphs were soaked for 24 hours in a 0.125 M sodium hydroxide (NaOH) solution. The samples were then solubilized using dilute HCl (pH is around 3) and freeze-dried in glass vials for analysis on a mass spectrometer. To evaluate sample quality, C:N ratios and percent collagen yield were calculated (van Klinken 1999). Ambrose (1990) set down that the C:N ratio should fall between 2.9 and 3.6, and that collagen yield should be greater than 1% yield. If samples meet these requirements, then the collagen is considered to be well-preserved. Measurements were made at the Stable Isotope Facility at the University of California, Davis (under the supervision of Dr. Joy Matthew) using a PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20-20 isotope ratio monitoring mass spectrometer. Laboratory standards are calibrated against NIST Standard Reference Materials. The long term standard deviation is 0.2‰ and 0.3‰ for ^{13}C and ^{15}N, respectively.

Sample preparation for the ovicaprid tooth enamel included drilling parallel bands of approximately 12 mg of enamel from each tooth using a dental drill. Between each sample, the drill was cleaned thoroughly with de-ionized water. Powdered enamel samples were first immersed in 0.1 M NAOCl in order to remove organic material. The samples were then rinsed in de-ionized water. To remove diagenetic carbonates, they were then further immersed in 5% glacial acetic acid for 4h. Finally, the samples were rinsed again in de-ionized water and then freeze dried. Measurements were made at the Stable Isotope Facility at the University of Wyoming using a Thermo Finnigan Gasbench II, an automatic carbonate preparation device connected to a Thermo Finnigan Delta Plus XP continuous flow isotope ratio mass spectrometer.

4.5.4 Charring Correction for Crop δ^{15}N Values

Fraser et al. (2013a) have shown through experimental studies on several different crop species, including *Lens culinaris*, *Hordeum vulgare*, and *Triticum monococcum*, that charring increases $\delta^{15}N$ values by around 1‰. Their results also indicated that there was not a significant charring effect on the $\delta^{13}C$ values. These results contrast those by Kanstrup et al. (2012) and Aguilera et al. (2008) who did not find charring effects for either the carbon or nitrogen stable isotopes. However, their samples were exposed to experimental temperatures for only 2 hours, which is likely not enough time to replicate the type of charring that causes preservation in the archaeological record (Nitsch et al. 2015:4764; Vaiglova et al. 2013:205). More recently, Nitsch et al. (2015) estimated more precisely the size of the small adjustment that needs to be made to measurements of ancient charred crop remains. They found that there was a statistically significant charring effect on both the $\delta^{13}C$ and $\delta^{15}N$ values. For the $\delta^{13}C$ values, the estimated effect of charring is between 0.003 and 0.22‰, with an average of +0.11‰. For the $\delta^{15}N$ values, the estimated effect of charring is between 0.05 and 0.57‰, with an average of +0.31‰, which is significantly lower than the estimates reported by Fraser et al. (2013). The differences between the two findings is primarily due to the fact that Fraser et al. (2013) relied "on a more conservative estimate of the charring offset of 1‰, meaning that the estimated uncharred $\delta^{15}N$ was made lower and closer to what would have been the estimated value based on the faunal collagen in accordance with the 'standard model'" (Nitsch et al. 2015:11).

For this study, I am going to provide the corrected $\delta^{15}N$ values of the carbonized crop remains from *Ais Giorkis* using both Fraser et al. (2013a) and Nitsch et al. (2015) corrections for the charring effect. Thus, I will correct for the charring effect by subtracting 1‰ and 0.57‰, following Fraser et al. (2013a) and Nitsch et al. (2015), respectively. I will also provide the corrected $\delta^{13}C$ values of the carbonized crop remains. Specifically, I will subtract the worst-case estimate (i.e., the more conservative estimates) of 0.22‰ determined by Nitsch et al. (2015). I have chosen to use both of the worst-case estimates for the carbon and nitrogen isotopes by Nitsch et al. (2015) because my sample sizes are often smaller than the recommended minimum (i.e., minimum of 5 pulse seeds or cereal grains per sample). In addition, I am presenting both corrections for charring effects for two primary reasons. The first is much of the published literature continues to use the 1‰ correction. As a result, in order to compare my results with the published literature, I will also use this correction factor. The second reason is that the 1‰ correction does represent the most conservative estimate. If my results still demonstrate ^{15}N enrichment with this estimate, then it will further support the idea that the Neolithic peoples were manipulating the soil that crops were being grown in.

4.6 Conclusion

This chapter primarily focuses on the stable isotopes of interest in this study: carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$), oxygen isotopes ($\delta^{18}O$). Bone collagen, tooth enamel, and charred cereal remains are the archaeological materials used here. Carbon and nitrogen stable isotope analysis of animal bone collagen provides detailed information about animal diet. In turn, animal diet sheds light on landscape use, the nature of the continued hunting of wild animals, and the herding of domesticated animals (Pearson et al. 2015:69). Oxygen and carbon isotopes in caprine tooth enamel help establish the seasonality and locality of food and water intake of these animals. This evidence allows for the investigation of annual herding mobility and breeding and birth seasonality (Henton 2012; Henton et al. 2010). Recent investigations in the stable isotope field have demonstrated the potential of obtaining direct evidence of agricultural practices from archaeobotanical remains. $\delta^{15}N$ and $\delta^{13}C$ values reflect crop growing conditions, including soil nitrogen composition and water availability (Bogaard et al. 2007, 2013; Fraser et al. 2011, 2013a; Vaiglova et al. 2014; Wallace et al. 2013). The integration of geochemical studies on ancient crop and faunal remains study represents the first of its kind for a Cypriot archaeological site. The results of this study are presented in the next chapter.

CHAPTER 5: CARBON AND NITROGEN ISOTOPE RESULTS OF THE *AIS GIORKIS* CEREALS AND CROP MANAGEMENT STRATEGIES

5.1 Introduction

This chapter discusses the crop management strategies that can be inferred from the nitrogen and carbon isotope analysis of the cereal grains and lentil seeds from *Ais Giorkis*. I first present the results, including how the reliability of crop isotope measurements was assessed. Next, I focus on the δ^{15}N values, in particular how humans were managing the soil that the crops were grown in. I then discuss the δ^{13}C values, and what they reveal about plant water status and water management strategies. For both of these sub-sections I compare the results from the *Ais Giorkis* cereals with stable isotope measurements of crop remains from Neolithic sites from the Southwest Asian and European mainlands. The reasons for this are twofold. For one, the comparative data allow me to make a stronger case for particular crop management strategies. In addition, it enables the crop management strategies by the island's inhabitants to be placed within a broader pan-Southwest Asian context. Finally, I conclude by incorporating the stable isotope results with the macrobotanical evidence to provide a more holistic understanding of crop management strategies at *Ais Giorkis*.

5.2 Results from the δ^{15}N and δ^{13}C Analysis of the *Ais Giorkis* Crop Remains

This section presents the results from the δ^{15}N and δ^{13}C analysis of the crop remains from *Ais Giorkis*, including how the reliability of the crop isotope measurements was assessed. The section outline primarily follows that of Vaiglova et al. (2014). As noted in Chapter 4, these authors similarly integrated stable isotope analyses of ancient botanical and faunal remains from a Neolithic village in southern Greece.

5.2.1 Assessing the Reliability of the Crop Isotope Measurements

In contrast to assessing the reliability of bone collagen (Chapter 4 and Chapter 6), there are no agreed upon rules for accepting or rejecting crop isotope measurements based on their C:N ratios (Vaiglova et al. 2014:205). Recently, Roberts et al. (2018) provided guidelines for reporting results from stable isotope applications in archaeology. They noted that common diagenetic checks for crop remains include providing %C, %N, and the C:N atomic ratio (Roberts et al. 2017:363, Table 1). As a result, I provide this information (Table 5.1). Furthermore, following Vaiglova et al. (2014), I also compared the C:N ratios obtained in this study to values of experimentally charred cereals and pulses (Tables 5.2-5.3). The experimental data are from Fraser et al (2013a) who found that after pre-treatment, the %C and %N contents and the C:N ratios can provide useful criteria for assessing the preservation of archaeobotanical remains.

Table 5.1 %C, %N, and C:N values for *Ais Giorkis* crop remains

Lab Code	Area/context	%C	%N	C:N atomic ratios reported by Beta Analytics	C:N atomic ratios[a]
Hulled Barley					
PL-2	20N 40W SWQ	40.6	2.8	16.8	16.9
PL-5	20N 40W SEQ	59.5	2.1	32.7	33.1
PL-8	20N 40W	60.9	2.0	36.3	35.5
Two-grained Einkorn					
PL-3	20N 50W SEQ	60.8	3.5	20.4	20.3
PL-6	20N 40W SWQ	57.4	3.0	22.7	22.3
				SD (1σ) of C:N for cereals	8.2
				C:N max for Cereals	35.5
				C:N min for Cereals	16.9
Lentil					
PL-1	20N 45W SEQ	41.4	4.5	10.7	10.7
PL-4	20N 45W SEQ	60.7	8.5	8.3	8.3
PL-7	20N 30W SEQ	40.6	2.8	16.8	16.9
				SD (1σ) of C:N for pulses	4.4
				C:N max for pulses	16.9
				C:N min for pulses	8.3

[a] I calculated the C:N ratios following the equation used by Vaiglova et al. (2014): (%C/%N)*(14/12). The results are similar to the C:N atomic ratios calculated by Beta Analytics.

Table 5.2 %C, %N, and C:N values for experimentally charred modern cereals (data are from Fraser et al. 2013a)

Sample ID	Cereal taxon	%C[a]	%N[b]	C:N atomic ratios[c]
BAD04-18W	Bread wheat	59.0	1.9	36.2
BAD07-44W	Bread wheat	62.3	2.8	26.0
ASK08-513E	Emmer	62.2	4.1	17.7
ASK08-524E	Emmer	60.7	2.9	24.4
ASK08-526E	Emmer	62.4	3.4	21.4
ASK08-532E	Emmer	62.0	3.2	22.6
ASK08-544E	Emmer	63.4	3.7	20.0
SUT08-25E	Emmer	67.1	3.3	23.7
SUT08-31K	Einkorn	63.2	3.8	19.4
SUT08-37K	Einkorn	66.1	3.7	20.8
BAD07-6G	Hulled barley	63.9	2.6	28.7
BAD07-12G	Hulled barley	63.3	3.3	22.4
BAD07-18G	Hulled barley	63.3	2.9	25.5
ASK08-513G	Naked barley	63.8	3.4	21.9
ASK08-524G	Naked barley	64.1	3.9	19.2
ASK08-526G	Naked barley	63.6	3.6	20.6
ASK08-532G	Naked barley	63.0	3.9	18.8
ASK08-544G	Naked barley	64.5	3.3	22.8
			SD (1σ) of C:N for cereals	4.3
			C:N max for Cereals	36.2
			C:N min for Cereals	17.7

[a] The %C values come from Supplementary Table 1.

[b] The %N values come from Supplementary Table 2.

[c] Vaiglova et al. (2014) calculated the C:N ratio using the following equation: (%C/%N)*(14/12)

Table 5.3 %C, %N, and C:N values for experimentally charred modern pulses (data are from Fraser et al. 2013a)

Sample ID	Cereal taxon	%C[a]	%N[b]	C:N atomic ratios[c]
BAD07-6P	Pea	64.9	7.1	10.7
BAD08-6P	Pea	65.0	6.0	12.6
BAD08-12P	Pea	65.4	5.8	13.2
BAD08-18P	Pea	65.6	6.3	12.1
BAD07-18P	Pea	58.1	6.5	10.4
BAD08-6B	Broad bean	62.6	8.3	8.8
BAD087-12B	Broad bean	62.3	7.5	9.7
EW07-25B	Broad bean	57.2	6.7	10.0
ICA09-11L	Lentil	64.5	6.4	11.8
ICA09-12L	Lentil	64.1	7.0	10.7
ICA09-13L	Lentil	63.1	6.4	11.5
ICA09-14L	Lentil	62.6	7.1	10.3
ICA09-15L	Lentil	62.2	7.0	10.4
ICA09-16L	Lentil	64.1	6.7	11.2
ICA09-17L	Lentil	62.1	6.8	10.7
			SD (1σ) of C:N for pulses	1.2
			C:N max for pulses	13.2
			C:N min for pulses	8.8

[a]The %C values come from Supplementary Table 1.
[b]The %N values come from Supplementary Table 2.
[c]Vaiglova et al. (2014) calculated the C:N ratio using the following equation: (%C/%N)*(14/12)

The C:N ratios of the *Ais Giorkis* cereals are between 16.9 and 35.5; those of modern experimentally charred cereals lie between 17.7 and 36.2. Statistically, there are no significant differences between these two groups (two sample t-test with equal variance between *Ais Giorkis* cereals and modern charred cereals, $p = 0.2843$). The C:N ratios of the *Ais Giorkis* lentils are between 8.3 and 16.9; those of modern experimentally charred lentils lie between 8.8 and 13.2. Statistically, there are no significant differences between these two groups (Welch two sample t-test between *Ais Giorkis* lentils and modern charred lentils, $p = 0.7282$).[39] In addition, the %C

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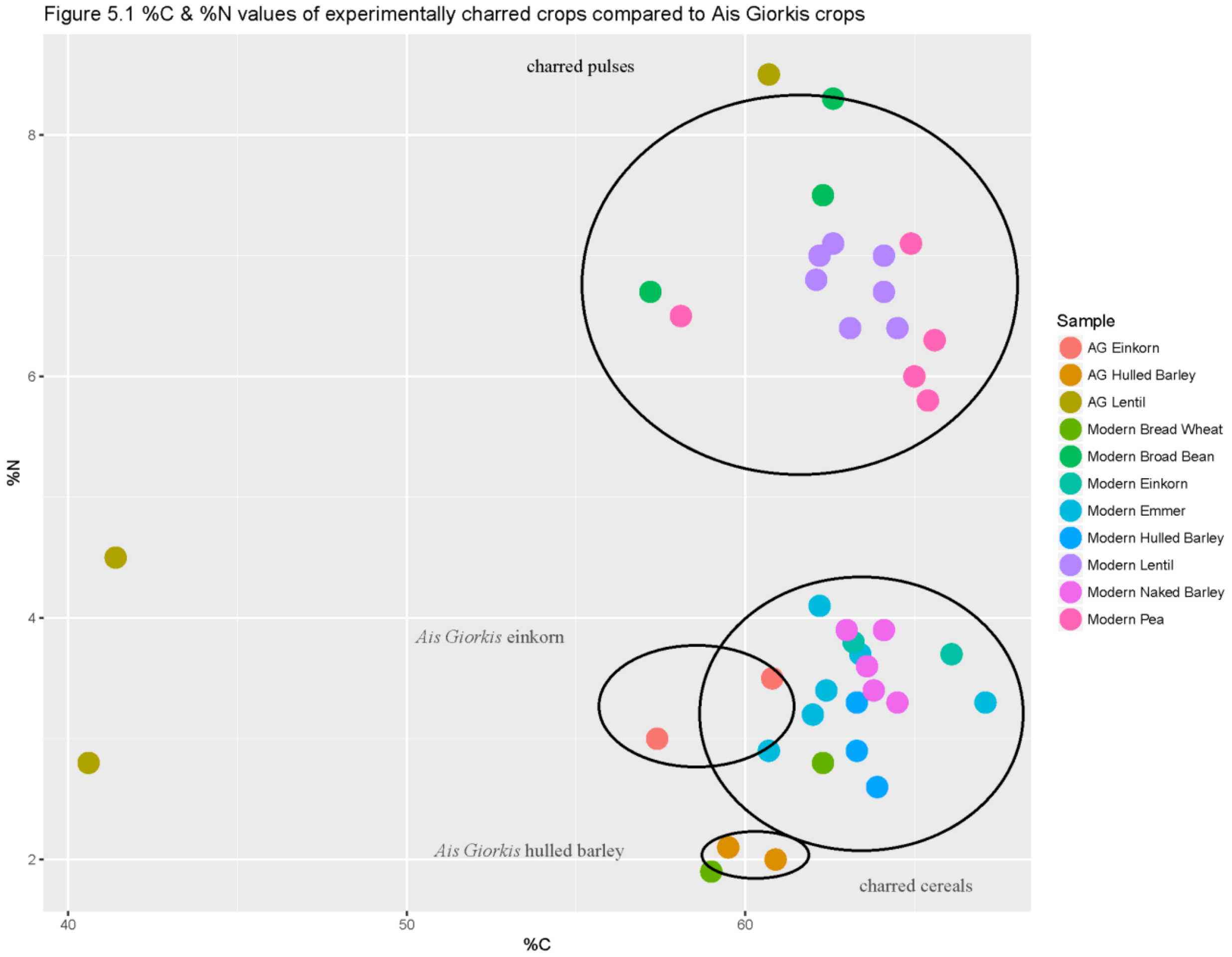
[39] I first tested the differences between the variances using an F-test (*var.test* in the statistical package R). There was not a statistically significant difference between the variances of the *Ais Giorkis* cereals and modern charred cereals ($p = 0.06$). This means that the variances between both groups was homogenous. As a result, I used the two-sample t-test with equal variance (*t.test(a,b,var.equal*=TRUE) in R). There was a statistically significant difference between the variances of the *Ais Giorkis* pulses and modern charred pulses ($p < 0.001$). This means that the variances between the two groups are different. Thus, I used the Welch two sample t-test (*t.test(a,b)* in R) to account for the unequal variance.

and %N measurements from the *Ais Giorkis* crop samples generally show similar trends as the experimentally charred samples: 1.) pulses generally have higher %N than cereals; 2.) among the cereals, there is some species clustering in %N (Figure 5.1); and 3.) the cereals and pulses have indistinguishable %C values (two sample t-test with equal variance between *Ais Giorkis* cereals and modern charred cereals, $p = 0.2843$).[40] Based on these observations, it appears that the crop remains are well-preserved, implying that the isotope measurements of the *Ais Giorkis* cereals should be reliable (i.e., the original δ^{15}N and δ^{13}C values can be obtained).

Figure 5.1 %C and %N values of experimentally charred crops compared to *Ais Giorkis* crops



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[40] Based on data provided by Fraser et al. (2013), the experimentally charred cereals and pulses have indistinguishable %C values (two sample t-test with equal variance between modern cereals and pulses, $p = 0692$). Both groups had homogenous variances (%C values for *Ais Giorkis* cereals and lentils, $p = 0.5729$; %C values for modern cereals and lentils, $p = 0.221$).

Table 5.4 Stable isotope results of Neolithic crop samples from *Ais Giorkis*

Lab Code	Area/context	Original δ^{13}C	Original δ^{15}N	δ^{13}C (Nitsch et al. 2015 charring correction)[a]	δ^{15}N (Fraser et al. 2013 charring correction)[b]	δ^{15}N (Nitsch et al. 2015 charring correction)[b]	δ^{13}C of CO2[c]	Δ^{13}C[d]
Hulled Barley								
PL-2	20N 40W SWQ	-23.3	4.6	-23.5	3.6	4.0	-6.6	17.3
PL-5	20N 40W SEQ	-23.7	4.5	-23.9	3.5	3.9	-6.6	17.7
PL-8	20N 40W	-23.5	5.2	-23.7	4.2	4.6	-6.6	17.5
			Average	-23.7	3.8	4.2		17.5
			SD (1σ)	0.2	0.4	0.4		0.2
Two-grained Einkorn								
PL-3	20N 50W SEQ	-22.6	0.7	-22.8	-0.3	0.1	-6.6	16.6
PL-6	20N 40W SWQ	-22.2	1.3	-22.4	0.3	0.7	-6.6	16.2
			Average	-22.6	0.0	0.4		16.4
			SD (1σ)	0.3	0.4	0.4		0.3
Lentil								
PL-1	20N 45W SEQ	-27.4	-0.9	-27.6	-1.9	-1.5	-6.6	21.6
PL-4	20N 45W SEQ	-24.2	1.4	-24.4	0.4	0.83	-6.6	18.3
PL-7	20N 30W SEQ	-23.6	-1.0	-23.8	-2.0	-1.6	-6.6	17.6
			Average	-25.3	-1.2	-0.7		19.2
			SD (1σ)	2.0	1.4	1.4		2.1

[a] All reported plant δ13C values have been corrected for the charring effect by subtracting 0.22‰ (Nitsch et al. 2015).

[b] All reported plant δ15N values have been corrected by subtracting 1‰ (Fraser et al. 2013a) and 0.57‰ (Nitsch et al. 2015). Please see Chapter 4 for a discussion on why both values are reported.

[c] Average value for the chronological time period, which is calculated using AIRCO2_LOESS data calibrator (Ferrio et al. 2005).

[d] The equation is presented in Chapter 4.

5.2.2 Crop δ^{15}N and δ^{13}C Values

Table 5.4 presents the stable isotope results of the crop samples from *Ais Giorkis*. To account for the effects of charring on crop δ^{15}N values, I subtracted 1‰ and 0.57‰ from the original values based on experimental studies conducted by Fraser et al. (2013a) and Nitsch et al. (2015), respectively. In Chapter 4, I discuss why I provide both corrections. For this section, I only present the values using the correction factor by Nitsch et al. (2015). The δ^{15}N values of the hulled barley range from 3.9 to 4.6‰, with an average of 4.2 ± 0.4‰. The mean of the δ^{15}N values of the two-grained einkorn wheat is 0.4 ± 0.4‰.

Through experimental studies, Nitsch et al. (2015) strongly suggest that if the confidence range is extended ± 0.5‰ for δ^{13}C or ± 1.0‰ for δ^{15}N than the results are too variable to merit interpretation. If the δ^{13}C and δ^{15}N measurements fall within this range, we can consider the results 95% likely to encompass the true population mean. This appears to, in part, be tied to the number of seeds/grains per sample, with their recommendation being that a sample should have no less than 5 seeds or grains (Nitsch et al. 2015). The confidence ranges for the nitrogen isotope results from both the hulled barley and the two-grained einkorn wheat are less than ± 1.0‰. This implies that the values can be interpreted, although still cautiously given the small sample size. There is also no overlap between these two cereals' δ^{15}N values. Furthermore, the two groups are statistically different from one another (two sample t-test with equal variance, $p < 0.001$).

The δ^{15}N values of the three lentil seeds range from -1.6 to 0.83‰, with an average of -0.7 ± 1.4‰. Unfortunately, the confidence range for the lentil nitrogen isotopes values extends beyond ± 1.0‰. This implies that the results are too variable to merit interpretation (Nitsch et al. 2015:12). This makes sense given that each sample only has a single seed, lending further support to conclusions made by Nitsch et al. (2015) about the importance of bulk samples to account for natural variation in the plant.

To take into consideration the charring effect on the $\delta^{13}C$ values, I subtracted 0.22‰ from the original values, based on experimental studies conducted by Nitsch et al. (2015). The $\delta^{13}C$ values of the hulled barley range from -23.9 to -23.5‰, with an average of -23.7 ± 0.2‰. The average $\delta^{13}C$ value for the two-grained einkorn samples is -22.6 ± 0.3‰. The confidence range falls within the recommended range; thus, these values can be interpreted. There is no significant difference in $\delta^{13}C$ values for the hulled barley and the two-grained einkorn (two sample t-test with equal variance, $p = 0.06$). The $\delta^{13}C$ values from the *Ais Giorkis* cereal samples are similar to values reported from Neolithic sites in southwest Asia (Wallace et al. 2015), further discussed below.

As noted in Chapter 4, atmospheric $\delta^{13}C$ values have changed over time. In order to compare results both from different periods as well as with modern crops grown under known watering conditions, the carbon results should be expressed as $\Delta^{13}C$ (carbon discrimination) (Ferrio et al. 2005). Based on calculations using the AIRCO2_LOESS data calibrator (Chapter 4; Ferrio et al. 2005), the $\delta^{13}C$ value of atmospheric CO_2 at the time *Ais Giorkis* was inhabited was -6.6‰. The $\Delta^{13}C$ values for the hulled barley range between 17.3 and 17.7‰, with an average of 17.5 ± 0.2. For the two-grained einkorn, the mean $\Delta^{13}C$ is 16.4 ± 0.3‰.

The $\delta^{13}C$ values of the three lentil seeds fall between -27.6 and -23.8‰, with a mean of -25.3 ± 2.0‰. Similar to the nitrogen measurements, the confidence range is greater than the recommended ± 0.5‰. As such, the results are too variable to be able to provide an interpretation.

To summarize, the confidence range for the $\delta^{15}N$ and $\delta^{13}C$ values of the *Ais Giorkis* cereals fall within the recommended values. This means that the results merit interpretation. Unfortunately, the confidence range for the nitrogen and carbon measurements of the *Ais Giorkis* lentils fall beyond the recommended value. These results are too variable, and thus, we are not able to provide interpretations.

5.3 Environmental vs. Anthropogenic Reasons for Crop ^{15}N Enrichment

As noted above, there is no overlap between the $\delta^{15}N$ values of the hulled barley (mean $\delta^{15}N = 4.2 \pm 0.4‰$) and the two-grained einkorn wheat (mean $\delta^{15}N = 0.4 \pm 0.4‰$), which is also shown in Figure 5.2. In contrast to the wheat, the hulled barley samples have an enriched $\delta^{15}N$ value. Vaiglova et al. (2014:205) suggest that, "the only possible explanation for such a striking difference is that the crops were cultivated in different soils with distinct soil N properties." To be able to explain the differences between soils where these two crops were grown, I consider the environmental and then anthropogenic reasons. To do this, I provide a literature review of possible environmental and anthropogenic aspects that could be impacting the $\delta^{15}N$ values. I argue that the enriched nitrogen is likely due to human involvement in the plant growing process. In the next section, I discuss how humans might have manipulated the soil that the barley was growing in.

5.3.1 Environmental Reasons

A wide variety of natural environmental factors have been found to influence the $\delta^{15}N$ values of plants, as introduced in Chapter 4, and include: denitrification, soil salinity, sea-spray of nitrates, and aridity. None of these environmental factors are likely to have affected the fields where the hulled barley and two-grained einkorn from *Ais Giorkis* were being grown.

Denitrification occurs in water-logged conditions, such as marshlands/wetlands. A recent study by Markogianni et al. (2014) has identified over 300 wetland sites; however, many of these sites are artificial or semi-artificial water bodies. Numerous natural small wetland features have also been severely degraded by anthropogenic changes. In addition, the majority of the wetlands in western Cyprus are located on or near the coast. None appear to be near *Ais Giorkis* (Markogianni et al. 2014:Figure 1). Recall that there is limited paleoenvironmental data for the Early Neolithic. Thus, it is hard to determine whether wetland environments were exploited by people during this time period. Historically, wetlands on the island were perceived as potentially valuable agricultural land; but, they were also host-areas for diseases, including malaria. *Mylouthkia* is currently the only other securely dated and excavated Cypro-PPNB coastal site (Chapter 2) in western Cyprus. According to the map of survey results produced by Markogianni et al. (2014), today there are wetland sites near this settlement. At *Mylouthkia*, there is little evidence of the early stages of crop processing, which implies that agricultural fields were not near the site. While it is possible that Neolithic peoples could have been utilizing wetlands for agriculture, I would argue against this based on: 1.) crop processing evidence from *Mylouthkia*; 2.) the location of *Ais Giorkis* (i.e., there are no wetlands near the site); and 3.) the fact that most wetland habitats in the western region are found along the coasts. Thus, based on current evidence, I do not believe that denitrification impacted the nitrogen values of the *Ais Giorkis* cereals.

Salinization is the process in which sodium chloride is added to agricultural fields. Typically, this occurs in areas where there is poor drainage, naturally high salt levels in the soils, low rainfall, high water table, excessive irrigation water, high levels of evaporation, and insufficient uptake of water by crops (Altaweel 2013). Geophysical and hydrological reconstructions of the environment at *Ais Giorkis* indicate that it was well-drained. Furthermore, there is almost no archaeological evidence that salinization impacted soils during the Early Neolithic. Thus, I do not believe that salinization would have affected the nitrogen values of the hulled barley and two-grained einkorn wheat from *Ais Giorkis*.

Plants growing near coasts can have elevated δ^{15}N values due to ^{15}N enrichment of nitrates in sea-spray (Heaton 1987; Virginia and Delwiche 1982). Since *Ais Giorkis* is not located near the coast, it seems unlikely that nitrates could have been introduced to the site through sea-spray. While we currently do not know where the crops recovered from *Ais Giorkis* were grown, the only archaeological site located on the western coast during the Cypro-PPNB (*Mylouthkia*) does not have strong evidence for fields being located at or near the site. As a result, sea-spray of nitrates likely did not cause the ^{15}N enrichment that we see in the hulled barley.

A number of studies of vegetation and soil have found a positive correlation between aridity (i.e., low rainfall and high evapotranspiration) and δ^{15}N values (e.g., Aranibar et al. 2004; Hartman and Danin 2010; Heaton 1987; Swap et al. 2004). If there was an ecosystem aridity effect, this likely would have affected the entire region. Elevated δ^{15}N values would have been found in both fields, rather than one field but not the other. In addition, both cereals had enough water available to them (discussed below), making it unlikely that they suffered from varying degrees of water stress (Vaiglova et al. 2014:206).

5.3.2 Anthropogenic Reasons

As introduced in Chapter 4, there are a handful of anthropogenic factors that can affect nitrogen isotope values: clear-cutting of forests, fossil fuel burning, middening, and manuring. It is unlikely that the first two factors affected the *Ais Giorkis* cereals. Burning of fossil fuels was clearly not occurring during the Neolithic. In addition, the clear-cutting of forests only produces a short-term enrichment; thus, it likely would not impact plant nitrogen values. Middening and manuring provide interesting possibilities for the enrichment of at least the hulled barley. For the purpose of this study, middening refers to the spread of domestic waste on arable land and manuring is the use of animal dung on agricultural fields (Bogaard 2012:25).

Several studies have created different experimental farm settings which have demonstrated that the addition of manure to the soil raises the $\delta^{15}N$ values of the cultivated crops (e.g., Bogaard 2012; Bogaard et al. 2007, 2016a, 2016b; Fraser et al. 2011; Kanstrup et al. 2012, 2014; Styring et al. 2016). One of the first pilot studies was examining the impact of manure on bread wheat $\delta^{15}N$ values at Rothamsted (Hertfordshire, England) and a similar long-term experiment in Leipzig-Halle, Germany. This study found that manuring causes significant increases in crop $\delta^{15}N$ values on the order of trophic level (Bogaard et al. 2007). These results have been confirmed by follow-up projects, which include a range of traditional and experimental farming studies across Europe (Fraser et al. 2011; Bogaard et al. 2012) and the Mediterranean (Bogaard et al. 2016a, 2016b; Styring et al. 2016). In several of these experiments, the $\delta^{15}N$ values have increased by up to 10‰, depending on the intensity of manuring (Fraser et al. 2011).

Animal dung is added to cultivation plots in order to restore nutrients and increase crop yields. Animal manure has high $\delta^{15}N$ values because ^{14}N is preferentially lost in gaseous ammonia through volatilization. As a result, the heavier ^{15}N is left behind in the soil. This residual ammonium is subsequently converted to nitrate with high $\delta^{15}N$ values, which is taken up by the plants (Bogaard 2012:38; Bogaard et al. 2007:336; Vaiglova et al. 2014:206).

Middening is typically considered an extension of manuring, because kitchen waste material decomposes and provides ^{15}N enrichment to the soil (Bogaard 2012; Vaiglova et al. 2014: 206). However, it is thought that household domestic waste alone would be insufficient for intensive application across the cultivation plot that is required to produce staple grain crops. A small-scale household of five to seven people would need to cultivate around one hectare to grow staple pulses and cereals, assuming reasonably high area yields (Bogaard 2004:42-43, Table 2.2). It is unlikely that the household would be able to generate more than a few tons of waste each year (e.g., Dalzell et al. 1987:44, 63). Thus, application, and especially intensive application (i.e., an amount that would result in an enriched ^{15}N signal in the crop remains), of domestic waste would only be possible on a small portion of the household's arable land. Bogaard (2012:33) suggests that the size could be no more than one-third of a hectare with 3 tons of domestic waste per year. She considers this domestic waste amount possible only if there is high availability of composted waste, although this amount is still assuming only moderate levels of domestic waste being applied to cultivation plots (i.e., 10 tons per hectare). The issue of middening is complicated by the fact that domestic waste is often fed to domestic animals, particularly pigs, that are kept near the household (Bogaard 2012:33).

Currently, modern studies have not measured the effect of middening on crop nitrogen isotope values, although, because of the issues brought up above, it is expected that mixed domestic waste would not have as high of an effect as that provided by manure (Bogaard 2012:38). One of the ways to document this practice in the archaeological record is through the presence of pottery sherds in areas of potential cultivated plots. For example, land surveys at

Kouphovouno have revealed the presence of Neolithic pottery. It has been hypothesized that some of these sherds originated from kitchen waste, raising the question of whether domestic waste at this site might have provided an opportunity for soil enrichment (Vaiglova et al. 2014). Unfortunately, the Cypro-PPNB does not have pottery. While kitchen waste could have been transported in perishable materials, both the lack of pottery and the unknown location of Early Neolithic fields makes it difficult to determine whether middening could have influenced the nitrogen values of the *Ais Giorkis* cereal remains. It is plausible that Early Neolithic peoples in Cyprus did add domestic waste to their crop fields, but it was likely not in sufficient enough quantities to be the cause of the ^{15}N enrichment that we see with the hulled barley samples. As noted by Bogaard (2012:33): "The chronic shortage of domestic waste as intensive fertilizer for staple grains highlights the key role potentially played by animal manure."

Fraser et al. (2011) define three isotope ranges which represent three different bands of manure treatment based on a range of manuring levels/regimes at locations extending from northwest Europe to the eastern Mediterranean: 1.) cereals grown without manure over the long-term are low in ^{15}N ($\delta^{15}N$ values below 2.5‰); 2.) medium level of manuring (values between ~2.5 and 6.0‰) resulting from early years of a new cultivation regime, residual effects after a period of intensive manuring, or long-term cultivation with low manuring; and 3.) long-term continued cultivation of crops with high levels of manure deposited annually (values above 6‰). The experimentally manured crops used to establish the manure band are based on the application of 20-35 tons of manure per hectare, raising the question: how plausible was it for Neolithic peoples to practice manuring in Cyprus?

Cattle provide between two and twelve tons of manure per animal per year depending on their body size and diet (Bogaard 2012:33-34; Rowley-Conwy 1981:94). They roughly provide

27 kg of excrement each day (McClure 2015:Table 1). Sheep and goats produce far less manure than a single cow; the former produces between 1.5-2 kg/day and the latter between 2-2.5 kg/day (McClure 2015:Table 1). Thus, they produce around one-tenth to one-eighth the manure of a single cow each year (Bogaard 2012:34). The manure of all domestic animals would need to be combined in order to have enough manure available during the Early Neolithic to achieve soil enrichment.

Application of the manure to cultivation plots would need to be done manually. If animals alone were allowed to graze on the fields during the off-season, this likely would not produce the degree of enrichment implied by the isotope data (Bogaard 2012). This means that the manuring strategy was not simply a by-product of herding animals on cultivated plots. Rather, it involved a very conscious and planned manipulation of the soil (Vaiglova et al. 2014:207). Draught animals could also be used for spreading manure on fields. Documentation of this is often done through the analysis of pathologies on these animals, such as cattle (Bogaard 2012:34-35; Isaakidou 2008; Vaiglova et al. 2014:207). Ultimately, it is plausible that Neolithic peoples on Cyprus were applying manure to crops, which is discussed more below.

The manure bands (discussed above) can be used as a proxy for reconstructing cultivation regimes. However, these bands can only be used for comparative purposes, rather than for definitively assigning labels to measured values from archaeological crop remains. This is because absolute ratios vary in different climatic zones. Rather than providing absolute environmental conditions about the soil crops were grown in, these manuring bands allow us to discuss inter-species differences, which are related to crop management strategies (Vaiglova et al. 2014:206).

Before discussing the crop management strategies of the *Ais Giorkis* cereals, I will first discuss comparative data from the European and Southwest Asian mainlands. The primary reason is that I believe these data will enable me to make a stronger case for how I believe the people were managing the soil that the hulled barley was grown in.

5.4 Comparative $\delta^{15}N$ Data from the European and Southwest Asian mainlands

Table 5.5 presents the crop $\delta^{15}N$ values from several European and Southwest Asian mainland sites. Figure 5.2 shows these crop $\delta^{15}N$ values, along with those from *Ais Giorkis*. I tried to only include sites that were roughly contemporaneous with *Ais Giorkis*. To the best of my knowledge, there are only three Neolithic sites from the Middle East with $\delta^{15}N$ values for crop remains: ‘Ain Ghazal, Abu Hureyra, and Çatalhöyük (Table 2.1).[41] I also included data from Kouphovouno (Table 2.1).[42] The site dates to the Neolithic; however, the Neolithic in Greece is later in time than that of Southwest Asia. Because I reference this site in my dissertation, I feel that it is important to include in Figure 5.2.

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[41] ‘Ain Ghazal is located in present-day Jordan. It was occupied for over 2,000 years from c. 8500 to 5500 cal BC (middle PPNB to the Yarmoukian phase of the Pottery Neolithic) (Styring et al. 2016, citations therein). Abu Hureyra is located on the southern bank of the Euphrates river. Occupation at the site spanned the transition from a hunting-gathering to farming economy. The data in Figure 6.2 focuses on the period from 8800 to 7400 cal BC (early to middle PPNB) (Styring et al. 2016, citations therein). Çatalhöyük is located in central Anatolia and it is a Neolithic tell site. It dates to around 7400-6200 cal BC (Styring et al. 2015).

[42] Kouphovouno is located in mainland southern Greece, around 2.5 km southwest of Sparta on the Peloponnesian Peninsula. Occupation at the site spanned from the middle (5950-5459 cal BC) to late (5450-4500 cal BC) Neolithic, but the strata from which the data for Figure 6.2 are from span a narrower range: c. 5800-5000 cal BC (Vaiglova et al. 2014).

Table 5.5 Crop δ15N values from select European and Southwest Asian mainland archaeological sites

Site[a]	Species	N of grains/ sample[c]	$\delta^{15}N$[d]
Abu Hureyra	Hulled barley	5	9.9
Abu Hureyra	Hulled barley	5	6.7
Abu Hureyra	Hulled barley	5	7.1
Abu Hureyra	Hulled barley	5	9.6
Abu Hureyra	Hulled barley	5	7.2
Abu Hureyra	Hulled barley	5	10.7
Ain Ghazal	Hulled barley	32	4.7
Ain Ghazal	Hulled barley	60	5.0
Ain Ghazal	Hulled barley	22	5.9
Ain Ghazal	Hulled barley	30	3.3
Ain Ghazal	Hulled barley	17	1.5
Ain Ghazal	Hulled barley	50	4.5
Ain Ghazal	Hulled barley	40	2.4
Ain Ghazal	Hulled barley	40	5.2
Ain Ghazal	Hulled barley	20	4.8
Ain Ghazal	Lentil	80	1.4
Ain Ghazal	Lentil	80	1.2
Ain Ghazal	Pea	40	2.3
Ain Ghazal	Pea	15	2.6
Ain Ghazal	Pea	20	2.2
Ain Ghazal	Pea	15	2.6
Ain Ghazal	Pea	15	2.0
Çatalhöyük cereal grains[b]	Cereal grains	-	6.7
Çatalhöyük pulse seeds[b]	Pulse seeds	-	2.7
Kouphovouno	Bread/durum wheat	-	4.9
Kouphovouno	Bread/durum wheat	-	7.1
Kouphovouno	Bread/durum wheat	-	5.4
Kouphovouno	Bread/durum wheat	-	5.8
Kouphovouno	Bread/durum wheat	-	5.6
Kouphovouno	Bread/durum wheat	-	6.6
Kouphovouno	Bread/durum wheat	-	7.0
Kouphovouno	Bread/durum wheat	-	5.2
Kouphovouno	Bread/durum wheat	-	5.5
Kouphovouno	Bread/durum wheat	-	5.9
Kouphovouno	Bread/durum wheat	-	5.9
Kouphovouno	Bread/durum wheat	-	5.4
Kouphovouno	Bread/durum wheat	-	5.5
Kouphovouno	Hulled barley	-	3.1
Kouphovouno	Hulled barley	-	4.2
Kouphovouno	Hulled barley	-	2.7
Kouphovouno	Hulled barley	-	3.5
Kouphovouno	Hulled barley	-	0.7
Kouphovouno	Hulled barley	-	2.7
Kouphovouno	Hulled barley	-	1.6
Kouphovouno	Pea	-	0.9
Kouphovouno	Pea	-	1.6
Kouphovouno	Pea	-	1.3
Kouphovouno	Pea	-	1.1
Kouphovouno	Pea	-	1.4
Kouphovouno	Pea	-	1.2
Kouphovouno	Pea	-	1.7

[a] Data for the nitrogen isotope values of the crop remains are from: Styring et al. 2016:Supplementary Table 2 (Ain Ghazal and Abu Hureyra); Styring et al. 2015 (Çatalhöyük); and Vaiglova et al. 2014 (Kouphovouno).

[b] The data originally are from Vaiglova et al. (2014). However, the samples were artificially contaminated and subjected to different treatment protocols. As a result, I used the data summarized by Styring et al. (2015), who provided the mean values of the cereal grains and pulses. I was not able to determine the results for bulk samples of hulled barley, emmer wheat, and bread/drum wheat separately.

[c] All samples are bulk samples (they should have at least 5 seeds/grains), and I included specific numbers/sample when available.

[d] All δ15N values were adjusted for the charring effect following Fraser et al. (2013a).

Figure 5.2 Crop δ^{15}N values from Ais Giorkis and select mainland sites

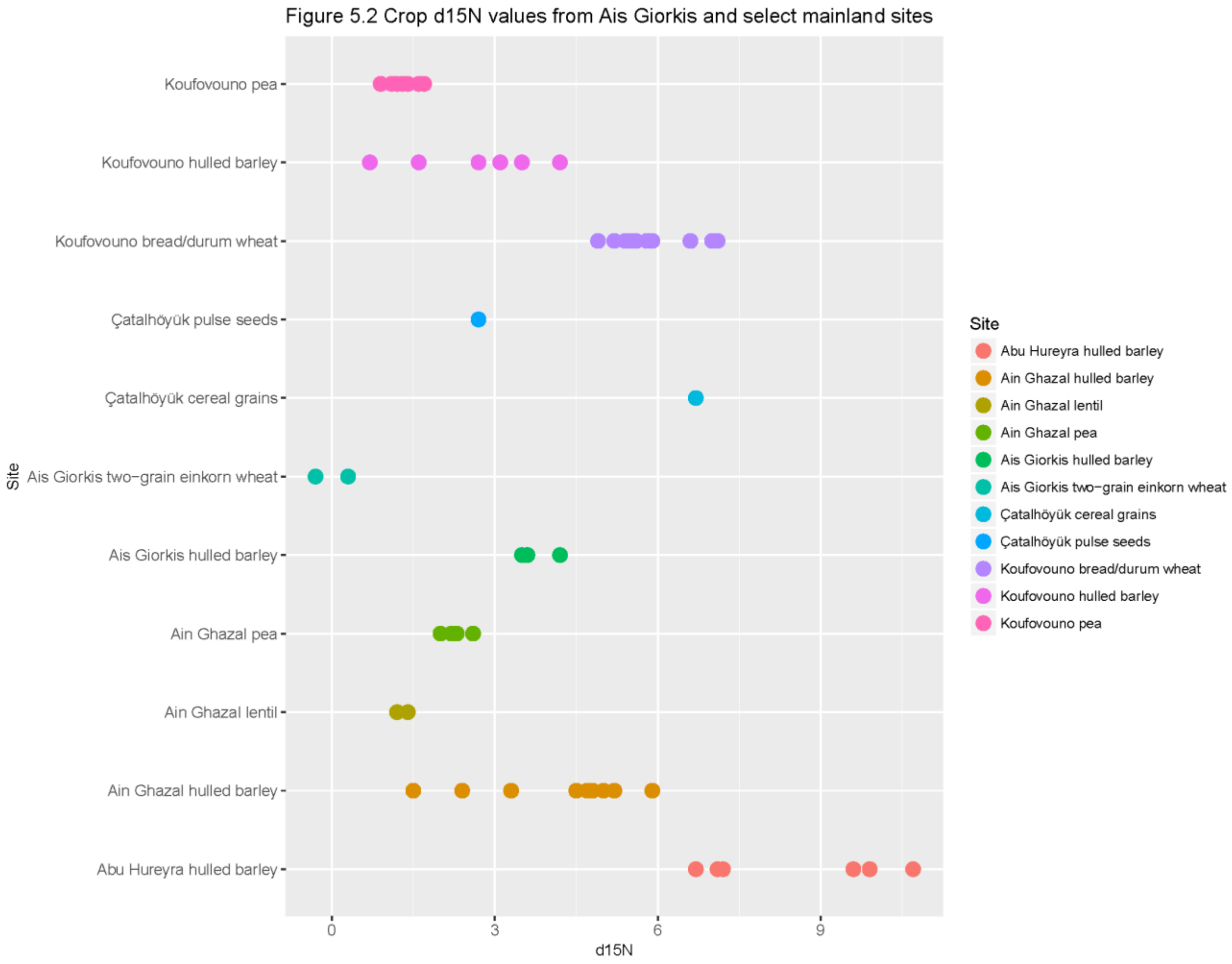

Figure 5.2 further supports that the two-grained einkorn wheat from *Ais Giorkis* was not enriched in ^{15}N. Of the Neolithic sites included in the plot, the *Ais Giorkis* hulled barley grains appear to be most similar to those from ‘Ain Ghazal. Styring et al. (2016) note that the δ^{15}N values of barley grains from this site are relatively low, ranging from 1.2 to 5.6‰. These values are similar to or lower than the δ^{15}N value of the unmanaged plants, which was estimated from faunal δ^{15}N data (4.9‰). They plot the barley samples against the natural log scale of the range of estimated past annual rainfall, and the samples fall within the low-medium bands of manuring. As a result, the authors conclude that the manuring input was minimal.

The $\delta^{15}N$ values of the hulled barley grains from Abu Hureyra are quite high, ranging from 6.4 to 10.4‰. Styring et al. (2016) plotted these values against the natural log scale of the range of estimated past annual rainfall, to estimate the effect of aridity on the samples. In part, this was done because the site does not have faunal $\delta^{15}N$ data, which is used to estimate the $\delta^{15}N$ value of the unmanaged/unmanured plants. The barley grain values plotted within the high band of manuring at all annual rainfall values (Styring et al. 2016:Figure 6). The authors conclude that some degree of manure application cannot be excluded; however, they also suggest that cultivation could have occurred in soils that experience temporary waterlogging, including wadi slopes and floodplains (Hartman and Danin 2010; Styring et al. 2016:15).

The values of the barley grain from Abu Hureyra are not significantly lower than those of individual rye grains that were also analyzed at the site and that likely date to the Epipaleolithic (Araus et al. 2014). Based on carbon and nitrogen isotope signatures of kernels and charcoal from 11 Upper Mesopotamian archaeological sites, with chronologies spanning from the Epipaleolithic to Roman times, Araus et al. (2014) suggest that soil fertility has progressively decreased, leading to decreasing crop $\delta^{15}N$ values over time. In addition, water conditions have fluctuated in relation to major climatic events and the rainfed nature of these crops. Based on this evidence, Styring et al. (2016:15) also suggest that if soil fertility has decreased from the Epipaleolithic to the PPNB, then this provides support that inhabitants of Abu Hureyra were managing the crops in some way, given that they do have higher $\delta^{15}N$ values than those expected of unmanaged plants.

The hulled barley and free-threshing wheat from Kouphovouno fall into the medium manuring category. However, free-threshing wheat appears to have been manured more intensively than barley given the varying degree of ^{15}N enrichment (Vaiglova et al. 2014).

Vaiglova et al. (2014:206-207) suggest that this difference may reflect a conscious decision on the part of the farmers'. Barley can grow in more marginal conditions than wheat. Farmers' might have observed this in the field, which could explain the differential values of the crops. There are other indicators of crop management at Kouphovouno, besides crop δ^{15}N values. The pathologies from the cattle indicate that these animals were used for traction, which could have included spreading manure on fields. In addition, the Neolithic pottery sherds recovered from the likely fields (discussed above) lends additional support to the idea that the Neolithic inhabitants at the site were manipulating the soil in some way to increase its fertility (Vaiglova et al. 2014).

In sum, δ^{15}N data from roughly contemporary Southwest Asian mainland sites support the idea that people were manipulating the soil by at least the PPNB to increase fertility. It still requires further testing to determine whether this manipulation included the application of manure to soils. Kouphovouno and other Neolithic European sites (e.g., Bogaard et al. 2013; Fraser et al. 2013b) have clearer evidence for early farmers using livestock manure to enhance crop yields. However, use of manure appears to be limited by both scale of herding and by the labor costs of hauling manure. Bogaard et al. (2013:12593) argue that manuring would have been an investment by Neolithic farmers to sustainability and territorial claims.

5.5 *Ais Giorkis* Crop δ^{15}N Values and Soil Growing Conditions

In this study, the two-grained einkorn samples fall into the no long-term manuring category (Figure 6.1, Table 5.4). All δ^{15}N values are below 2.5‰, regardless of whether the δ^{15}N values have been corrected for the charring effect following Nitsch et al. (2015) or Fraser et al. (2013a). In contrast, the hulled barley samples fall into the medium manuring category: their δ^{15}N values are between 2.5 and 6.0‰. It is important to note that the correction calculations following both Nitsch et al. (2015) and Fraser et al. (2013a) do not change the category for these samples.

Another way to infer ^{15}N enrichment in cultivated crops is to compare the measured crop values to a local ‘unmanured baseline’ (Chapter 4). For this study, I examine both the mean domestic (sheep, goats, and cattle) herbivore value and the mean wild (deer) herbivore value because the published literature often provides one or the other (e.g., mean domestic herbivore value: Vaiglova et al. 2014; mean wild herbivore value: Bogaard et al. 2016). At *Ais Giorkis*, the mean domestic herbivore value is 4.65‰ (Chapter 6). Subtracting the approximate value of the trophic enrichment of 4 ± 1‰ from the value of the local domestic herbivores gives a value for local forage of 0.65 ± 1‰. The mean wild herbivore value is 5.19‰ (Chapter 6); thus, the local forage value is 1.19 ± 1‰. Both of these figures are lower than the value of the measured hulled barley, but not the two-grained einkorn wheat. As noted above, the δ^{15}N hulled barley results from *Ais Giorkis* appear to plot the most similar to ‘Ain Ghazal hulled barley δ^{15}N values. However, an examination of the local unmanured baseline presents a different story for both sites. At ‘Ain Ghazal, there appears to be little difference between the local unmanaged plants and the δ^{15}N values of the cereals. However, this is not the case at *Ais Giorkis*. These lines of evidence further corroborate the arguments that: 1.) the two cereals were grown in different plots; and 2.) the hulled barley was grown in soils more enriched in ^{15}N than the land on which animals grazed/browsed.

5.5.1 Ais Giorkis Cereals and Agricultural Plots

The fact that the two cereals were grown in different plots is puzzling. Wheat and barley are often planted together as a mechanism for reducing risk in crop yield (Halstead and Jones

1989:51). In a good rainfall year, the mixed crops produce food for humans as well as animal fodder. Wheat typically outproduces barley; the latter which is often used as animal fodder (Halstead and Jones 1989:51; Marston 2011:192), although it is also used to make bread on Cyprus (Baker 2011 [1879]). In a bad rainfall year, the drought resistant barley will make-up a greater portion of the crop yield compared to the wheat. Typically, humans will eat the entire crop, and animals will be given hay (Halstead and Jones 1989:51). Given that wheat is often the preferred cereal for human consumption, it is interesting that there is no evidence of human's managing the soil that this cereal was grown in to increase its yield. Furthermore, the two-grained einkorn wheat is more abundant than the hulled barley, representing 79.8% of the cereal grains that were identifiable to the genus or species. This contrasts with 11.6% for barley. As noted several times in this study, botanical preservation is an issue in Cyprus. Thus, these proportions could be due to sample preservation, rather than human preferences. However, typically low barley to wheat ratio from sites where water is a limiting resource indicates a riskier agricultural system focused on producing the more valuable crop for human consumption (Marston 2011:195). Yet, it appears that the inhabitants of *Ais Giorkis* were providing barley with greater resources to ensure its growth; a point that will be returned to below.

5.5.2 Source of the Nitrogen Enrichment of the Hulled Barley Samples

For the source of nitrogen enrichment of the hulled barley samples, I believe that there are two possibilities: the application of manure or rotating cereals with small-seeded legumes. Manuring of fields is important because it implies "an investment in the land, since 'topping up' of nutrient levels is only required if plots are long-lived; consecutive crop harvests eventually strip the soil of nutrients, which must be replaced if subsequent crop yields are to be maintained"

(Styring et al. 2016:3). Manuring also indicates a certain labor input as well as close interdependence between crop and animal husbandry. The collection and spreading of manure requires management of domestic animals and it is costly in terms of labor and time (Halstead 2014; Styring et al. 2016). Furthermore, manure is a finite resource. Thus, strategic decisions must be made in order to maximize crop yields (Halstead 1989).

Based on data from contemporary Neolithic sites on the mainland, we do not have clear evidence for manuring during the PPNB, although this strategy has not been ruled out. Manure is typically concentrated at specific locations in the landscape, largely due to the fact that it is heavy to transport. As a result, it is often used in close proximity to pens (Bogaard et al. 2013:12590). There is limited evidence for livestock pens during the Cypro-PPNB (Chapter 3). The strongest evidence comes from *Shillourokambos*, although the excavators also hypothesize that the curvilinear and trapezoidal enclosures cut into the bedrock might have been domestic areas (Guilaine and Briois 2006:163; Guilaine et al. 2011:143-151; Knapp 2013:88; Vigne 2013b:118; Vigne et al. 2011:258, 2017:11-12). The botanical preservation from this site is extremely poor; thus, it is difficult to determine whether crops were being grown near the site. Furthermore, the poor preservation limits the ability to conduct nitrogen isotope analysis on the remains, which might shed light on whether this site was a source of manure for the inhabitants. The majority of the preserved crops are also wild varieties, which is somewhat unexpected given the time period.

The recovery of a single *Sporormiella* dung fungal spore from *Ais Giorkis* could also indicate the presence of grazing animals near the site (Chapter 3). However, the macrobotanical evidence implies that the crops were not being grown at or near the site. Thus, even if dung was being kept at *Ais Giorkis*, it does not appear that the site's inhabitants were adding it to agricultural plots. The cattle bones from *Ais Giorkis* also do not have osteoarthritic pathological conditions that would indicate they were being used as draft animals (personal communication Dr. Paul Croft). These conditions include: remodeling of articular surfaces, development of osteophytes, eburnation of hip joints, and the grooving of articular surfaces. The latter occur primarily on the phalanges and distal metapodials. Based on examination of modern carcasses with known life histories, these injuries, which are the result of repetitive stress or trauma on the joints, are incurred in traction (Isaakidou 2008:96).

While draft animals are not necessary for manure application to agricultural fields, they can play a significant role in manure transportation. In turn, this enhances the feasibility of intensive application of manure on significant amounts of arable land (Bogaard 2012:34). However, Bogaard (2012:35) notes that small scaled animal-keeping (i.e., a few cattle, sheep, goat, and pigs per household) would allow intensive manuring of a significant portion of a household's arable land each year, although not the entire area. In fact, an ethnographic study carried out in conjunction with Simmons' Kholetria *Ortos* Archaeological Project (Marks 1999) documented the use of manure as an essential fertilizer for agricultural fields. Typically, the manure was from animals grazing on fallow lands to clear weeds and stubble or from *mandres* (i.e., sheep/goat folds that are primarily used away from the village). Thus, there is, unsurprisingly, a history of manure-use by Cypriots. While I do not believe that we can rule out the possibility that the Neolithic inhabitants were applying manure to the fields, I also do not think we have conclusive evidence of this management practice during the Cypro-PPNB.

Another possible alternative to manure application is rotating cereals with small-seeded legumes or growing cereals and legumes together. Marks (1999:71) has documented both of these practices by Kholetria villagers. In addition, studies have shown that in rainfed areas of

Cyprus, the inclusion of legumes, such as common vetch, result in higher grain yield as compared to cereal crops with less nitrogenous fertilizer (Papastylianou 1988). Direct or indirect transfer of fixed-N to the intercropped non-legume has been observed (van Kessel and Hartley 2000); however, there has been limited research on how planting legumes with crops impacts the δ^{15}N value of the crops. Furthermore, it remains unknown how long the enriched nitrogen signal stays in the soil from legumes (Szpak 2014). Thus, we cannot say with any confidence that the enriched δ^{15}N values of the hulled barley is due to either crop-rotation or intercropping with legumes.

5.5.3 Summary

The δ^{15}N values of the two-grained einkorn wheat and the hulled barley do not overlap, supporting the idea that these cereals were grown in separate fields. Furthermore, at the very minimum, the inhabitants of *Ais Giorkis* appear to be managing soil conditions in some way for the hulled barley; particularly when their nitrogen isotope values are compared to the baseline of unmanaged plants. Based on current evidence, it is difficult to determine the reason behind the enriched δ^{15}N values of the hulled barley. I believe that either the application of manure or crop rotation or inter-cropping with legumes could help to explain these values. However, both the current archaeological evidence and the limitations of nitrogen stable isotope analysis make it difficult to determine which strategy might have been employed by the Neolithic inhabitants. As a result, we can make 3 tentative conclusions based on the nitrogen isotope values: 1.) the two-grained einkorn wheat and hulled barley were grown in separate fields; 2.) the soil conditions of the hulled barley were being managed in a way to increase soil fertility; and 3.) the inhabitants of *Ais Giorkis* appear to intentionally be providing barley with greater resources to ensure its growth in comparison to two-grained einkorn wheat. Ultimately, the $\delta^{15}N$ values still tell us that the inhabitants of *Ais Giorkis* were making strategic decisions about the crop growing strategies for the hulled barley and two-grained einkorn wheat.

5.6 Cereal $\Delta^{13}C$ and Crop Water Status

Stable carbon isotope analysis of plant remains as a direct means of inferring crop water status and water management practices was discussed in Chapter 4. To recap, crop carbon isotope values reflect the water status of the crop during its period of growth. In C_3 plants (e.g., hulled barley and two-grained einkorn), differences in plant $\delta^{13}C$ values relate to the stomatal conductance, which is regulated through water availability. Plant $\delta^{13}C$ values are converted to $\Delta^{13}C$ values so that archaeological samples can be compared with samples from different time periods, including modern experimentally grown crops (Araus et al. 1997, 2014; Farquhar and Richards 1984; Faraquhar et al. 1989; Wallace et al. 2013).

Much of the research on this issue has been based on experimental farm settings (Bogaard et al. 2016; Wallace et al. 2013; Styring et al. 2016). Based on these studies, it has been determined that the degree of discrimination of ^{13}C varies between species (Ferrio et al. 2005; Flohr et al. 2011; Wallace et al. 2013). For example, barley and wheat that are grown in the same field will have different $\delta^{13}C$ values. Water status can be influenced by a number of factors, including: type of water input (e.g., rainfall and anthropogenic watering), evapotranspiration (water losses), and the soil’s capacity to hold water (Styring et al. 2016:6). As a result, Wallace et al. (2013) proposed three broad levels of water status based on crop $\Delta^{13}C$ values from experimental farm settings (Figure 4.5): ‘poorly watered’, ‘moderately watered’, and ‘well-watered’ crops. These levels differ slightly depending on the plant species. Wheat grain in the ‘moderately watered band’ exhibits values between 16 and 17‰. Values of grains that are higher than 17‰ fall into the ‘well-watered band’ and those that are lower than 16‰ are grouped into the ‘poorly watered band.’ The bands for barley have been defined by adding a mean offset of 1.5‰ to the wheat bands, due to the physiological differences between these two cereal species. For example, barley grains in the ‘moderately watered band’ exhibits values between 17.5 and 18.5‰ (Araus et al. 1997; Wallace et al. 2013).

5.7 *Ais Giorkis* Cereal Δ^{13}C and Cereal Water Status

The two-grained einkorn wheat and hulled barley Δ^{13}C values (16.4 ± 0.3‰ and 17.5 ± 0.2‰, respectively) are grouped into the ‘moderately watered band.’ Based on these data, it is clear that both crops received sufficient amounts of water during their growth. To be able to further discuss the water management strategies of the cereal crops from the site, we first examine comparative Δ^{13}C data from the Southwest Asian mainland.

5.8 Comparative Δ^{13}C Data from the Southwest Asian mainland

Figure 5.3 shows crop Δ^{13}C values from Southwest Asian mainland sites, along with those from *Ais Giorkis*. Wallace et al. (2015) is the source of the mainland data. In their study, stable carbon isotope discrimination was determined for 275 charred grain samples from nine archaeological sites, dating from the Neolithic to the Bronze Age.[43] One of their primary goals

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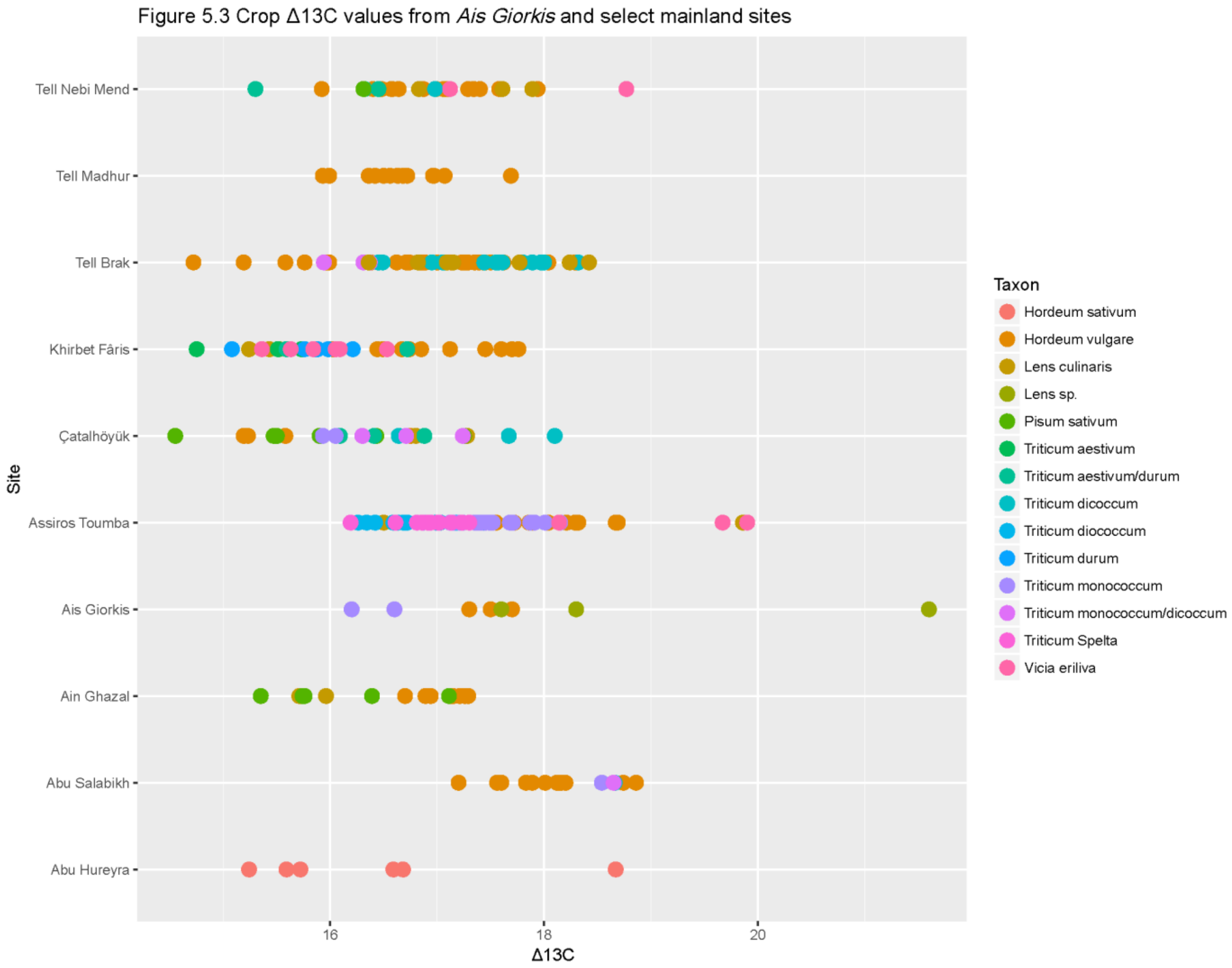
[43] The sites that are roughly contemporaneous with *Ais Giorkis* are: Abu Hureyra, ‘Ain Ghazal, and Çatalhöyük. The samples from Tell Madhur date to the ‘Ubaid (Late Neolithic; 5300-4000 BCE) period. Samples from Tell Brak cover the entire Uruk (Chalcolithic to Early Bronze Age) period and post-Uruk periods (6600-900 BCE, but samples from 4200-2300 BCE). The samples from Abu Salabikh date to the late Uruk to Early Dynastic III periods (majority of the samples are from the latter period: 3000-2400 BCE). Most of the Tell Nebi Mend samples are from the Bronze Age (2700-1200 BCE), although a few are from the Iron Age. Samples from Assiros Toumba are from the Late Bronze Age (c. 1350 BCE). The latest site is Khirbet Fâris, which dates to the Islamic period (5th-13th centuries AD) (Wallace et al. 2015:3-4, Table 1).

was to look at crop water management trends through time in the Eastern Mediterranean and Western Asia. In order to better understand water management strategies of the *Ais Giorkis* cereals, I believe it is relevant to see where they fit into the broader pan-Southwest Asian context.

Figure 5.3 Crop $\Delta^{13}C$ values from *Ais Giorkis* and select mainland sites



Çatalhöyük is the only other Neolithic site with wheat (free threshing wheat and glume wheat). The mean $\Delta^{13}C$ values are between 16-17‰, which are indicative of the ‘moderately

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watered band.’ The wheat grains from Tell Nebi Mend have similar values as those from Çatalhöyük. The only sites that have mean wheat Δ^{13}C values that fall into the ‘well-watered band’ are later than the Neolithic: Assiros Toumba, Tell Brak, and Abu Salabikh. The values for some of these sites are tied to flood irrigation (Abu Salabikh), climate (Assiros Toumba), or cultivation of naturally most soils near rivers, watering by hand, or flood irrigation (Tell Brak). There is variation seen in the Δ^{13}C values of wheat grown at the same site, which has been attributed to multiple crop growing locations in a single year. Khirbet Fâris is the only site with wheat grains that fall into the ‘poorly watered band,’ which is likely best explained by climate aridification (Wallace et al. 2015:6, Table 2, Figures 2-3).

At most of the sites analyzed by Wallace et al. (2015), the Δ^{13}C values for barley fall between 16.2 to 17.9‰; a similar range for wheat. As noted above, the Δ^{13}C values for barley grown under the same conditions as those for wheat are typically 1.5‰ higher. Thus, these data from the mainland imply that barley was grown under drier conditions than wheat. Barley does not ever fall into the ‘well-watered band,’ although the values are close at Assiros Toumba and Abu Salabikh. The wheat grains at both sites were found to be well-watered, and could imply irrigation (Wallace et al. 2015:8-10, Table 2, Figures 2-3).

At Çatalhöyük, the barley Δ^{13}C values (mean = 15.77 ± 0.66‰) suggest that the crop was grown under drier conditions than those at other sites. In addition, the values, on average, were 0.83‰ lower than those for wheat at the site. The barley samples from Abu Hureyra exhibit variation in their Δ^{13}C values (mean =16.42 ± 1.24‰), which indicates that they were grown under a diversity of growing conditions. In contrast, the samples from ‘Ain Ghazal exhibit little variation (mean = 17.08 ± 0.19‰), suggesting that they were grown under the same conditions (Wallace et al. 2015:10, Table 2, Figures 2-3). The ‘Ain Ghazal samples were not deposited at the same time. This suggests that farmers had significant control over water availability, which was perhaps mediated through use of the floodplains or springs near the site (Wallace et al. 2015:12).

An interesting conclusion drawn by Wallace et al. (2015:12) is that there is perhaps evidence of preferential treatment of crops. There were 6 sites that had both wheat and barley samples. At three of these sites, including Çatalhöyük, the Δ^{13}C values were lower than those for wheat. They argue that this provides a strong indication that barley was typically grown under drier conditions than wheat. Even at the other three sites, the barley Δ^{13}C values do not indicate that they were grown under sufficiently wetter conditions. They note that it is conceivable for the difference between barley and wheat to be due to physiological differences between the plants (i.e., barley uses water more efficiently). However, they also cite data from Neolithic sites in Central Europe where barley Δ^{13}C samples are in excess of 20‰. Because water availability is known to have been high for these sites, Wallace et al. (2015) conclude that their results reflect that barley was grown under drier conditions than wheat. This differential treatment suggests that greater measures were taken to ensure a successful wheat harvest, even possibly at the expense of barley.

5.9 Crop Water Management at *Ais Giorkis*

The above data allow us to explore several water management strategies for the crops at *Ais Giorkis*, as well as place the site's data within a broader Mediterranean context. In contrast to Çatalhöyük, both the *Ais Giorkis* two-grained einkorn wheat and hulled barley samples fall within the 'moderately watered band.' These data suggest that barley from *Ais Giorkis* was not grown under drier conditions than wheat, which reinforces the idea that the site's inhabitants favored the growth of barley over wheat. At least for the Cypro-PPNB, inhabitants do not appear to be taking greater measures to ensure a successful wheat harvest at the expense of barley. Rather, it seems that either equal or greater resources are being given to barley. Unfortunately, in order to determine if this is an island trend, we need additional isotopic data.

Similar to the barley Δ^{13}C values from Ain Ghazal, the *Ais Giorkis* samples have little variation. However, the samples are from the same general area, but different levels and quads. It is difficult to tease apart whether this pattern is due to the samples being deposited at the same time or because the farmers did have significant control over water availability. The wheat samples also have little variation, and they are from different units (although the same general area of the site). These samples provide stronger evidence that farmers had significant control over water availability, although I do emphasize caution given the small sample size. Since we do not currently know where the samples were grown, it is difficult to say how these farmers might have had control over the watering of the plants. It is likely that they utilized springs or even floodplains, similar to farmers at ‘Ain Ghazal.

5.10 Conclusion: Crop management Strategies Based on *Ais Giorkis* Cereals

This chapter presented the results from the δ^{15}N and δ^{13}C analysis of the crop remains from *Ais Giorkis*. The confidence range for the δ^{15}N and δ^{13}C values of the *Ais Giorkis* cereals fall within the recommended values, which means that the results merit interpretation. In contrast, the confidence range for the nitrogen and carbon measurements of the *Ais Giorkis* lentils fall beyond the recommended value, and I was not able to discuss these data.

Three tentative conclusions can be made about the two-grained einkorn wheat and hulled barley samples based on the nitrogen isotope values: 1.) the two-grained einkorn wheat and hulled barley were grown in separate fields; 2.) the soil conditions of the hulled barley were being managed in a way to increase soil fertility; and 3.) the inhabitants of *Ais Giorkis* appear to be providing barley with greater resources to ensure its growth in comparison to two-grained einkorn wheat. The $\Delta^{13}C$ values of the cereals possibly also support that they were being grown in different fields, although the little variation seen in the hulled barley samples could also be a product of deposition. Both of the cereals are grouped into the ‘moderately watered band.’ This observation was somewhat surprising because current evidence on the mainland suggests that barley was grown under drier conditions than wheat. Thus, both the $\delta^{15}N$ and $\Delta^{13}C$ values imply that inhabitants of *Ais Giorkis* were making strategic decisions about the crop growing strategies between the hulled barley and two-grained einkorn wheat. They seemingly preferred barley. In Chapter 7, I will discuss possible reasons for this preference.

As discussed in Chapter 3, the weed data from Cypriot prehistoric sites is suggestive of agriculture on nitrogen poor soils. The isotopic evidence from *Ais Giorkis* hulled barley samples appear to contradict these data, because of the enriched nitrogen signal. However, the advantage of stable isotope analysis of the crop itself, is that water conditions and soil composition conditions can be inferred for specific crop remains. This cannot be achieved on the basis of weed analysis, unless weed seeds are directly associated with samples of a single crop (Wallace et al. 2015:2). In addition, the sample size in this study is both small and time-period specific. It is possible that other sites, including from the Cypro-PPNB, have different crop management strategies. Thus, while conclusions from this study are tentative, stable isotope analysis of cereal remains provides interesting avenues for better understanding agricultural practices during the Cypro-PPNB.

CHAPTER 6: CARBON, NITROGEN, AND OXYGEN RESULTS OF THE AIS GIORKIS ANIMAL BONE COLLAGEN AND TOOTH ENAMEL AND ANIMAL MANAGEMENT PRACTICES

6.1 Introduction

In this chapter, I present the results of the $\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$ analyses of the animal bone collagen and tooth enamel from *Ais Giorkis*. The primary goal of this chapter is to begin to characterize animal management practices at the site, including the general environmental setting, diet, and herd movement. I also briefly discuss caprine birth seasonality, although interpretations should be taken cautiously due to the low sample resolution and non-normalized tooth length. First, I present the results of the carbon and nitrogen isotope measurements of bone collagen, which is followed by a discussion on the carbon and oxygen isotope results from the caprine mandibular molar animal. The carbon and nitrogen stable isotope results are then used to investigate past environmental settings, including whether the animals were 1.) consuming strictly C_3 or C_4 diets or a combination of these two plant types; 2.) foraging in environments with a closed canopy; and 3.) consuming marine resources, such as seaweed. The next section discusses animal diets at *Ais Giorkis* based on the bone collagen $\delta^{13}C$ and $\delta^{15}N$ values and the ovicaprid molar enamel $\delta^{13}C$ values. Diet is important because it provides insights into possible herding strategies. I conclude by discussing birth seasonality and herd movement using the $\delta^{18}O$ and $\delta^{13}C$ values from the sequentially sampled caprine molars.

6.2 Results from the $\delta^{15}N$ and $\delta^{13}C$ Analysis of the Animal Bone Collagen

This section presents the results from the $\delta^{15}N$ and $\delta^{13}C$ analysis of 100 animal bone collagen samples. At *Ais Giorkis*, the taxa sampled for bone collagen analysis include sheep

(*Ovis aries*), goat (*Capra hircus*), Mesopotamian fallow deer (*Dama dama mesopotamica*), cattle (*Bos taurus*), and pig (*Sus scrofa domesticus*). The archaeological context and sampling strategy is discussed in Chapter 4. The outline and presentation of the results follows that of Balasse et al. (2013).

Table 6.1 Stable isotope values for the domestic pig and cattle bone samples

Lab ID	Identification Number	Species	Area/Context	Element	C Amount (μg)	N Amount (μg)	C:N	Collagen Yield	δ^{13}C (‰)	δ^{15}N (‰)
Lab ID 31	105-Sus	*Sus scrofa*	15n30w	radius R	76.46	25.80	3.46	0.60%	-21.17	1.93
Lab ID 32	107-Sus	*Sus scrofa*	15n30w	radius R	329.93	119.55	3.22	4.89%	-20.67	3.42
Lab ID 33	111-Sus	*Sus scrofa*	15n30w	radius R	378.43	137.47	3.21	6.23%	-20.53	2.85
Lab ID 34	112-Sus	*Sus scrofa*	15n30w	radius R	336.82	120.38	3.26	5.31%	-20.52	3.61
Lab ID 35	113-Sus	*Sus scrofa*	15n30w	radius R	48.39	16.21	3.48	1.31%	-21.42	2.79
Lab ID 36	117-Sus	*Sus scrofa*	20n25w	tibia R	87.00	30.15	3.37	1.94%	-20.34	4.94
Lab ID 37	119-Sus	*Sus scrofa*	20n45w	tibia R	38.39	12.34	**3.63**	0.61%	-21.80	0.82
Lab ID 38	127-Sus	*Sus scrofa*	30n45w	radius R	127.44	46.00	3.23	1.29%	-20.43	2.85
Lab ID 39	128-Sus	*Sus scrofa*	30n45w	tibia R	94.66	31.76	3.48	3.06%	-20.42	2.61
Lab ID 40	131-Sus	*Sus scrofa*	30n45w	tibia R	187.07	64.99	3.36	3.91%	-20.89	4.74
Lab ID 41	135-Sus	*Sus scrofa*	5n30w	tibia R	175.94	60.58	3.39	3.14%	-20.52	4.40
Lab ID 42	136-Sus	*Sus scrofa*	5n30w	tibia R	281.22	100.46	3.27	4.90%	-20.58	3.21
AY0058	121-Sus	*Sus scrofa*	30n40w	humerus L	26.59	6.09	**5.09**	0.69%	-22.91	2.37
AY0059	122-Sus	*Sus scrofa*	30n40w	tibia L	33.11	8.61	**4.48**	1.18%	-22.98	0.47
AY0060	124-Sus	*Sus scrofa*	30n40w	humerus L	91.12	27.96	**3.80**	0.67%	-21.34	3.76
AY0061	125-Sus	*Sus scrofa*	30n45w	humerus L	76.46	23.19	**3.85**	0.28%	-22.04	3.03
AY0062	115-Sus	*Sus scrofa*	20n25w	humerus R	72.37	23.07	**3.66**	0.90%	-20.89	1.20
AY0063	102-Sus	*Sus scrofa*	15n20w	tibia L	73.33	22.59	**3.79**	0.71%	-21.56	2.40
AY0064	101-Sus	*Sus scrofa*	10n25w	humerus L	162.33	55.33	3.42	1.19%	-21.06	4.19
AY0065	108-Sus	*Sus scrofa*	15n30w	humerus L	247.26	85.91	3.36	1.41%	-20.97	3.75
AY0066	109-Sus	*Sus scrofa*	15n30w	humerus R	196.02	64.35	3.55	1.20%	-20.80	3.52
Lab ID 43	139-Bos	*Bos taurus*	10n30w	humerus R	131.68	45.64	3.37	2.69%	-20.55	5.19
Lab ID 44	143-Bos	*Bos taurus*	15n20w	tibia R	41.12	11.93	**4.02**	3.04%	-21.72	4.60
Lab ID 45	149-Bos	*Bos taurus*	20n25w	tibia R	215.20	75.84	3.31	4.83%	-20.25	5.25
Lab ID 46	150-Bos	*Bos taurus*	20n25w	humerus R	155.51	53.53	3.39	3.86%	-20.95	5.39
AY0051	148-Bos	*Bos taurus*	20n25w	radius L	106.49	37.13	3.35	0.46%	-20.72	4.22
AY0052	147-Bos	*Bos taurus*	15n30w	femur L	127.85	42.01	3.55	-0.30%	-21.18	5.21
AY0053	152-Bos	*Bos taurus*	5n30w	humerus L	36.72	3.39	**12.64**	0.44%	-25.19	3.02
AY0054	146-Bos	*Bos taurus*	15n20w	humerus L	78.14	20.21	**4.51**	0.39%	-22.25	5.78
AY0055	137-Bos	*Bos taurus*	10n25w	radius L	231.07	79.40	3.40	2.08%	-21.06	4.97
AY0056	140-Bos	*Bos taurus*	10n30w	femur L	155.87	53.66	3.39	0.69%	-20.41	5.32
AY0057	151-Bos	*Bos taurus*	30n40w	radius R	77.66	20.45	**4.43**	0.77%	-22.84	5.31

Table 6.2 Stable isotope values for the Mesopotamian fallow deer bone samples

Lab ID	Identification Number	Species	Area/Context	Element	C Amount (µg)	N Amount (µg)	C:N	Collagen Yield	δ^{13}C (‰)	δ^{15}N (‰)
Lab ID 1	11-Dama	*D. mesopotamica*	15n20w	tibia R	83.28	27.05	3.59	4.64%	-21.49	7.12
Lab ID 2	13-Dama	*D. mesopotamica*	15n20w	tibia R	128.72	42.34	3.55	4.18%	-20.94	5.75
Lab ID 3	15-Dama	*D. mesopotamica*	15n25w	tibia R	102.26	34.97	3.41	3.58%	-20.96	5.09
Lab ID 4	19-Dama	*D. mesopotamica*	15n30w	tibia R	160.30	56.22	3.33	5.87%	-20.58	5.42
Lab ID 5	23-Dama	*D. mesopotamica*	15n30w	tibia R	233.34	82.81	3.29	5.36%	-20.66	5.98
Lab ID 6	29-Dama	*D. mesopotamica*	20n45w	tibia R	132.00	45.74	3.37	3.24%	-20.59	5.42
Lab ID 7	2-Dama	*D. mesopotamica*	5n30w	tibia R	182.47	63.55	3.35	2.74%	-20.63	5.28
Lab ID 8	32-Dama	*D. mesopotamica*	20n45w	tibia R	151.09	52.91	3.33	5.48%	-21.06	6.51
Lab ID 9	40-Dama	*D. mesopotamica*	30n40w	tibia R	123.51	42.43	3.40	2.10%	-21.01	5.78
Lab ID 10	42-Dama	*D. mesopotamica*	30n40w	tibia R	316.63	113.34	3.26	5.62%	-20.99	6.38
Lab ID 11	44-Dama	*D. mesopotamica*	30n45w	tibia R	216.20	77.16	3.27	6.75%	-20.92	4.67
Lab ID 12	47-Dama	*D. mesopotamica*	30n45w	tibia R	201.41	71.11	3.30	6.03%	-21.13	5.83
Lab ID 13	5-Dama	*D. mesopotamica*	5n30w	tibia R	72.99	23.29	**3.66**	4.90%	-21.37	5.80
Lab ID 14	48-Dama	*D. mesopotamica*	30n45w	radius R	251.85	89.06	3.30	7.82%	-20.43	4.73
Lab ID 15	50-Dama	*D. mesopotamica*	30n45w	radius R	21.11	4.88	**5.05**	3.49%	-24.58	-0.72
Lab ID 49	3-Dama	*D. mesopotamica*	5n30w	humerus R	17.56	3.46	**5.92**	3.58%	-25.06	-11.38
Lab ID 50	4-Dama	*D. mesopotamica*	5n30w	humerus R	22.59	4.68	**5.63**	0.88%	-24.91	-0.53
AY0084	9-Dama	*D. mesopotamica*	10n30w	tibia L	94.97	29.39	**3.77**	1.43%	-21.92	3.65
AY0085	7-Dama	*D. mesopotamica*	10n30w	tibia L	18.36	2.32	**9.22**	1.39%	-24.85	-5.83
AY0086	10-Dama	*D. mesopotamica*	15n20w	tibia L	52.63	16.75	**3.67**	1.04%	-21.28	3.55
AY0087	14-Dama	*D. mesopotamica*	15n25w	tibia L	219.88	77.27	3.32	2.54%	-20.65	5.17
AY0088	16-Dama	*D. mesopotamica*	15n25w	tibia L	17.95	2.60	**8.06**	0.55%	-24.11	0.15
AY0089	18-Dama	*D. mesopotamica*	15n25w	tibia L	94.25	29.51	**3.73**	1.66%	-21.50	3.39
AY0090	20-Dama	*D. mesopotamica*	15n30w	radius R	124.01	41.06	3.52	1.44%	-21.12	3.75
AY0091	31-Dama	*D. mesopotamica*	20n45w	tibia L	86.32	29.03	3.47	1.10%	-21.09	3.21
AY0092	34-Dama	*D. mesopotamica*	25n25w	radius L	62.02	18.78	**3.85**	0.69%	-21.91	4.34
AY0093	38-Dama	*D. mesopotamica*	25n45w	tibia L	33.59	6.99	**5.61**	0.42%	-23.86	0.37
AY0094	39-Dama	*D. mesopotamica*	30n40w	radius L	65.39	19.61	**3.89**	0.79%	-22.02	4.87
AY0095	33-Dama	*D. mesopotamica*	20n45w	radius R	64.67	20.80	**3.63**	1.91%	-21.54	3.92
AY0096	41-Dama	*D. mesopotamica*	30n40w	radius L	53.59	17.46	3.58	0.94%	-21.76	3.79
AY0097	45-Dama	*D. mesopotamica*	30n45w	radius L	98.57	32.37	3.55	1.50%	-21.22	4.43
AY0098	49-Dama	*D. mesopotamica*	30n45w	tibia L	80.79	26.17	**3.60**	1.82%	-21.59	2.97
AY0099	26-Dama	*D. mesopotamica*	20n25w	radius L	163.53	56.16	3.40	2.20%	-20.76	4.87
AY0100	27-Dama	*D. mesopotamica*	20n25w	radius L	166.87	57.58	3.38	2.17%	-20.85	4.59

Table 6.3 Stable isotope values for the caprine bone samples

Lab ID	ID Number	Species	Area/ Context	Element	C Amount (µg)	N Amount (µg)	C:N	Collagen Yield	δ^{13}C (‰)	δ^{15}N (‰)
Lab ID 16	55-Caprine	Caprine	15n20w	tibia R	147.57	51.04	3.37	5.22%	-20.72	3.73
Lab ID 17	59-Caprine	Caprine	15n25w	tibia R	343.18	123.98	3.23	6.59%	-21.01	4.55
Lab ID 18	65-Caprine	Caprine	15n30w	tibia R	321.63	115.42	3.25	5.53%	-20.86	4.74
Lab ID 19	68-Caprine	Caprine	20n25w	tibia R	141.31	48.89	3.37	2.48%	-20.31	5.56
Lab ID 20	70-Caprine	Caprine	20n25w	tibia R	17.06	3.45	**5.78**	4.90%	-27.06	-7.91
Lab ID 21	72-Caprine	Caprine	20n25w	tibia R	240.71	85.43	3.29	5.62%	-20.53	3.51
Lab ID 22	80-Caprine	Caprine	20n25w	tibia R	198.35	70.06	3.30	4.01%	-20.73	4.35
Lab ID 23	96-Caprine	Caprine	5n30w	tibia R	293.42	104.46	3.28	6.51%	-20.47	3.54
Lab ID 24	82-Caprine	*Ovis aries*	20n45w	radius R	243.96	87.10	3.27	7.36%	-20.37	5.78
Lab ID 25	92-Caprine	*Capra hircus*	30n45w	humerus R	192.22	66.95	3.35	6.20%	-20.46	3.45
Lab ID 26	56-Caprine	*Ovis aries*	15n25w	radius R	341.18	123.97	3.21	4.67%	-21.14	3.85
Lab ID 27	57-Caprine	*Capra hircus*	15n25w	humerus R	252.45	90.44	3.26	3.46%	-20.45	4.48
Lab ID 28	78-Caprine	*Capra hircus*	20n25w	humerus R	382.99	138.36	3.23	5.98%	-20.16	5.68
Lab ID 29	58-Caprine	*Capra hircus*	15n25w	humerus L	296.88	106.71	3.25	4.85%	-20.67	3.29
Lab ID 30	64-Caprine	*Ovis aries*	15n30w	humerus L	271.43	96.55	3.28	7.70%	-20.72	5.40
Lab ID 47	81-Caprine	*Capra hircus*	20n45w	humerus R	392.44	141.46	3.24	3.89%	-19.66	5.83
Lab ID 48	83-Caprine	*Capra hircus*	20n45w	humerus R	136.52	47.16	3.38	3.11%	-20.93	6.70
AY0067	73-Caprine	*Capra hircus*	20n25w	humerus L	132.64	37.97	**4.08**	0.58%	-21.90	4.98
AY0068	75-Caprine	*Capra hircus*	20n25w	humerus L	193.40	67.55	3.34	1.13%	-20.66	1.59
AY0069	79-Caprine	Caprine	20n25w	tibia L	77.90	26.29	3.46	1.58%	-21.31	2.32
AY0070	54-Caprine	*Capra hircus*	15n20w	humerus L	368.13	122.96	3.49	2.05%	-20.62	5.85
AY0071	60-Caprine	*Ovis aries*	15n30w	radius R	53.83	14.12	**4.45**	0.73%	-22.41	3.27
AY0072	52-Caprine	Caprine	15n20w	tibia L	173.09	58.53	3.45	1.54%	-20.45	4.19
AY0073	85-Caprine	*Ovis aries*	20n45w	humerus L	427.03	145.29	3.43	2.34%	-20.34	5.88
AY0074	89-Caprine	*Ovis aries*	25n30w	humerus L	254.40	87.80	3.38	0.94%	-20.19	5.83
AY0075	87-Caprine	*Ovis aries*	20n45w	radius R	74.77	25.22	3.46	1.48%	-21.37	4.65
AY0076	88-Caprine	*Capra hircus*	20n45w	humerus R	235.36	82.12	3.34	2.76%	-20.21	5.66
AY0077	69-Caprine	*Capra hircus*	20n25w	humerus R	160.66	55.21	3.40	2.31%	-21.22	2.91
AY0078	62-Caprine	*Capra hircus*	15n30w	radius L	135.99	42.37	**3.74**	0.00%	-21.18	2.76
AY0079	67-Caprine	*Capra hircus*	15n35w	radius L	163.05	54.02	3.52	1.86%	-20.94	5.37
AY0080	93-Caprine	Caprine	30n45w	tibia L	98.33	32.13	3.57	1.26%	-21.13	5.35
AY0081	94-Caprine	Caprine	30n45w	humerus L	159.22	53.54	3.47	2.24%	-21.24	3.29
AY0082	95-Caprine	Caprine	35n50w	humerus L	78.38	24.38	**3.75**	0.57%	-21.73	4.61
AY0083	98-Caprine	Caprine	5n30w	humerus L	16.02	1.75	**10.68**	1.29%	-25.01	-8.92

6.2.1 Collagen Preservation

Tables 6.1-6.3 present the sample quality indicators for carbon and nitrogen isotopes and the δ^{15}N and δ^{13}C values of the bone collagen for each sample. To evaluate sample quality, percent collagen yield and C:N ratios were calculated. The collagen yield for 23 samples was not above 1% yield, which suggests that collagen was not viable (Ambrose 1990; van Klinken 1999). However, 6 of these samples fell within the established C:N ratio between 2.9 and 3.6 for viable samples (Ambrose 1990). Thus, it is possible that there was an error with the analytical balance of these 6 samples, since the vials clearly had sufficient collagen for isotope analysis (Beasley et al. 2013). Sixty-nine samples fell within the atomic C:N criteria defined for collagen suitable for isotopic analysis (Ambrose 1990). Thirty-one samples were outside the range; thus, their results cannot be interpreted because these samples contained too little amounts of carbon and/or nitrogen.

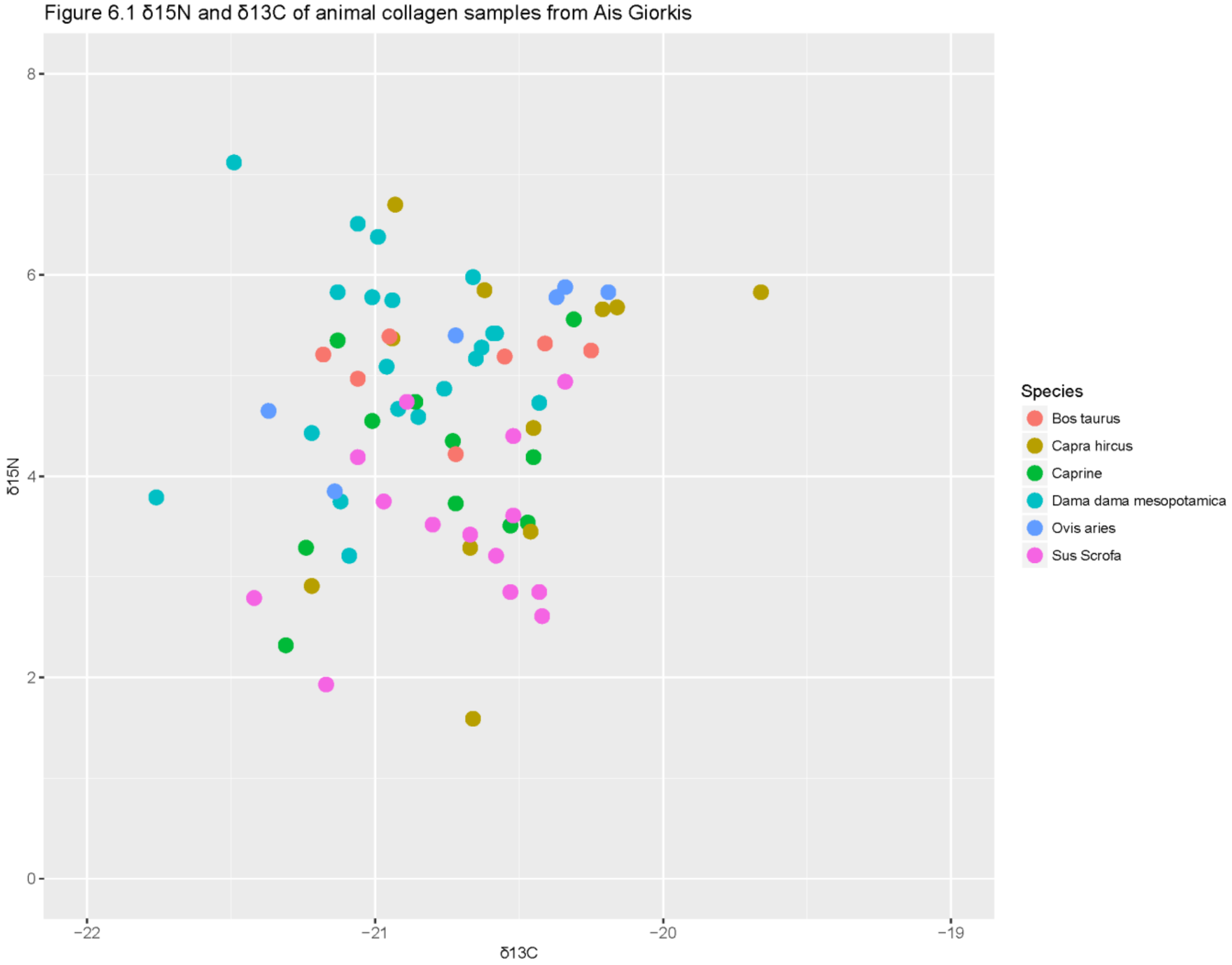
6.2.2 Bone Collagen Carbon and Nitrogen Stable Isotope Values

Table 6.4 presents a summary of the isotope data. Figure 6.1 shows the δ^{13}C and δ^{15}N of the animal collagen samples. At *Ais Giorkis*, the δ^{13}C values for the domestic animals range from -21.37 to -19.66‰ (mean = -20.67 ± 0.4‰) in caprine, from -21.18 to -20.25‰ (mean = -20.73 ± 0.3‰) in cattle, and -21.42 to -20.34‰ (mean = -20.74 ± 0.3‰) in pig. The δ^{15}N values vary from 1.59 to 5.88‰ (mean = 4.55 ± 1.3‰) in caprine, 4.22 to 5.39‰ (mean = 5.08 ± 0.4‰) in cattle, and 1.93 to 4.94 (mean = 3.48 ± 0.9‰) in pig. The δ^{13}C values for the Mesopotamian fallow deer range between -21.49 and -20.43‰, with an average of -20.94 ± 0.3‰. The range for their δ^{15}N values is between 3.21 and 7.12‰, with a mean of 5.19 ± 1.0‰.

Table 6.4 Carbon and nitrogen summary isotope data (minimum, maximum, range, mean, and standard deviation) data for fauna at *Ais Giorkis* (n=69)

		$\delta^{13}C$ (‰)					$\delta^{15}N$ (‰)				
Taxa	**n**	**Min**	**Max**	**Range**	**Mean**	**s.d.**	**Min**	**Max**	**Range**	**Mean**	**s.d.**
Caprine	28	-21.37	-19.66	1.71	-20.67	0.4	1.59	6.70	5.11	4.55	1.3
Ovis aries	6	-21.37	-20.19	1.18	-20.69	0.5	3.85	5.88	2.03	5.23	0.8
Capra hircus	11	-21.22	-19.66	1.56	-20.54	0.4	1.59	6.70	5.11	4.62	1.6
Cattle	7	-21.18	-20.25	0.93	-20.73	0.3	4.22	5.39	1.17	5.08	0.4
Pig	14	-21.42	-20.34	1.08	-20.74	0.3	1.93	4.94	3.01	3.48	0.9
Mesopotamian fallow deer	20	-21.76	-20.43	1.33	-20.94	0.3	3.21	7.12	3.91	5.19	1.0

Figure 6.1 δ^{15}N and δ^{13}C of animal collagen samples from *Ais Giorkis*



To summarize, bone preservation at *Ais Giorkis* appears to be generally good, with an average success rate of 69% of bones sampled yielding collagen. Of the 100 faunal samples that were taken, 31 samples failed to yield well-preserved collagen leaving a total faunal sample of 69. Results presented in this section are based on these 69 samples. I observed trends in poorer preservation for the deer and pig bones.

6.3 Tooth Enamel Carbon and Oxygen Stable Isotope Values

For the $\delta^{18}O$ values and the $\delta^{13}C$ values, the presentation of the results primarily follows that of Marciniak et al. (2017) and Balasse et al. (2013), respectively. The raw data for each analyzed sample are reported in Table 6.5 and Figures 6.2-6.8. ^{18}O isotope analysis of tooth carbonate yielded values on the V-PDB scale. Several publications (e.g., Henton 2012; Henton et al. 2010; Leon 2016) convert $\delta^{18}O_{VPDB}$ values into corresponding $\delta^{18}O_{V\text{-}SMOW}$ values using the following correlation (Friedman and O'Neil 1977): $\delta^{18}O_{V\text{-}SMOW} = (1.0309 \text{ X } \delta^{18}O_{VPDB}) + 30.9$. In addition, these publications also provide estimates of the ingested water following the equations by D'Angela and Longinelli (1990) and Iacumin et al. (1966) (Chapter 4). I have included these values on Table 6.5. It is important to emphasize that the small sample size precludes any statistically secure interpretations of animal management strategies through oxygen isotope measurements.

Table 6.5 Carbon and oxygen values for sequentially sampled caprine teeth from *Ais Giorkis*

ID Number	Lab ID	Tooth	Taxon	$\delta^{13}C_{VPDB}$ (‰)	$\delta^{18}O_{VPDB}$ (‰)	$\delta^{18}O_{VSMOW}$ (‰)	Ingested water
AY101	2017-003-51.1	M3	Ovis/Capra	-12.48	-3.50	27.29	-6.06
	2017-003-51.2			-12.32	-3.10	27.71	-5.78
	2017-003-51.3			-11.57	-1.84	29.00	-4.92
	2017-003-51.4			-12.45	-0.51	30.38	-4.01
	2017-003-51.5			-13.14	-2.20	28.63	-5.17
	2017-003-51.6			-13.49	-3.07	27.73	-5.77
	2017-003-51.7			-12.87	-2.85	27.96	-5.61
	2017-003-51.8			-12.36	-1.06	29.81	-4.39
AY102	2017-003-52.1	M3	Ovis/Capra	-12.83	-4.84	25.91	-6.97
	2017-003-52.2			-12.59	-3.81	26.97	-6.27
	2017-003-52.3			-13.04	-3.49	27.31	-6.05
	2017-003-52.4			-13.12	-2.97	27.84	-5.69
	2017-003-52.5			-12.65	-2.61	28.21	-5.45
	2017-003-52.6			-11.65	-2.43	28.40	-5.33
	2017-003-52.7			-11.42	-2.04	28.80	-5.06
	2017-003-52.8			-12.53	-1.34	29.52	-4.58
AY103	2017-003-53.1	M3	Ovis/Capra	-12.85	-4.43	26.33	-6.69
	2017-003-53.2			-12.03	-3.61	27.18	-6.13
	2017-003-53.3			-12.41	-2.75	28.07	-5.54
	2017-003-53.4			-13.02	-3.72	27.07	-6.21
	2017-003-53.5			-12.61	-3.37	27.42	-5.97
	2017-003-53.6			-12.42	-2.83	27.98	-5.60
	2017-003-53.7			-12.60	-1.56	29.29	-4.73
	2017-003-53.8			-12.81	-2.07	28.77	-5.08
AY104	2017-003-54.1	M2	Capra	-12.17	-2.79	28.02	-5.57
	2017-003-54.2			-12.70	-1.51	29.35	-4.70
	2017-003-54.3			-12.93	-1.96	28.88	-5.01
	2017-003-54.4			-13.03	-1.41	29.45	-4.63
	2017-003-54.5			-12.35	-0.97	29.90	-4.33
	2017-003-54.6			-12.30	0.06	30.96	-3.63
	2017-003-54.7			-12.61	-0.47	30.41	-3.99
	2017-003-54.8			-12.66	-1.67	29.18	-4.81
AY105[a]	2017-003-55.1	M2	Ovis/Capra	-12.74	-3.04	27.77	-5.74
	2017-003-55.2			-11.88	-2.95	27.86	-5.68
	2017-003-55.3			-11.08	-0.40	30.48	-3.94
	2017-003-55.4			-11.83	0.08	30.98	-3.62
	2017-003-55.5			-12.75	-2.10	28.74	-5.10
	2017-003-55.6			-11.92	-2.88	27.94	-5.63
	2017-003-55.7			-11.81	-3.79	26.99	-6.26
	2017-003-55.8			-11.73	-3.75	27.04	-6.22
AY106	2017-003-56.1	M2	Ovis/Capra	-11.94	-4.41	26.35	-6.68
	2017-003.56.2			-11.96	-4.68	26.08	-6.86
	2017-003.56.3			-12.07	-4.31	26.45	-6.61
	2017-003.56.4			-11.87	-3.29	27.51	-5.91
	2017-003.56.5			-11.91	-3.54	27.25	-6.09
	2017-003.56.6			-12.08	-3.76	27.03	-6.23
	2017-003.56.7			-11.80	-4.52	26.24	-6.75
	2017-003.56.8			-11.92	-4.24	26.53	-6.56
AY107	2017-003-57.1	M2	Ovis	-13.47	-3.91	26.87	-6.33
	2017-003-57.2			-13.09	-3.04	27.76	-5.75
	2017-003-57.3			-13.31	-2.53	28.29	-5.40
	2017-003-57.4			-10.85	1.64	32.59	-2.55
	2017-003-57.5			-12.49	1.19	32.12	-2.86
	2017-003-57.6			-12.63	-1.25	29.61	-4.52
	2017-003-57.7			-12.61	-2.49	28.33	-5.37
	2017-003-57.8			-12.16	-3.95	26.83	-6.36

[a] The peak amplitude for sample 2017-003-55.3 is too low for reliable results.

Figure 6.2 $\delta^{13}C_{VPDB}$ and $\delta^{18}O_{VPDB}$ values of sequential enamel samples from AY101. Panel A represents the $\delta^{13}C_{VPDB}$ values and Panel B represents the $\delta^{18}O_{VPDB}$ values

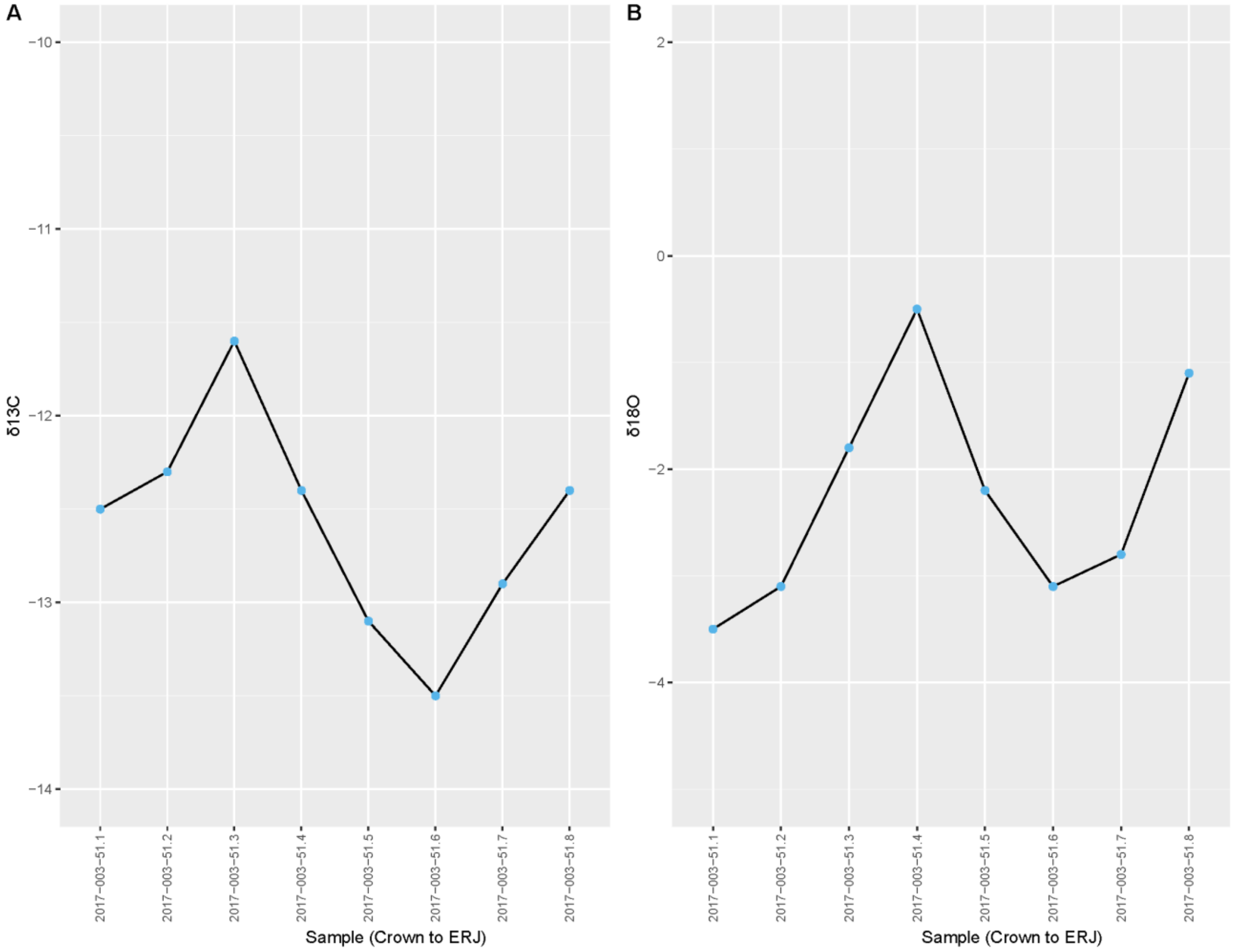


Figure 6.3 $\delta^{13}C_{VPDB}$ and $\delta^{18}O_{VPDB}$ values of sequential enamel samples from AY102. Panel A represents the $\delta^{13}C_{VPDB}$ values and Panel B represents the $\delta^{18}O_{VPDB}$ values

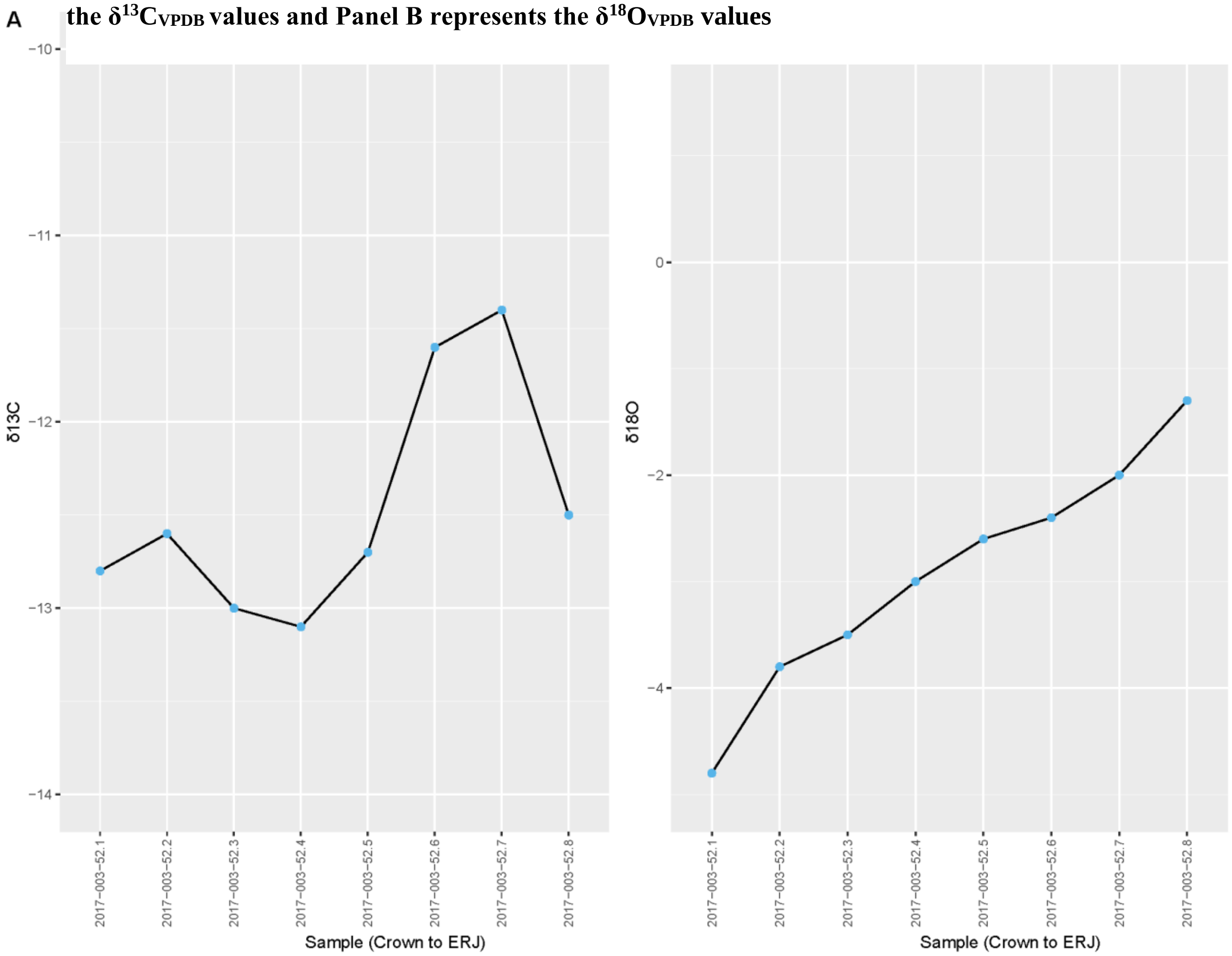


Figure 6.4 δ^{13}C$_{VPDB}$ and δ^{18}O$_{VPDB}$ values of sequential enamel samples from AY103. Panel A represents the δ^{13}C$_{VPDB}$ values and Panel B represents the δ^{18}O$_{VPDB}$ values

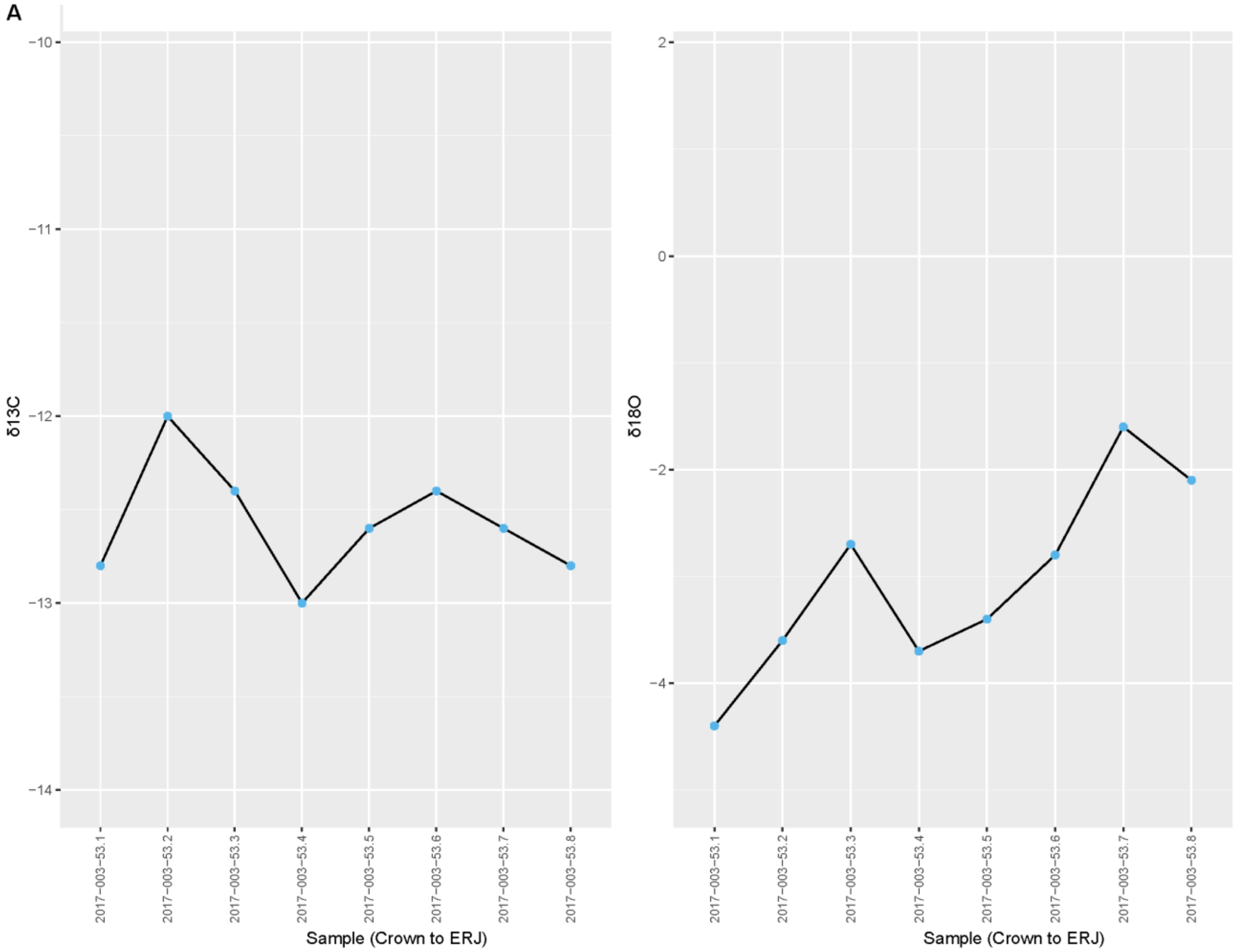


Figure 6.5 $\delta^{13}C_{VPDB}$ and $\delta^{18}O_{VPDB}$ values of sequential enamel samples from AY104. Panel A represents the $\delta^{13}C_{VPDB}$ values and Panel B represents the $\delta^{18}O_{VPDB}$ values

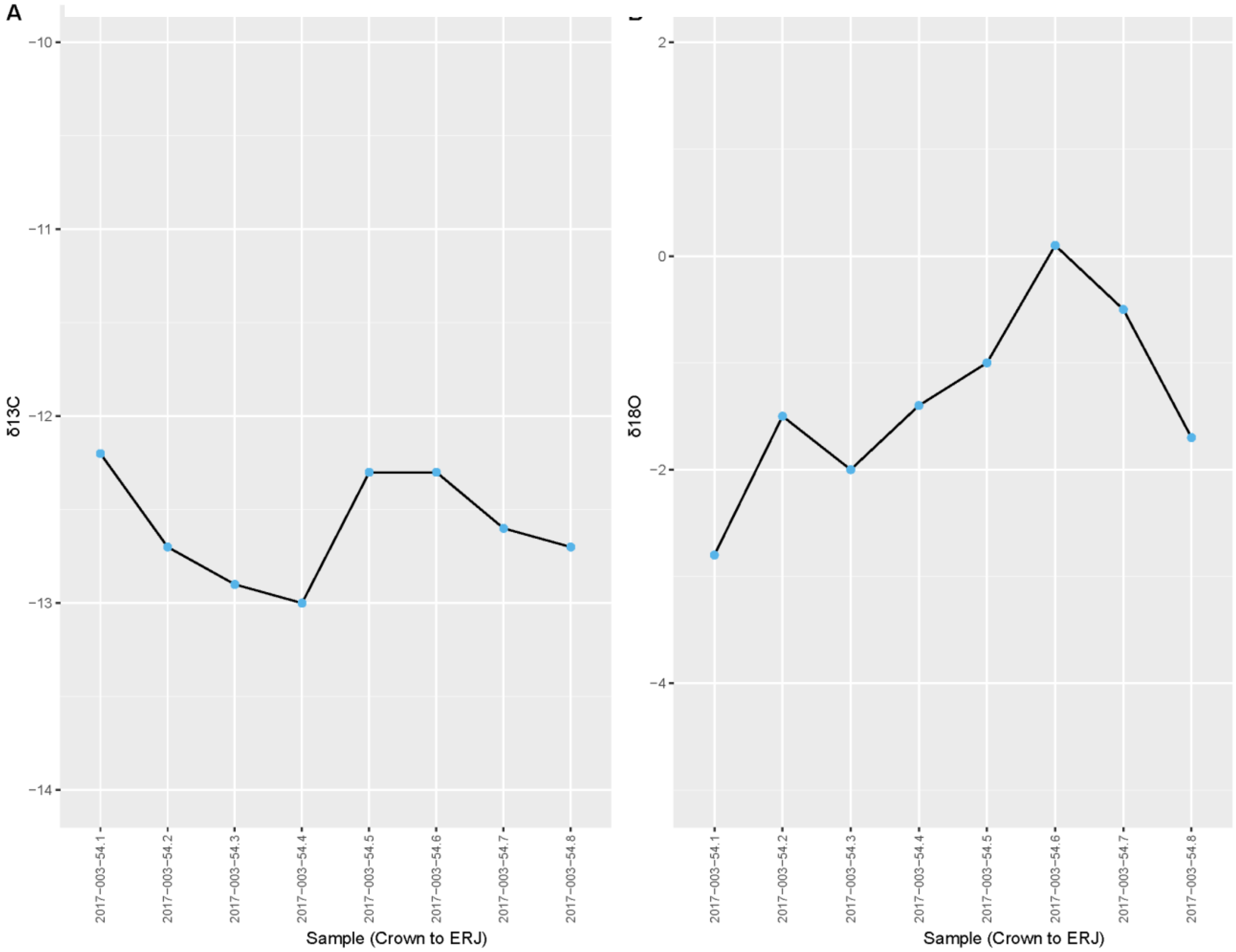


Figure 6.6 $\delta^{13}C_{VPDB}$ and $\delta^{18}O_{VPDB}$ values of sequential enamel samples from AY105. Panel A represents the $\delta^{13}C_{VPDB}$ values and Panel B represents the $\delta^{18}O_{VPDB}$ values

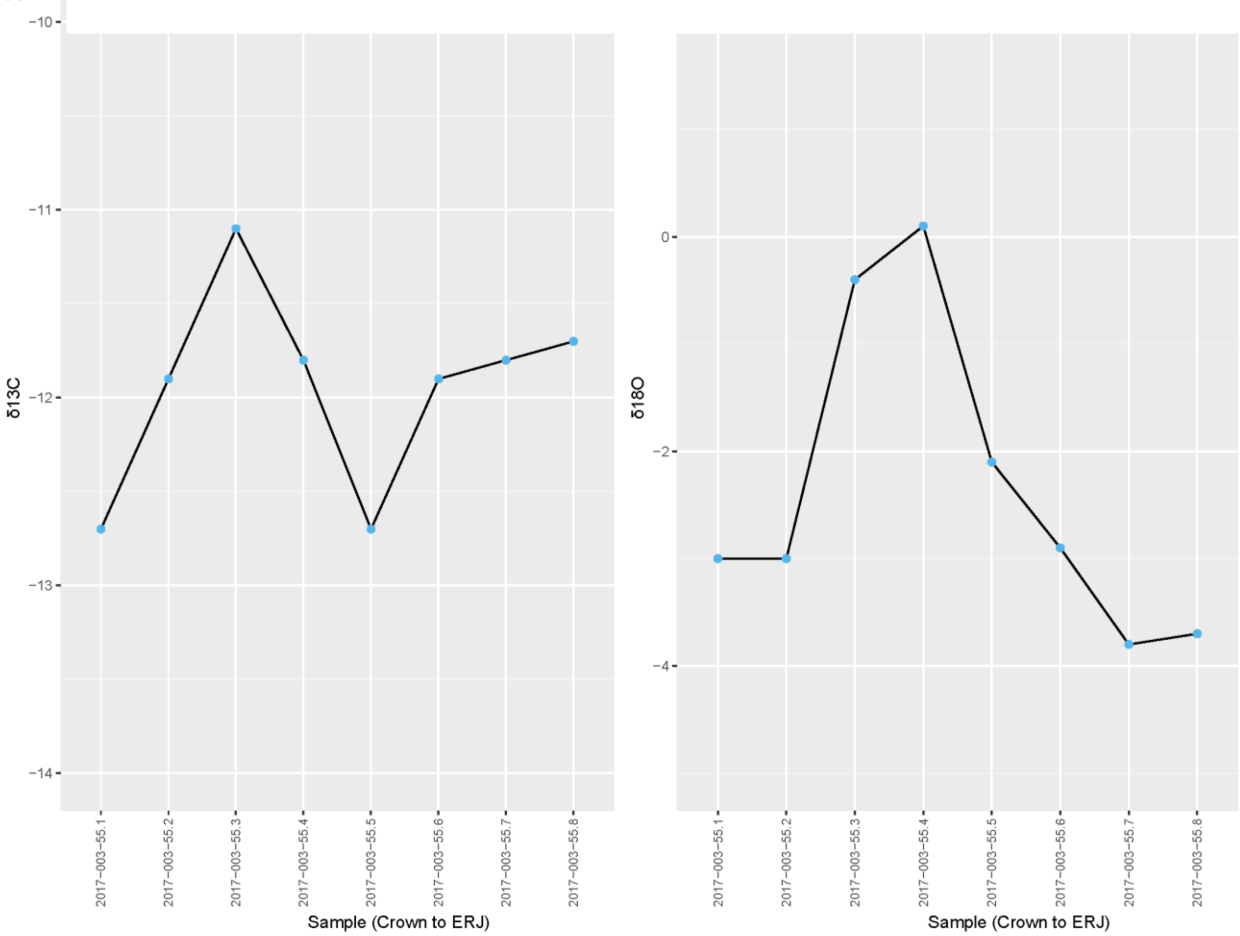


Figure 6.7 $\delta^{13}C_{VPDB}$ and $\delta^{18}O_{VPDB}$ values of sequential enamel samples from AY106. Panel A represents the $\delta^{13}C_{VPDB}$ values and Panel B represents the $\delta^{18}O_{VPDB}$ values

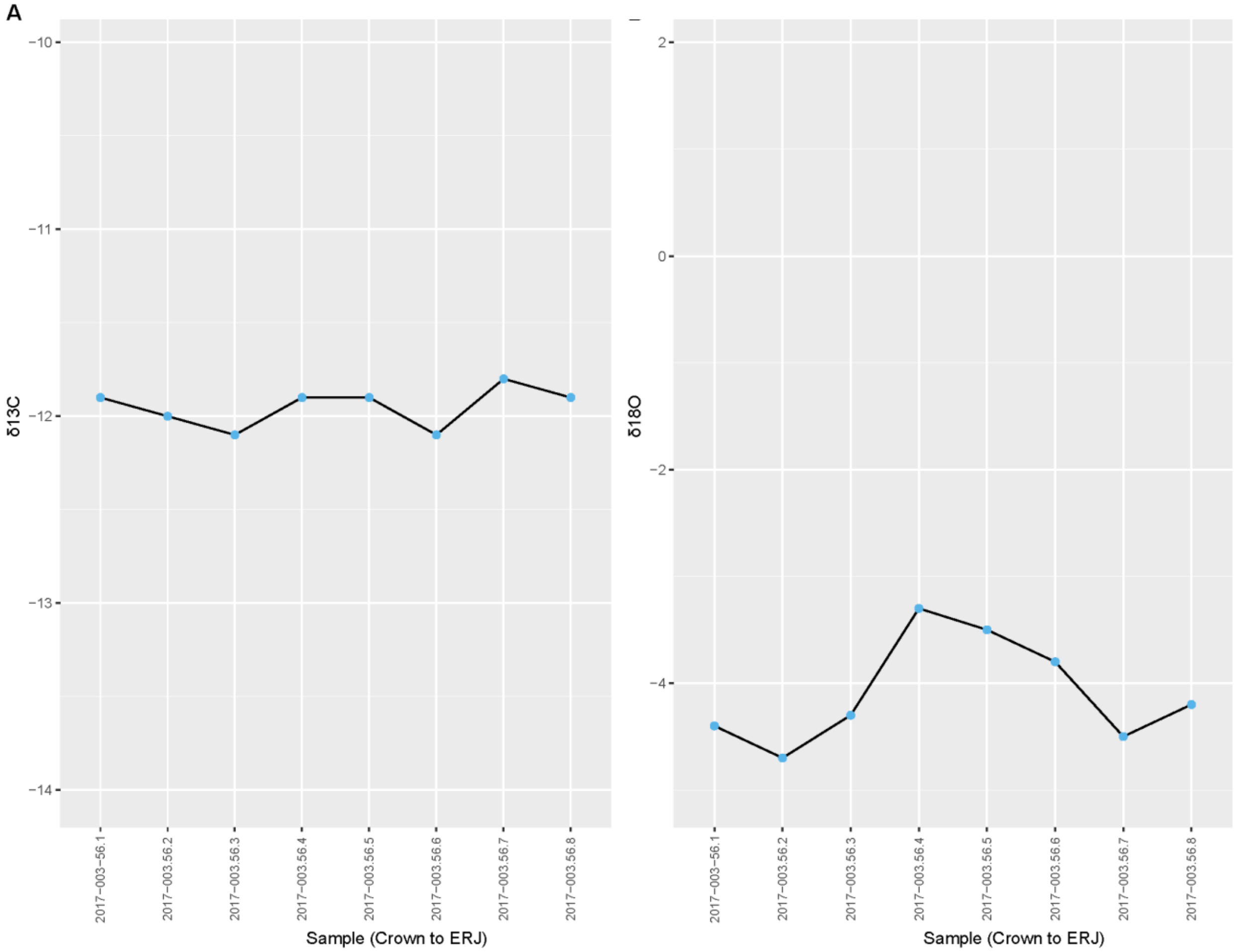
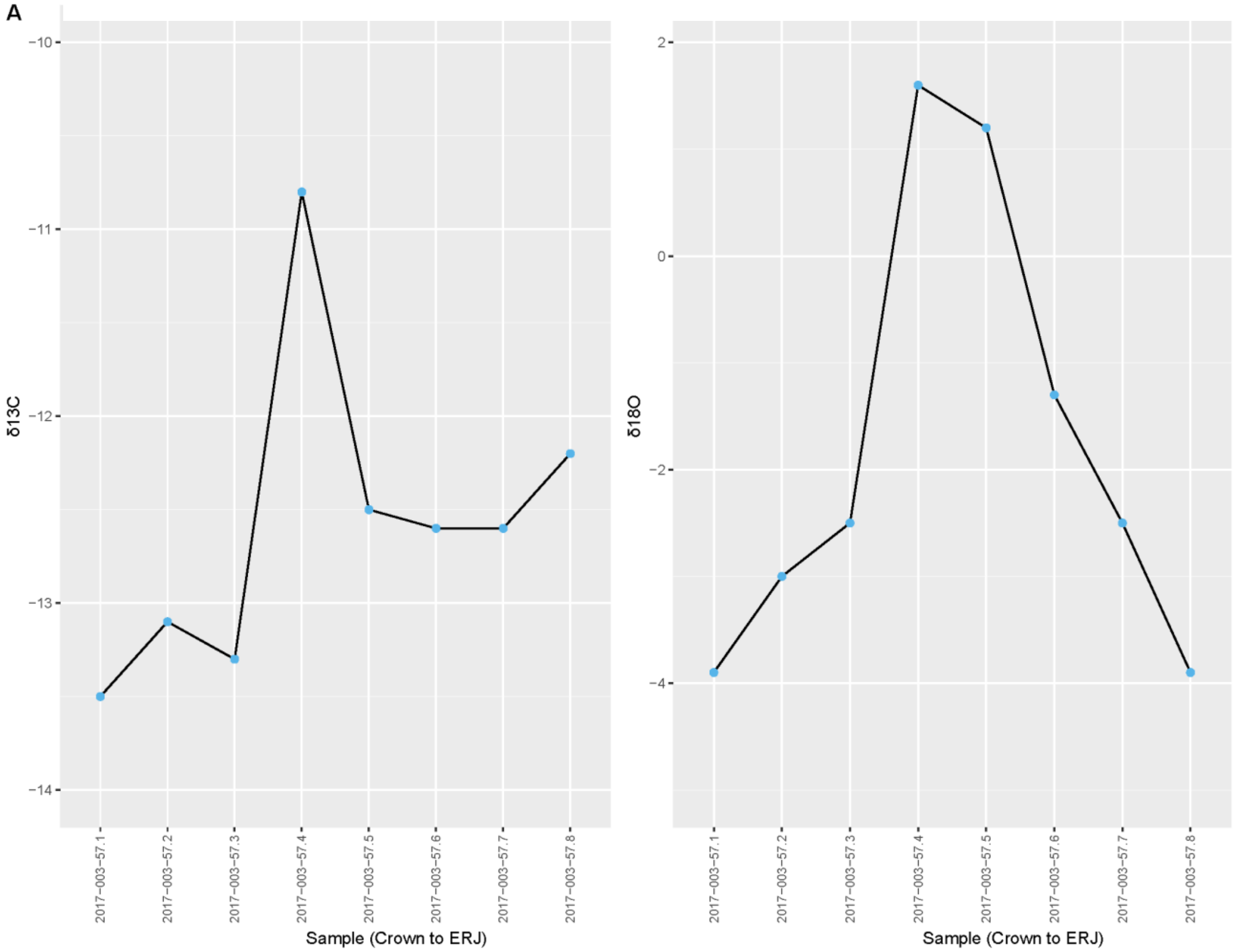
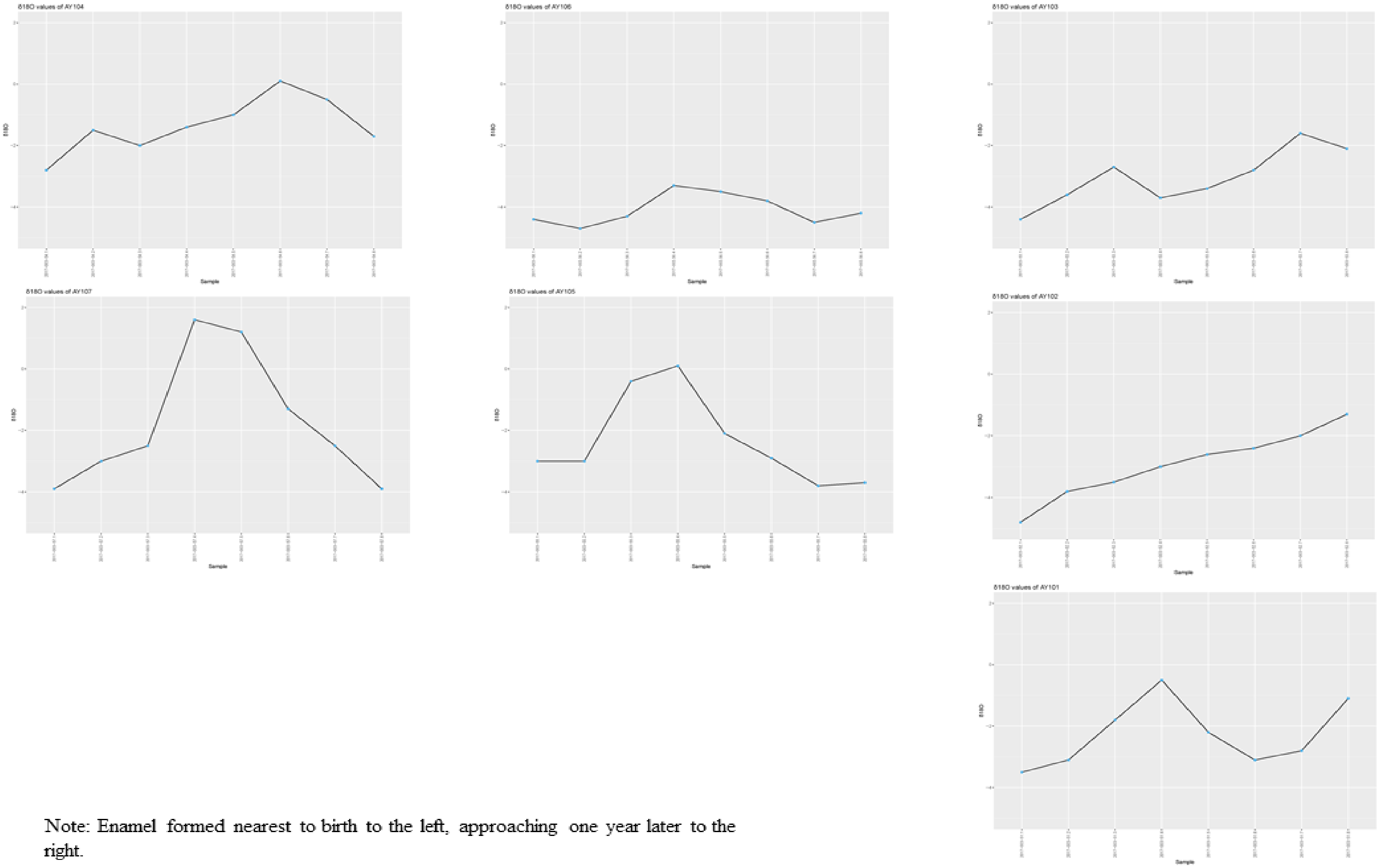


Figure 6.8 $\delta^{13}C_{VPDB}$ and $\delta^{18}O_{VPDB}$ values of sequential enamel samples from AY107. Panel A represents the $\delta^{13}C_{VPDB}$ values and Panel B represents the $\delta^{18}O_{VPDB}$ values



At *Ais Giorkis*, the total $\delta^{18}O_{VPDB}$ variation was 6.4‰ (1.6 to -4.8‰) and the intra-tooth variation ranged from 1.4 to 5.5‰. Figure 6.9 displays the $\delta^{18}O_{PDB}$ values in the sequential sampling of each tooth specimen all together. The curves in the left and center columns are of second mandibular molars, with the first column on the left including the only two molars that were confidently identified to goat (AY104, top) and sheep (AY107, bottom). The center column includes AY106 and AY105. The curves in the right column are the third mandibular molars (AY103, AY102, and AY101). Most of the specimens exhibit intra-tooth cyclical variation in oxygen isotopes, which reflects seasonal shifts in the oxygen isotopic composition of ingested water. Lower (or depleted) $\delta^{18}O$ values reflect winter season intake and higher (or enriched) $\delta^{18}O$ values correspond to summer season intake (Makarewicz et al. 2017a:72). The $\delta^{18}O_{VPDB}$ curve for AY102 does not top or bottom out clearly; thus, interpretations for this molar will be done with care. The remaining curves allow for discussion of variations in seasonal uptake of water over roughly an annual cycle.

Figure 6.9 Charts of $\delta^{18}O_{VPDB}$ values in sequential samples from seven tooth specimens



Note: Enamel formed nearest to birth to the left, approaching one year later to the right.

Table 6.6 Carbon and oxygen isotope summary statistics for sequentially sampled caprine teeth from *Ais Giorkis*

			δ13C (‰)				δ18O (‰)			
ID Number	**Lab ID**	**Taxon**	**Mean**	**Min.**	**Max.**	**Δ**	**Mean**	**Min.**	**Max.**	**Δ**
AY101	2017-003-51	Ovis/Capra	-12.6	-13.5	-11.6	1.9	-2.3	-3.5	-0.5	3.0
AY102	2017-003-52	Ovis/Capra	-12.5	-13.1	-11.4	1.7	-2.9	-4.8	-1.3	3.5
AY103	2017-003-53	Ovis/Capra	-12.6	-13.0	-12.0	1.0	-3.0	-4.4	-1.6	2.8
AY104	2017-003-54	Capra	-12.6	-13.0	-12.2	0.8	-1.3	-2.8	0.1	2.7
AY105	2017-003-55	Ovis/Capra	-12.0	-12.7	-11.1	1.6	-2.4	-3.8	0.1	3.7
AY106	2017-003-56	Ovis/Capra	-11.9	-12.1	-11.8	0.3	-4.1	-4.7	-3.3	1.4
AY107	2017-003-57	Ovis	-12.6	-13.5	-10.8	2.7	-1.8	-3.9	1.6	5.5

Table 6.6 provides summary statistics (maximum, minimum, and range) of the sequentially sampled molars. The maximum $\delta^{18}O_{VPDB}$ ranges from 1.6‰ (AY107) down to -3.3‰ (AY106). The minimum $\delta^{18}O_{VPDB}$ ranges from -2.8‰ (AY104) to -4.8‰ (AY102). The ranges spread from 1.4‰ (AY106) to 5.5‰ (AY107).

Similar to the $\delta^{18}O$ curves, the carbon sequences exhibit changes along the tooth crown (Figures 6.2-6.8). In all specimens, the highest $\delta^{13}C$ values occur when the $\delta^{18}O$ values are the highest, and vice versa. The total $\delta^{13}C$ variation was 2.7‰ (-10.8 to -13.5‰) and the intra-tooth variation ranged from 0.3 to 2.7‰. The maximum and minimum $\delta^{13}C$ ranges are from -10.8‰ (AY107) to -12.2‰ (AY104) and -12.1‰ (AY106) to -13.5‰ (AY101 and AY107), respectively. The ranges spread from 0.8‰ (AY104) to 2.7‰ (AY107).

6.4 Environments of Animal Husbandry at *Ais Giorkis*

Stable isotope analyses of wild animal remains are used by archaeologists to investigate past environmental settings. For environmental reconstructions, they are preferred over domestic animals, because humans can manipulate the diet of herd animals through their choice of animal feed. In turn, human's control the domestic animals' isotopic values (Stevens et al. 2006). In this study, I compare the bone collagen $\delta^{13}C$ and $\delta^{15}N$ values between the Mesopotamian fallow deer and the other animal species as well as the sequentially sampled molar $\delta^{13}C$ values to examine: 1.) if animals were consuming strictly C_3 or C_4 diets or a combination of these two plant types; 2.) whether some animals were foraging in environments with a closed canopy; 3.) whether there was the addition of marine resources to their diet, including seaweed. In general, the results between the wild deer and domestic animals to not differ substantially from one another. All of these different elements allow us to better understand the environmental setting that animals were foraging in.

6.4.1 Environment Dominated by C_3 Plants, C_4 Plants, or Both

As discussed in Chapter 4, C_3 plants today exhibit a wide range of carbon isotopic compositions (-37 to -22‰). The majority of C_3 plants with values greater than -25.5‰ are found in dry environments, where mean annual precipitation is less than 500 mm/year (e.g., Cyprus). Carbon isotope values lower than -25.5‰ are typically associated with wetter environments. Values above -22‰ are almost entirely restricted to the Atacama Desert, the driest desert on Earth (Kohn 2010). Dense forest (i.e., closed canopy) also produces a canopy effect, which is indicated by negative $\delta^{13}C$ values.[44] Specifically, $\delta^{13}C$ values in dense forests have been observed to range from around -29‰ to -30.5‰ (Ambrose 1986; Drucker et al. 2008; Tieszen 1991; van der Merwe and Medina 1981). Recently, Kohn (2010) argued that the threshold value for understory vegetation in modern times is -31.5‰. Due to the fossil fuel effect, we need to

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[44] The canopy effect corresponds to a vertical gradient in leaf $\delta^{13}C$ values from the ground to the canopy of forested areas. The most depleted ^{13}C plants occur near the ground, which is explained by: 1.) enhanced recycling of CO_2 that is ^{13}C-depleted in the forest; 2.) photosynthesis under low light conditions, which elevates C isotope fractionation; and 3.) other physiological mechanisms (e.g., Stevens and Hedges 2004; Doppler et al. 2017; Drucker et al. 2008; van der Merwe and Medina 1991). In general, plants growing under forested closed canopies have $\delta^{13}C$ values that are ^{13}C depleted relative to the same type of plant growing in more open conditions (Drucker et al. 2008). The depleted $\delta^{13}C$ is passed along the food chain from vegetation into animal tissues, including bone collagen and molar enamel (Doppler et al. 2017).

add a correction factor of -1.5‰ (Freyer and Belacy 1983), in order to determine carbon isotope value of C_3 plants in pre-Industrial times. Thus, the corresponding values for plants prior to the Industrial Revolution would be between -24.0 and -20.5‰. The first value represents plants grown in dry environments and the second value (and particularly numbers that are greater) represent extreme arid conditions. The value for understory vegetation in pre-Industrial times would be around -30.0‰.

Most of the research on the 'canopy effect' is done in Europe, where there is a dense canopy. In the Mediterranean, however, woodlands tend to have thinner canopy, resulting in increased light intensity at the forest floor. This would promote the escape of depleted carbon; thus, decreasing the 'canopy effect' contributing to ^{13}C-depleted carbon isotope values in forest plants and the herbivores that feed on these plants. Thus, the understory vegetation could have a slightly higher $\delta^{13}C$ value than -30.0‰ (Makarewicz et al. 2016). To interpret the results in this study, I follow other publications that have conducted isotopic analysis on animal remains from the Mediterranean (e.g., Makarewicz et al. 2016).

The overall range of variation of bone collagen $\delta^{13}C$ values in this study suggests that all taxa lived in an environment that was dominated by C_3 plants. The carbon isotope value cut-off for pure C_3 plant consumption in herbivore bone collagen is -19.0‰. Individuals with higher carbon isotope values would indicate the input of some C_4 plants in their diet (Fuller et al. 2012; Marciniak et al. 2017:1471). None of the animals in this study have values above -19‰, implying that there was little contribution of C_4 plants in their diet. This result is similar to Scirè Calabrisotto's (2017a, 2017b) findings (Chapter 4).

The molar enamel $\delta^{13}C$ values also support that sheep and goats were feeding in areas dominated by C_3 vegetation. Typically, pure C_3 plant consumption does not fall above -7.7‰.

All samples in this study are lower than -7.7‰, indicating C_4 plant resources were not part of caprine diet at *Ais Giorkis*.

The environment of Cyprus was also likely wetter than today, which is not surprising given that the Early Holocene is believed to have been wetter than present conditions. Due to metabolic fractionation effects, the $\delta^{13}C$ values of bone collagen is depleted by around -5‰ compared to dietary (plant) $\delta^{13}C$ values (Koch, Fogel, and Tuross 1994). This means that the animals in this study were consuming plants with $\delta^{13}C$ values between -26.49 and -25.54‰.

Similarly, studies have also demonstrated that there is around a 14.1‰ carbon isotope fractionation between enamel and dietary plant $\delta^{13}C$ values (Cerling and Harris 1999; Cerling et al. 1997; Lee-Thorp and van der Merwe 1987; Lee-Thorp et al. 1989; Wang et al. 1994). Thus, sheep/goat were consuming plants with $\delta^{13}C$ values between -27.6 and -24.9‰. As noted above, the typical value for C_3 plants grown in dry environments, like Cyprus, in pre-Industrial times would have been around -24.0‰. Overall, these data suggest that C_3 plants dominated the environment. The climate also appears wetter than today, although some plants were still grown under drier conditions. Hadjikoumis et al. (forthcoming) also reached similar results about the vegetation and climate of the Cypro-PPNB from the caprine enamel samples.

6.4.2 Closed or Open Environment for Foraging

Based on both the bone collagen and molar enamel $\delta^{13}C$ values, some animals might have been foraging in a canopied Mediterranean woodland. Carbon isotopic shifts of up to -3‰ in the collagen of herbivores from ancient European environments have been attributed to a canopy effect (e.g., Doppler et al 2017; Drucker et al. 2008). However, the exact amplitude of impact the canopy effect has on the carbon isotopic composition of understory floral growth, and the herbivores feeding on that growth, is not uniform. Rather, the impact depends on light levels and the density of forest growth (Makarewicz et al. 2016:10). The minimum $\delta^{13}C$ value is not equal to or less than -30.0‰ for plants consumed by the animals in this study. However, the $\delta^{13}C$ cut-off value of -22.0‰ for herbivore collagen is typically used by researchers to denote foraging behavior in open or closed environments (Doppler et al. 2017; Drucker et al. 2008). Given that many of the animal species in this study have depleted $\delta^{13}C$ values (many of which are close to -22.0‰), I do not believe that we can rule out that some might have been foraging under a light canopy. The molar enamel $\delta^{13}C$ values also support this conclusion on a seasonal scale (discussed below). Today, forests in the Troodos mountains are located approximately 2-3 km northeast of *Ais Giorkis* (Stewart 2006:207). While we do not know where the forests were located at the time of site occupation, it is unlikely that they were much farther than this distance. Thus, animals would not have had to travel far to forage under a canopy.

6.4.3 Marine Resource Consumption

Seaweed as fodder for domestic animals in prehistory has been suggested for some islands, particularly the North Atlantic isles (e.g., Balasse et al. 2009; Jones and Mulville 2016). As discussed in Chapter 4, marine and terrestrial plants have different $\delta^{13}C$ values because they rely on different carbon sources (Smith 1972; Smith and Epstein 1971). Consumers of marine resources will also show higher $\delta^{15}N$ values because of the effects of marine environments and trophic levels (Lee-Thorp 2008). In herbivore collagen, typically $\delta^{13}C$ values greater than -19‰ are associated with seaweed consumption. Enamel $\delta^{13}C$ values are also quite high. However, the interpretation of terrestrial vs marine plant resources becomes tricky when there are also C_4 plants in the environment. Herbivore collagen with $\delta^{15}N$ values of around 8‰ and greater have been suggested for evidence the addition of marine resources to animal diet (e.g., Britton et al. 2008; Müldner et al. 2014; Richards and Hedges 2003).

In this study, no contribution of seaweed was detected in any of the animals. Both the $\delta^{13}C$ and $\delta^{15}N$ values fall within the range for consumers of terrestrial resources. Scirè Calabrisotto (2017a; 2017b) also did not find evidence of marine food consumption by humans or animals from prehistoric sites in Cyprus. Given the location of Ais Giorkis in the uplands, this finding is not surprising. However, if the animals were being moved from the lowlands to the uplands on a seasonal basis, it could have been possible for them to be consuming seaweed. The isotopic evidence does not support this.

6.4.4 Summary

In summary, the environment of Early Holocene Cyprus is dominated by C_3 plants. In addition, the climate appears wetter than today, however some plants were still grown under dry conditions. Some of the animals might also have been foraging under a light canopy, which was likely located within a few kilometers of the site. There is also no evidence for the consumption of marine resources by animals from *Ais Giorkis*.

6.5 Animal Diets at *Ais Giorkis*

As mentioned in Chapter 2, deer dominate the faunal assemblage at *Ais Giorkis* (around 56% of the total faunal assemblage), followed by pig (26%), caprines (16%), and cattle (2%). This section discusses animal diets at *Ais Giorkis* based on the bone collagen $\delta^{13}C$ and $\delta^{15}N$ values and the ovicaprid molar enamel $\delta^{13}C$ values. Diet is important because it provides insights into herding strategies.

6.5.1 Sheep and Goat

At *Ais Giorkis*, goat and sheep are present in roughly equal proportions (Croft 2017); although Hadjikoumis et al. (forthcoming) suggests that goats are slightly more abundant than sheep. There were no significant differences detected between sheep and goat carbon and nitrogen values on the bone collagen, but this could be a product of the small sample size of each species.[45] In spite of this, there does appear to be differences in carbon and nitrogen isotope values on an intra-species level (discussed below). Given that we only have molar samples from one sheep and one goat (the rest could not be confidently identified to the species), we cannot use statistical tests to determine if they were significantly different from one other.

There are two major factors that impact sheep and goat diets on an isotopic level: 1.) the choice of plant parts or plants that the animals consume, and 2.) the habitat type in which the animals graze/browse. Both of these factors are also possibly influenced by the sizes of the animal herds (Vaiglova et al. 2014:210). Sheep preferentially graze on grassy vegetation in open habitats, whereas goats favor more woody and leafy vegetation in closed environments (Chapter 3). Typically, when the animals are kept together in large numbers, they are herded separately and taken to their preferred habitats (Vaiglova et al. 2014:210). As a result, sheep and goat diets reflect both plant and habitat choices. If the animals are kept in smaller numbers, they are often herded together on the same parts of the landscape (Halstead 2006). In this case, differences in the isotope values would primarily be attributed to which plant parts the species consume (Vaiglova et al. 2014:211).

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[45] I first tested the differences between the variances using an F-test for both the carbon and nitrogen values of the sheep and goat samples. There were not statistically significant differences between the variances of either groups (carbon isotopes: $p = 0.7273$; nitrogen isotopes: $p = 0.1555$). Statistically, there were no significant differences between these groups using the Two sample t-test with equal variance (carbon isotopes: $p = 0.5331$; nitrogen isotopes: $p = 0.3965$).

Almost all $\delta^{13}C$ bone collagen values are greater than -20‰, with the only exception being one goat individual that had a $\delta^{13}C$ value of -19.66‰. This slight ^{13}C enrichment in this goat is curious. As discussed above, there is currently no evidence for the consumption of marine food or C_4 plant resources from animal and human isotopic data from prehistoric sites in Cyprus (Scirè Calabrisotto 2017a, 2017b). Woody vegetation typically has lower $\delta^{13}C$ values as a result of lignin being present in higher proportions than for grassy vegetation (Benner et al. 1987; Svendsen 2001). If the assumption that $\delta^{13}C$ values of woody vegetation was lower than that of grass is correct for western Cyprus, then we would expect the goats to have lower $\delta^{13}C$ values. Given that this one goat has ^{13}C enriched signal, it does not seem as if this is the case. The isotopic distinctions seen with this goat could then be due to feeding in different habitats than the other animals in this study (Vaiglova et al. 2014:211). Unfortunately, the cause of this ^{13}C enrichment in this goat cannot be exactly determined on the basis of current isotopic evidence.

In contrast to the carbon isotope range, which is relatively narrow, the nitrogen range for caprine is large (5.11‰). In fact, it is the largest of the animal species analyzed in this study. This wide range seems to be primarily driven by the goats who have the lowest and highest nitrogen values of the caprine and sheep samples. As herbivores, these differences can only be attributed to large variations in the local soils, plants, and the animals themselves (i.e., water availability and nutritional status) (Pearson et al. 2015:73). It is possible that these differences are due to goats being herded across a wider landscape than the sheep, which would have multiple environmental zones and thus more variable $\delta^{15}N$ values. In turn, this suggests that these two species might have been herded separately. An alternative theory is that the isotopic differences are due to sheep and goat consuming different plant parts. If the herds were small, which they likely were, these animals might have been herded together, but consumed different parts of the plant.

Animals with enriched $\delta^{15}N$ values might also have been foraging in fields where manure was added. Manuring would raise the $\delta^{15}N$ values in plants (Chapter 5), which can be passed along to animals. While the $\delta^{15}N$ hulled barley samples from *Ais Giorkis* are enriched, the source of this enrichment remains unclear (Chapter 5). It is difficult to attribute an explanation to the variation seen in nitrogen values of the goats, particularly since the differences between the sheep and goat samples are not statistically significant, and there remains a number of unknowns given that this study represents one of the first of its kind on Cyprus.

As noted above, most of the animals in this study have depleted $\delta^{13}C$, including the caprines. It is thought that Cyprus was more heavily forested than today (Chapter 2). Furthermore, *Ais Giorkis* is surrounded by mountains. The site, itself, might have had even more trees in the past, given that the landscape has been altered for agriculture over the last few millennia. Thus, the low $\delta^{13}C$ values could possibly be explained by some caprines consuming forage under a light canopy. Other caprines consumed plants that were grown in drier conditions. Hadjikoumis et al. (forthcoming) reached similar conclusions and suggests that there is a high probability that domestic caprine herds were lead to areas with more closed canopy. Of interest, this conclusion was for both *Ais Giorkis* and *Shillourokambos* sheep and goats. While *Shillourokambos* is located on the coast, it is in close proximity to upland areas of the Troödos. As a result, inhabitants at the site could have relatively easily moved their herds to more forested areas. The movement of sheep and goats to forested areas has been documented on Cyprus since at least the Ottoman period. Evidence from this study and Hadjikoumis et al. (forthcoming) suggest that this practice may extend even farther back in time and will be discussed in more detail in Chapter 7.

6.5.2 Cattle

There is no statistical difference between the carbon and nitrogen values of the cattle and the caprines.[46] However, the range in carbon and nitrogen values for this taxon is the narrowest of the animal species in this study. Despite the limited sample size, I will attempt to explain what this might mean. The cattle are situated in the same $\delta^{13}C$ and $\delta^{15}N$ regions as the caprines, suggesting that they shared the same pasture grasses. Because the range of their isotopic values are so narrow, it also suggests that the cattle were not being herded across a wide landscape. If this had been the case, one would expect greater variability in the isotopic values, because the cattle would be incorporating a wide range of different grasses with different isotopic values into their diet. Thus, I suggest, albeit tentatively, that the cattle were kept at or near *Ais Giorkis*. They also shared similar pasture with at least some of the caprines at the site.

6.5.3 Mesopotamian Fallow Deer

As discussed above, deer dominate the faunal assemblage at *Ais Giorkis*. The range of the carbon and nitrogen values fall in the middle of the other animal species. The lowest $\delta^{13}C$ value is found with this taxon, further supporting the idea that animals at the site were foraging, at least

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[46] I first tested the differences between the variances using an F-test for both the carbon and nitrogen values of the cattle and caprine samples. There was not a statistically significant difference between the variance seen in the carbon isotopes ($p = 0.7303$), but there was in the nitrogen isotopes ($p = 0.0088$). Statistically, there were no significant differences between these groups (carbon isotopes, Two sample t-test with equal variance: $p = 0.7349$; nitrogen isotopes, Welch Two Sample t-test: $p = 0.0691$).

some of the time, in forests or under light canopy. It is important to note that fallow deer are generalist feeders, and prefer to feed along the forest edges, although they will browse forest plants and leaves that have fallen from the forest canopy (Chapter 3). One of the deer also has the highest $\delta^{15}N$ value, and it seems that in general many of the deer have more ^{15}N enriched values compared to the other taxa. It is unknown what caused these higher $\delta^{15}N$ values, but it could be related to aridity and/or soil salinity (Ambrose 1991; Ugan and Coltrain 2011).

Few studies have conducted carbon and nitrogen stable isotope analyses on modern or ancient fallow deer remains. Table 6.7 presents the mean fallow deer $\delta^{13}C$ and $\delta^{15}N$ values from select archaeological and modern sites in Europe and the Mediterranean. Madgwick et al. (2013) suggest that fallow deer from the UK are, in general, removed from both the Mallorcan and Turkish individuals. They note that the majority of the UK samples are more depleted in ^{13}C, but have higher $\delta^{15}N$ values, although there are individuals that fall outside of these suggested trends. In contrast, samples from the Mediterranean have higher $\delta^{13}C$ and lower $\delta^{15}N$ values compared with the European fallow deer samples. The Mesopotamian fallow deer data from *Ais Giorkis* seem to generally fit into the Mediterranean trends. It is likely these isotopic patterns relate to differences in the climate and environment between northern Europe and the Mediterranean. These data are important, however, because they strengthen the hypothesis that it might be possible to differentiate fallow deer remains that lived/died in northern Europe from those that were imported from the Mediterranean on the basis of carbon and nitrogen isotopes (Madgwick et al. 2013). As discussed in Chapter 3, the spread of fallow deer from the eastern Mediterranean to Europe was largely due to human-mediated reintroductions.[47] As a result, the

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[47] At the time of the Last Glacial Maximum, the European fallow deer (*Dama dama dama*) became extinct in most of continental Europe and the British Isles. The species was restricted the eastern Mediterranean (Anatolia and possibly the Balkan Peninsula) (Masseti et al. 2008). Humans became translocating the species around the

distribution of fallow deer is a direct record of human activity and can potentially provide information on past human migration, ideology, and trade. While most of the data are substantially later than that from *Ais Giorkis*, similar to many of the sites, deer were also introduced to the island. As such, the *Ais Giorkis* Mesopotamian fallow deer play an important role in allowing us to understand this wider issue of translocating deer throughout the Mediterranean and beyond.

Mediterranean beginning in the Neolithic. The deer were reintroduced to northern Europe around the Roman period and they were even brought to the New World (Osborne 2017; Sykes et al. 2013).

Table 6.5 Mean δ13C and δ15N values on fallow deer from select archaeological and modern sites in Europe and the Mediterranean

Site	Time Period	Species	δ^{13}C Mean	δ^{13}C SD	δ^{15}N Mean	δ^{15}N SD	N
Ais Giorkis (Cyprus)	Early Neolithic	*Dama dama mesopotamica*	-20.94	0.3	5.19	1.0	20
Sagalassos (Turkey)[a]	Classical-Hellenistic	*Dama dama* sp.	-21.2	-	5.2	-	1
Fishbourne Palace (Sussex)[b]	Roman	*Dama dama* sp.	-22.0	0.44	6.5	1.18	34
Monkton[c]	Roman	*Dama dama* sp.	-21.0	0.51	6.5	0.97	8
Tothill Street, Minster (Isle of Thanet, Kent)[b]	Roman	*Dama dama* sp.	-21.8	1.35	5.4	1.21	3
East Kent Access Road (Isle of Thanet, Kent)[b]	Roman	*Dama dama* sp.	-21.6	0.53	5.8	0.03	2
London Bridge (London)[b]	Roman	*Dama dama* sp.	-23.0	-	2.2	-	1
Silvester Street (London)[b]	Roman	*Dama dama* sp.	-22.2	-	5.6	-	1
Pollentia (Mallorca)[d]	Roman	*Dama dama* sp.	-20.9	0.4	5.5	0.7	26
Sa Mesquida (Mallorca)[d]	Roman	*Dama dama* sp.	-20.0	0.3	5.3	0.7	26
Sagalassos (Turkey)[a]	Middle Byzantine	*Dama dama* sp.	-20.4	0.3	3.9	0.9	4
Wytham Woods (Oxfordshire, UK)[d]	Modern	*Dama dama* sp.	-22.6	0.8	5.5	1.0	50

Note: The summary statistics include both antler specimens and postcranial elements for many of the sites.

[a] Data are from Fuller et al. 2012.

[b] Data are from Madgwick et al. 2013

[c] Data are from Sykes et al. 2011

[d] Data are from Bonafini et al. 2013

6.5.4 Pig

Because pigs eat almost anything, they can be found at any step of the food web from strict herbivores to nearly carnivores (Albarella et al. 2006). Higher δ^{15}N values reflect a higher position in the food chain, which involves a greater consumption of animal products. An increase in δ^{13}C values reflects an increase in either C_4 plants or marine resources to the diet (Rowley-Conwy et al. 2012). The diets of domestic pigs are more easily influenced by feeding activities controlled by humans, than wild boars whose diets come from the natural environment. To better understand pig diet, including whether it was being managed by humans, their carbon and nitrogen values are typically compared to those from human or carnivores and herbivores. Domestic pig $\delta^{15}N$ values are often higher than those of herbivorous herd animals, but lower than humans, which reflects their omnivorous diet. Their diet is tied to their closer association with human settlements. Thus, domestic pigs not only consume wild resources, but also possibly crops and crop processing waste, waste from human food preparation and consumption (including other animals), and human excreta (Hamilton et al. 2009).

Unfortunately, we do not have human or carnivore isotopic data from the Early Neolithic period to compare to the *Ais Giorkis* pig isotope data. However, Scirè Calabrisotto's study (2017a) does provide preliminary isotopic evidence from human skeletal remains from Erimi *Laonin tou Porakou*, a Middle Bronze Age community. The mean $\delta^{15}N$ value is 9.4 ± 0.7‰, which points to a primarily terrestrial-based diet. The humans consumed C_3 plants and a variable level of terrestrial animal proteins from animals that fed in a C_3 plant dominated environment (Scirè Calabrisotto 2017a:303). Given that we currently lack any other human isotopic data from prehistoric Cyprus, I will use these data as a tentative analogy for the nitrogen isotope values of inhabitants at *Ais Giorkis*. The comparison of the *Ais Giorkis* pig remains against the Middle Bronze humans and *Ais Giorkis* herbivores should offer insight into whether their diet was being managed by humans.

The nitrogen isotope range of the *Ais Giorkis* pig remains is intermediate compared to the other animals. In addition, the mean value (which is the lowest) demonstrates that they have some of the lowest nitrogen isotope values compared with the other herbivore animals at the site. Their nitrogen values are also not close to those of the Middle Bronze Age humans. Because the values fall within the herbivore values, these data suggest that the pigs had a primarily herbivorous diet. As noted above, the keeping of pigs by the settlement and their feeding on domestic refuse, such as animal products and human feces, would have placed them on a higher trophic level than the herbivores. This means that they would have had higher $\delta^{15}N$ values than the herd animals. However, it seems that some of these individuals were consuming food with lower nitrogen isotope values than even the domestic cattle, sheep, and goat. Without further isotopic work, it is difficult to theorize what these food resources might have been.

The current consensus on the pig remains analyzed in this study is that they are domesticated, although wild and/or feral boar are thought to occur at the site. However, as noted in Chapter 3, they are one of the most challenging animals to determine domestic status. Thus, it is possible that at least some of the remains belong to wild or feral boar. Ballari and Barrios-García (2014) conducted a global review of wild boar diet and factors that affect their food selection. They found that wild boar diet is dominated by plant material (around 90%). In their paper, they highlight four main feeding behaviors: foraging on the ground (animal matter, fungi, and fruits), browsing and grazing (herbs, stems, leaves, and grasses), rooting (roots, invertebrates, and rhizomes), and predation (vertebrates) (Ballari and Barrios-García 2014). For many of these food sources, the nitrogen isotope values are not known. We do know that rhizomes and roots fix atmospheric nitrogen, resulting in lower nitrogen isotope values. Thus, these might have been an important source of protein for the *Ais Giorkis* pigs (or wild boar) (Pearson et al. 2015:73).

It is also possible that the domestic pigs were kept near the site and fed within areas such as gardens or cultivated areas. However, based on current archaeological evidence, we do not believe that cultivation areas were located near *Ais Giorkis*. A more likely possibility is that the domestic pigs were part of a free-range husbandry, which is seen in Sardinia (Albarella et al. 2011), Corsica (Albarella et al. 2007), Greece (Halstead and Isaakidou 2011), and Spain (Hadjikoumis 2012). Under this time of regime, pigs are often left on a plateau (or in the uplands), where they live essentially year-round. Herders will regularly move from villages in the lowland, where they spend time with their family, to the highlands, where they tend to their animals, including the pigs (Albarella et al. 2011). Based on ethnographic evidence, it appears that animals under this husbandry regime also primarily had an herbivorous diet.

The majority of the pig remains have $\delta^{13}C$ values that are greater than -21‰, suggesting that the animals primarily inhabited open environments. From these results, it appears that these animals cannot be considered wholly woodland species, although some individuals might have been foraging under a light canopy.

The isotopic evidence from these pig remains are not easy to interpret. At the very minimum, we can say that they were not being intensively managed by humans, because their nitrogen values are not enriched. Because we do not have C_4 plants, it is difficult to determine whether they were consuming agricultural waste, since the crops at *Ais Giorkis* are all C_3 plants. Thus, we cannot make a distinction between agricultural waste and C_3 plants from the local environment.

6.5.5 Summary of the Animal Diet Stable Isotope Data

These data have provided evidence of diet for herbivore animals from the Cypro-PPNB, which in turn allow us to infer animal management practices for the domesticated animals. While the pig are thought to be domestic, they seem to have been herbivorous, or at the very minimum their feeding activities were not closely controlled by humans. It is also possible that they were part of a free-range husbandry regime. Their nitrogen values are lower than the Middle Bronze humans, and in fact, fall within the range of the other herbivore values. The isotope data from the deer follows the general trends of other Mediterranean fallow deer. They also suggest that some individuals might have been foraging under a light canopy. Cattle have the narrowest nitrogen and carbon ranges of the species analyzed in this study, leading to the tentative conclusion that they were kept at or near *Ais Giorkis*. There were isotopically no significant differences detected between sheep and goat carbon and nitrogen values on the bone collagen, although there does appear to be differences on an intra-species level. One goat individual has a slight ^{13}C enrichment compared to the other caprines, but the cause cannot be determined based on the current isotopic data. The goats also have a larger nitrogen range than the sheep, which might possibly be due to these animals being herded across a wider landscape. This difference could also be due to sheep and goat consuming different plant parts. Based on depleted $\delta^{13}C$, the caprines were possibly being herded to areas with light canopy, which is a similar conclusion reached by Hadjikoumis et al. (forthcoming).

6.6 Sheep/Goat Husbandry Practices from the Stable Isotope Perspective

Stable isotopes make it possible to address dimensions of prehistoric animal management practices that are all but invisible to traditional zooarchaeological studies. In the previous section, I discussed diet and what this can allow us to infer about animal husbandry practices. I will now discuss birth seasonality and herd movement using the $\delta^{18}O$ and $\delta^{13}C$ values from the caprine remains. The small sample for $\delta^{18}O$ and $\delta^{13}C$ analyses from *Ais Giorkis* prevent me from formulating far-reaching conclusions. In addition, greater emphasis will be given to herd movement over birth seasonality, given the interest of this dissertation (i.e., examining animal management strategies to infer land and water use by the inhabitants of *Ais Giorkis*) and the expertise of the author.

6.6.1 Caprine Birth Seasonality

As presented in Figure 6.9, the sequential $\delta^{18}O$ curves taken from the caprine second and third mandibular molars makes it possible to offer tentative speculations on their birth seasonality. The M_2 teeth AY104 and AY107 follow the same general pattern. $\delta^{18}O$ values gradually increase in the early year of enamel formation, and then drop towards more negative $\delta^{18}O$ values towards the end of the tooth growth. This pattern suggests a birth season of late winter/early spring, which is the season with the lowest temperatures. Temperatures (and $\delta^{18}O$ values) would increase over the tooth growth and then both would decrease as the weather began to cool. The M_2 teeth AY105 and AY106 also have a similar pattern, and in fact do not diverge substantially from AY104 and AY107. These two teeth both have a short initial decrease for the first two data points, which is followed by the $\delta^{18}O$ values gradually increasing, and then decreasing. Of note, in contrast to AY104 and AY107, the growth of AY105 and AY106 seems to finish just before a period of more positive $\delta^{18}O$ values. This sequence of $\delta^{18}O$ values suggests that the animals might have been born in early winter.

The M_3 teeth AY103 and AY101 follow the same general pattern. The $\delta^{18}O$ values increase from the time of enamel formation, followed by a drop towards more negative $\delta^{18}O$ values, and then a gradual increase in the values. AY103 shows less variation in its $\delta^{18}O$ values than AY101. Based on oxygen isotope data from modern comparators (Blaise and Balasse 2011), this pattern seems to suggest spring births for these individuals. AY102 is difficult to interpret because it does not top or bottom out clearly.

It is important to remember that there is possibly a 6-month delay in signal due to the complexity of enamel formation. Thus, AY105 and AY107 and AY104 and AY107 may actually represent late spring and early spring births, respectively. Similarly, AY103 and AY101 could represent winter births. Based on 20th century traditional caprine husbandry, winter (and autumn) births did occur. Hadjikoumis et al. (forthcoming) conducted an ethnozooarchaeological survey of sheep/goat herders in Cyprus and found that sheep and goat births traditionally occurred in autumn and early winter, with births peaking between October and January. The reasons provided for this birth season is that milk production could be sustained for longer periods of time due to the greater availability of forage food after the first rains. It is interesting to note that the herders also mentioned that in the more distant past, when size of herds was much smaller and there was less systematic husbandry, birth season for sheep and goats was more random. There is ethnographic evidence from elsewhere in the Mediterranean that supports the occurrence of spring births, and oxygen isotope analysis of archaeological caprine molars from Çatalhöyük support this (Henton 2012; Henton et al. 2010). An advantage to spring birth lambs is that they would grow during warm weather and have fresh graze at least through the early summer (Henton et al. 2010:445).

The interpretations of birth seasonality from this study should be taken cautiously due to low sample resolution and non-normalized tooth length (see Hadjikoumis et al. forthcoming). However, the results showcase the potential of this approach to archaeological research on Cyprus, and I hope other researchers on the island will begin to incorporate stable isotope analyses in order for us to gain a more complex picture of sheep and goat birth seasonality during the Neolithic.

6.6.2 Herd Movement

There have been a number of recent attempts to identify altitudinal movement of domesticated goats and sheep, most of which have relied on the amplitude of variation in the intra-tooth oxygen isotopic measurements as a proxy for mobility. In general, these approaches use the altitudinal effect of oxygen isotopes in precipitation to explain differences in the oxygen isotopic composition of the molar enamel samples, but arrive at different interpretations of the sequential $\delta^{18}O$ values (Makarewicz 2017:17). For example, one approach contends that a combination of sinusoidal patterns and low amplitude of intra-tooth isotopic change is suggestive of herds escaping climatic extremes (both cold and hot) over the year (Britton et al. 2009; Pellegrini et al. 2008). Henton and colleagues (Henton 2012; Henton et al. 2010) assert that in the case of vertical transhumance, animals would move to highland pastures during the summer, resulting in the $\delta^{18}O$ range being dampened. This is due to the animals not ingesting water enriched in $\delta^{18}O$ values associated with summer lowland temperature extremes, nor water with depleted $\delta^{18}O$ values related to winter upland temperature extremes. Another framework argues that sinusoidal patterns in sequential $\delta^{18}O$ values implies that animals consumed water year-round from the same general area (Balasse et al. 2003; Fricke and O’Neil 1996). In contrast, others (e.g., Mashkour et al. 2005) suggest that a wide amplitude of intra-tooth oxygen isotope change is indicative of vertical transhumance. This is based on the argument that while meteoric water falling during the summer in the highlands would still exhibit low $\delta^{18}O$ values during the summer (relative to the lowlands), the $\delta^{18}O$ values would still be enriched in ^{18}O compared to precipitation that falls during the cooler months in the lowlands. They argue this effect is due to temperature-dependent seasonality.

Makarewicz (2017:17) notes that these conflicting interpretations are due to sheep and goats ingesting varied sources of water that have diverse isotopic compositions, including leaf water, ground water, open water, and stored water sources. In addition, we do not know about the spatial distribution of the δ^{18}O values of meteoric water in prehistoric environments. Recent studies (Makarewicz et al. 2017a; Tornero et al. 2016) have tried to better understand altitudinal mobility through paired oxygen and carbon isotope analyses of sequentially sampled teeth.
For this framework, inverse directionality in δ^{18}O and δ^{13}C sequences may indicate that the animals were moved as part of a vertical transhumant mobility strategy, which included winter lowland and summer upland pastures. ^{13}C depletion of graze or browse is thought to be typical for upland pastures during the summer months (Makarewicz 2017). This discussion follows that of recent studies (Makarewicz 2017; Makarewicz et al. 2017a, b), because I believe it is better to use multiple lines of evidence (i.e., two stable isotopes) to discuss herd movement, rather than focusing on only the results from a single stable isotope.

The mean δ^{18}O value of each tooth is plotted in Figure 6.10. The maximum, minimum, and range of δ^{18}O values are plotted in Figure 6.11 (also see Table 6.6). There is general clustering of the means and distribution of the δ^{18}O minima values for all molar samples, suggesting that during the winter months these animals might have ingested isotopically similar water sources. We currently do not have a reference oxygen isotopic data set derived from early Holocene bovids that wintered in the area surrounding *Ais Giorkis*, which makes it difficult to determine if the caprines in this study were pastured near *Ais Giorkis* or even further upland.

Figure 6.10 Mean δ^{18}O values of samples taken from archaeological teeth

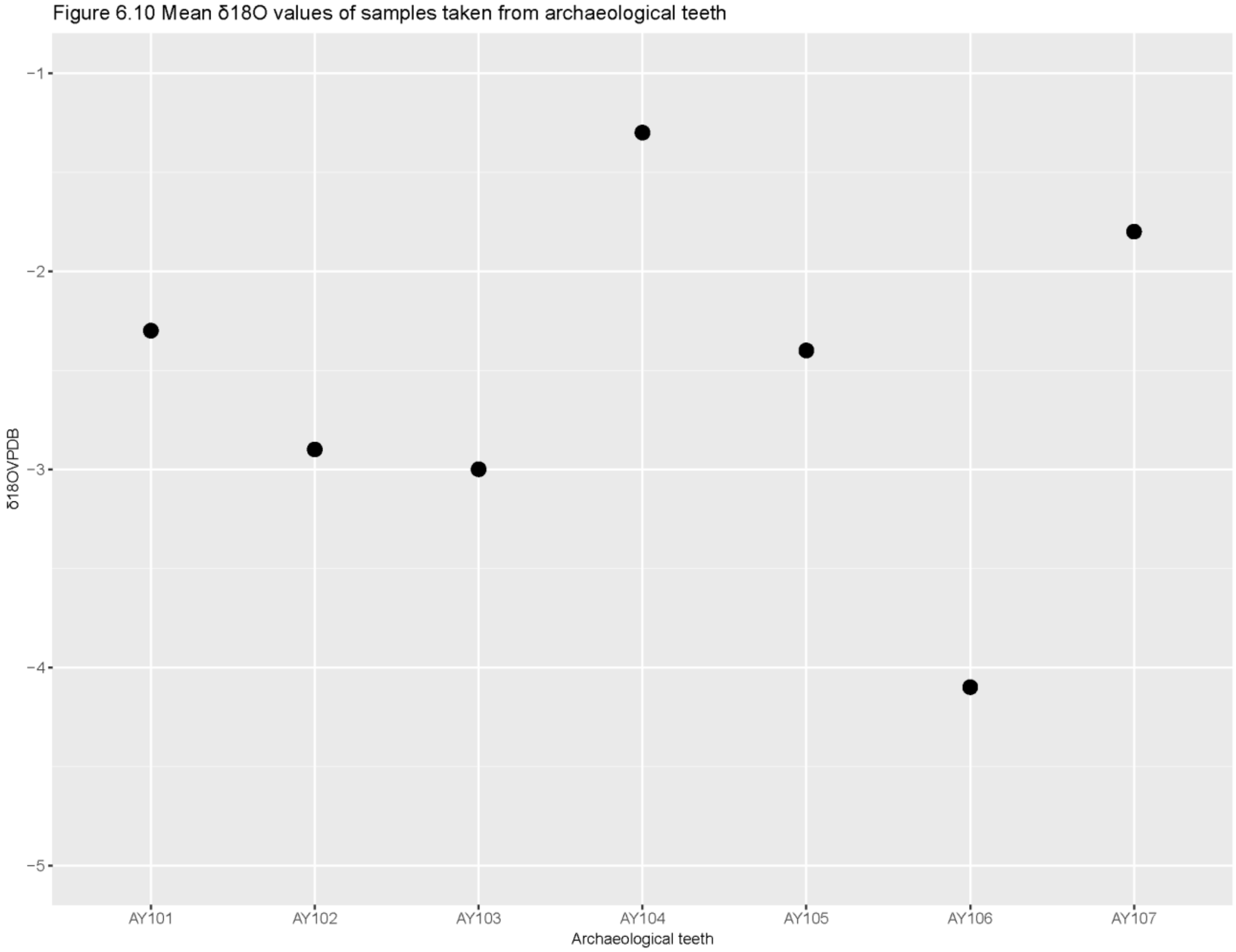
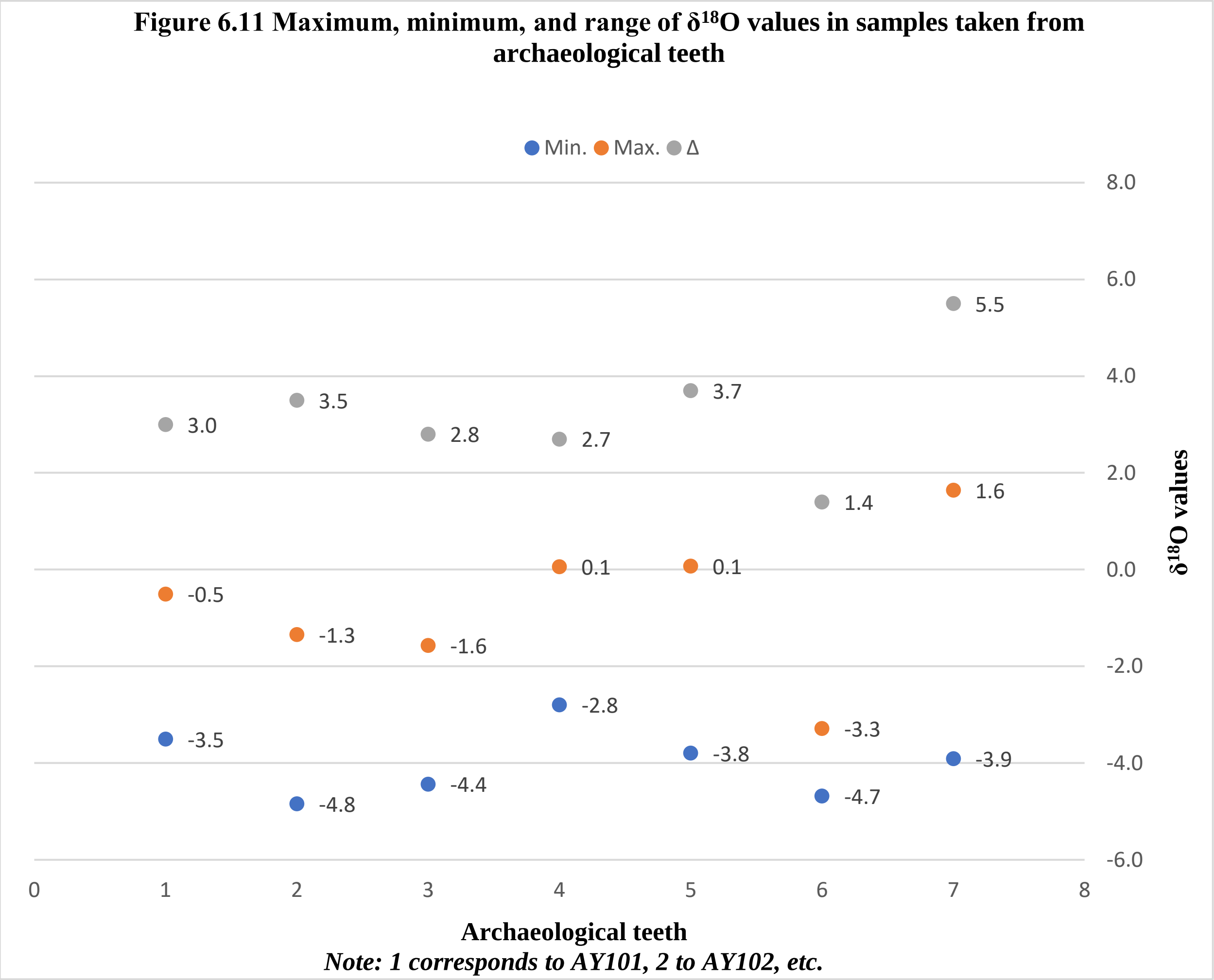


Figure 6.11 Maximum, minimum, and range of δ^{18}O values in samples taken from archaeological teeth



There does appear to be some partitioning in the distribution of δ^{18}O maxima values. Specifically, AY101, AY102, and AY103 all have δ^{18}O values that are lower (ca. 2‰) than AY104, AY105, and AY107. In addition, AY106 has the lowest maximum value, which is around 2‰ lower than AY101, AY102, and AY103. These differences may reflect geospatial variation in the location of summer pastures grazed by separate livestock herds, differences in the relative contribution of ^{18}O-enriched leaf water to body water of the caprines, or a combination of both.

It does appear that at least some of the caprines were consuming ^{18}O depleted water sources during the summer months. As discussed in Chapter 4, empirical research has established the relationship between δ^{18}O values and altitude (Poage and Chamberlain 2001): 100 m rise in altitude is equal to 0.3‰ decrease in δ^{18}O. This equation is roughly similar to the correlation that Boronina et al. (2005a) determined between elevation and oxygen isotopes from the Kouris catchment (Chapter 4). It may be that AY101, AY102, and AY103 grazed in pastures located around 600 m higher in elevation than AY104, AY105, and AY107. AY106 might have been grazing in pastures that were higher in elevation than all of the other individuals. Elevations approaching 600 m and higher were not located far from the site. In fact, Stewart (2006:207) notes that within 4-5 km from the site, the land rises steeply to around 850 m asl. Strontium isotopic data would help to clarify this partitioning seen in the study samples, as would δ^{18}O analysis of modern and archaeological transhumant sheep and goat.

It is also possible that the differences seen in the δ^{18}O values may be due to other environmental inputs outside of those related to geospatial variation in the location of summer pastures. Oxygen isotope ratios of sheep and goats reflect the oxygen isotopic composition of both open water and leaf water. As a result, these animals are known as semi-obligate drinkers. In contrast, cattle are considered obligate drinkers because they derive their water from open water sources, which allows for the tracking of oxygen isotopic composition of local precipitation (Makarewicz et al. 2017:76). The degree of isotopic enrichment in leaf water varies depending on leaf anatomy, aridity, and plant rooting levels (Cernusak et al. 2016; Dodd et al. 1998), all of which could impact the δ^{18}O values see in this study.

The elevated δ^{18}O summer season values that we see in AY104, AY105, and AY107 might be due to their consumption of higher levels of graze compared to the other animals in this study. Makarewicz et al. (2017b) have shown that caprines that feed mostly on graze during the summer months exhibit a 3‰ enrichment, on average, in $\delta^{18}O$ values relative to individuals who ingest a combination of browse and graze. Given that we do not have isotopic evidence for a C_4 presence in the caprine diet, it makes it difficult to determine the dietary proportions of browse and graze and whether differences could be response for the elevated $\delta^{18}O$ values seen in some individuals.

We cannot establish whether there is movement between the lowlands and uplands in the sheep and goat individuals from *Ais Giorkis* using oxygen isotopes alone, because we do not have contemporary isotope data from non-obligate and obligate drinkers (see above). The pairing of carbon and oxygen isotope data can help to clarify questions surrounding mobility. Figures 6.2-6.8 present the carbon and oxygen curves for each sequentially sampled molar. We do not have patterns of inverse cyclical variation in the oxygen and carbon isotope measurements. Rather, we have the $\delta^{18}O$ and $\delta^{13}C$ values increase together. This pattern possibly reflects either the consumption of graze that is water-stressed during the summer months or the consumption of seasonal replacement of C_3 species that are more drought tolerant and have higher $\delta^{13}C$ values (Tieszen 1991). This leads to the ^{13}C-enrichment that is seen in the carbon isotope values. The increase in both isotope values is followed by a roughly simultaneous decrease in both values, coinciding with the start of the cooler months. Fraser et al. (2008) and Hallin et al. (2012) identified similar isotopic patterns with wild herbivores that were stationary and feeding in semi-arid region biomes. Hadjikoumis et al. (forthcoming) also found similar carbon and oxygen isotope patterns from caprines at both *Shillourokambos* and *Ais Giorkis*. Of note, they observed the highest inter-individual variability in $\delta^{13}C$ values in sheep samples from *Shillourokambos,* leading them to suggest that this variability might be due to differences in pasture locations between the sites or even seasonal mobility patterns at *Shillourokambos*. Thus, the results of both this study and Hadjikoumis et al. (forthcoming) corroborate that the sheep and goat herds at *Ais Giorkis* were not being moved between lowland and highland pastures.

6.6.3 Summary

Given the low sample resolution and non-normalized tooth length, the interpretations of birth seasonality from this study should be taken cautiously (see Hadjikoumis et al. forthcoming); however, they do seem to follow both our current understanding of sheep/goat birth seasonality from Cyprus and the southwest Asian mainland during the Neolithic. The isotopic pattern seen with the δ^{18}O and δ^{13}C values of the sequentially sampled molars indicates that the caprine herds at *Ais Giorkis* were not seasonally moved between the lowlands and uplands. Rather, the data suggest that some of the individuals were being herded at or around the site and others might possibly have been moved to higher elevations (although these elevations were not located far from the site).

6.7 Conclusion

This chapter presented the results of the δ^{13}C, δ^{15}N, and δ^{18}O analyses of the animal bone collagen and molar enamel from *Ais Giorkis*. In general, the data do not support the idea that the domestic herds were being seasonally moved between the coast and uplands, which is counter to the original argument set out in this study. Cattle have the narrowest nitrogen and carbon ranges of the species analyzed. While the sample size is small, it is possible that they were kept at or near *Ais Giorkis*. The pairing of carbon and oxygen isotope data from the caprine molars help to clarify questions surrounding altitudinal mobility. I do not have patterns of inverse cyclical variation in the oxygen and carbon isotope measurements, which is usually indicative of vertical transhumance between the coast and upland areas on a seasonal basis. Rather, it appears that sheep and goat were being herded at or near the site or even farther upland. Pigs at the site also had a primarily herbivorous diet, suggesting that they were not intensively managed by humans. Ultimately, these data combined indicate that herd animals did not play a major role in the everyday life of the site’s inhabitants. This raises the question of what people/ the inhabitants were doing at the site, which is explored in the next chapter.

CHAPTER 7: INTEGRATING THE BOTANICAL AND FAUNAL CARBON, NITROGEN, AND OXYGEN ISOTOPE DATA: HOW WERE THE *AIS GIORKIS* INHABITANTS MANAGING THEIR LANDSCAPE?

7.1 Introduction

From the discussions in Chapter 2, the island of Cyprus was clearly not entirely devoid of resources or of human inhabitants. To date, we only have a handful of sites from the Late Epipaleolithic, Cypro-PPNA, and Cypro-PPNB; however, recent survey projects (McCartney 2004; McCartney et al. 2006, 2007, 2008; Şevketoğlu 2000; Simmons 1998a) have begun to identify a number of surface scatter sites, some of which have excavation potential. For example, the Elaborating Early Neolithic Cyprus Project (EENC) in central Cyprus has identified at least 22 Aceramic scatter sites in an area of around 26 km at the foot of the central Troödos massif. These same survey investigations have also revealed some 42 chert sources, 6 major topographical features and resources (i.e., calcareous and volcanic rock, which can be used to manufacture ground stone, and ochre), and 78 isolated lithic finds (McCartney et al. 2010:141-142).[48] There are also hints of inter-island and island-mainland exchange networks (discussed below). In spite of the current evidence, discussions of the Cypriot Aceramic Neolithic continue to be site-specific, rather than integrating data from sites to discuss the actual inhabitants on the island. Furthermore, current definitions of this time period employ the strict forager/farmer dichotomy, even though the archaeological evidence suggests otherwise (but see McCartney et al. 2010).

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[48] Without excavating these scatter sites, it is difficult to determine whether they actually date to the Aceramic Neolithic period. They could also be special activity areas from later periods. Chert sources were exploited up until relatively recently to make the *dhoukani* (threshing sledge; discussed below). However, their association with a known Cypro-PPNA site suggests that at least some of these scatter sites likely date to the early Neolithic.

This study set-out to address: How did the Neolithic inhabitants of western Cyprus manage their landscape? Contrary to the original hypothesis, based on the isotope data, I do not believe that the inhabitants of *Ais Giorkis* were partaking in seasonal movement of domestic animals from the lowlands to the uplands. In fact, domestic resources do not appear to have been that important to the people. Rather, I believe the data presented here provide two possibilities: 1.) animals were left at the site, and some groups from the lowlands would make seasonal trips to the site to check on the animals and collect key resources (e.g., chert for chipped stone, diabase for ground stone, and picrolite) and hunt deer and pig; or 2.) *Ais Giorkis* inhabitants focused on craft production of both ground stone and chipped stone industries, hunting and possibly tanning of animal hides, and picrolite manufacture for inter-island and possibly island-mainland exchange. Based on current evidence, I believe the latter option is the more likely of the two. In this chapter, I will present both ideas, and discuss why I believe this is the case, and how the data from this study supports this scenario.

7.2 Summary of the *Ais Giorkis* Botanical and Faunal Carbon, Nitrogen, and Oxygen Isotope Data

The isotopic data provides considerable evidence for the homogeneity of animal management practices at *Ais Giorkis*. There is limited evidence for seasonal movement of the cattle and caprines, which was surprising given previous hypotheses about the seasonal nature of site occupation. Rather, some of the caprine individuals were perhaps moved farther upland from *Ais Giorkis*. Many of the individuals also possibly foraged under a light canopy, which is a similar conclusion reached by Hadjikoumis et al. (forthcoming). As noted in Chapter 6, forests were located within a few kilometers of the site. There is evidence of pastoral activity taking place in hard-to-access mountains and forests, away from permanent settlements, during the Venetian and Ottoman periods in Cyprus. Ethnohistorical information confirms that goat folds were located in forested mountains above villages. It is thought that this distribution pattern might be partly because of the well-documented rivalry between farmers and pastoralists on the island (Given 2000:15). In addition, large flocks tended by specialized herders and owned by monasteries often grazed in the forested mountains. In this case, the location is thought to be tied, in part, to herders being able to avoid census officials or tax collectors (Given 2007:143-144). Currently, we have no evidence for mountain villages during the Cypro-PPNB, but perhaps there were at least some individuals that ventured into higher elevations with caprines or exchanged items with those who settled more permanently in the mountainous areas.

Halstead (1996:24) notes that mobile and sedentary herders alike commonly rationalize their behaviors in terms of the number of livestock that they manage: "'they [nomads/transhumants] have to move because they have so many animals, we [sedentary villagers] have few animals because we don't move.'" Large-scale herding (i.e., transhumance) places pressure on pasture resources and labor. The former is particularly important when grazing is scarce, such as late spring and summer seasons in semi-arid environments. Moving animal herds clearly requires significant labor. In addition, this problem is made even more challenging by the fact that these domestic animals have different grazing requirements (Halstead 1996:24). This study's results suggest that the *Ais Giorkis* inhabitants were practicing small-scale herding of the domestic animals, given the lack of data for their seasonal movement between the lowlands and uplands. This type of husbandry practice commonly keeps a range of livestock, which the *Ais Giorkis* faunal assemblage supports. While deer and pig dominate, there are also the remains of caprines and cattle. In contrast, large-scale pastoralists often specialize in goats, sheep, cattle, or horses. The results from the *Ais Giorkis* faunal remains contrast those from *Shillourokambos*, where Hadjikoumis et al. (forthcoming) have evidence of seasonal movement between the coastal site and upland areas. The latter were not located far from the site; however, the site's inhabitants appear to have a greater focus on domestic resources. In contrast to *Ais Giorkis*, domestic sheep and goat dominate the faunal assemblage by the final phases of occupation at *Shillourokambos*. Because it appears that labor and resources were not going towards caprine and/or cattle herding at *Ais Giorkis*, this raises the question of what the inhabitants were doing at the site?

Based on the current macrobotanical evidence (Chapter 3), most stages of crop processing likely occurred off-site. The *Ais Giorkis* assemblage is quite possibly the product of either fine-sieving or the final sorting of cereal grains (Lucas 2014, 2017). The botanical data from this study do not allow us to discuss where on the island the cereal crops were coming from; rather, the data shed light on soil and water management practices. Three tentative conclusions were made for the nitrogen isotope values of the two-grained einkorn wheat and hulled barley samples: 1.) the two-grained einkorn wheat and hulled barley were grown in separate fields; 2.) the soil conditions of the hulled barley were being managed in a way to increase soil fertility, which was not seen with the two-grained einkorn wheat; and 3.) the inhabitants of *Ais Giorkis* (or whomever they were getting the crops from) appear to be providing barley with greater resources to ensure its growth. Both crop cereals are grouped into the 'moderately watered band.' These results contrast evidence from the mainland, which suggest that barley was typically grown under drier conditions than wheat. Both the $\delta^{15}N$ and $\Delta^{13}C$ values imply that people were making strategic decisions about the crop growing strategies between the hulled barley and two-grained einkorn wheat found at *Ais Giorkis*. They seemingly preferred barley, which was surprising because einkorn is the most ubiquitous species at the site. Based on current evidence, the inhabitants of *Ais Giorkis* were not expending major resources or labor on cultivation, harvesting, and most post-harvesting crop processing activities. In some ways, this conclusion is rather ironic given that *Ais Giorkis* is one of the few sites with good botanical preservation. Lucas (2017) suggests that the cereals were brought to the site ready to be further processed into flour. Were the inhabitants of *Ais Giorkis* making something out of the cereal crops that went beyond meeting their own subsistence needs?

The carbon, nitrogen, and oxygen isotope data of the cereal crop remains and domestic herd animals coupled with the zooarchaeological and macrobotanical studies suggest that agricultural activities were a minor component of daily life for the people at *Ais Giorkis*. Based on the sheer number of deer and pig remains from the site (Chapters 2 and 6), it seems likely that these animals served an important function. The pig nitrogen values suggest that the animals were consuming a primarily herbivorous diet. At the very minimum, these animals were not foraging around the human settlement and consuming their “garbage,” including human feces or animal products, which would have resulted in higher nitrogen values. It is possible that these animals were wild or feral or that they were part of a free-range husbandry regime.

The carbon and nitrogen isotope values from the deer do not shed light on what their role might have been, although they do provide important information about the environmental setting of the site. The majority of deer skeletal elements are found at *Ais Giorkis*, implying that the whole animal/carcass was present at the site. It seems likely that deer were hunted near the site or even possibly brought back from hunting farther afield. In contrast, head and limb extremities are rarely recovered at *Shillourokambos*. This led Vigne et al. (2016) to suggest that butchering of fallow deer took place on the hunting site with these particular elements being left unused on the kill site. Perhaps though inhabitants at *Shillourokambos* were getting at least some of their deer meat from other areas of the island, such as *Ais Giorkis*.

To summarize, the carbon, nitrogen, and oxygen isotope data, suggest that the inhabitants of *Ais Giorkis* were not focusing resources and labor on agricultural practices. Rather, it seems that they exploited certain resources (discussed below) and hunted wild deer and domestic (feral or wild?) pig. While this provides additional information on what the inhabitants were doing at the site, it does not fully address why they were there or how they fit into the broader Cypro-PPNB world.

7.3 The Cypro-PPNB World and Beyond: Current Evidence for Inter-Island and Island-Mainland Exchange Networks

Evidence for inter-island and island-mainland exchange networks begins by at least the 12th millennium cal. BP. Based on evidence from Akrotiri, it is possible that wild boar were introduced to the island from the mainland around this time frame. Although only 18 wild boar bones (one incisor and 17 metapodials or phalanges) were recovered from the site, they are too small to have come from any known wild populations that were living on the continent (Vigne et al. 2009:16136). Vigne et al. (2009:16136) note that, "Consequently, even if these phalanges were part of a hide (or of butchered provisions), they could not have been imported from the mainland, and we conclude that suids were living on Cyprus at least 11,400 years ago." To add further support to this conclusion, wild boar remains recovered from the Cypro-PPNA sites of *Asprokremnos* and *Klimonas* are morphologically similar to those found at Akrotiri. Osteometric data from *Klimonas* confirm that the wild boar at the site were 10-16% smaller than both wild and domestic PPN suids (Vigne et al. 2012:8447). Given the ephemeral nature of Late

Epipaleolithic sites on Cyprus, it has been suggested that at least some people were seasonally traveling back and forth between the island and mainland.

These data support the idea that by the 12th millennium cal. BP, there were established exchange networks between Cyprus and the Southwest Asian mainland. Unfortunately, there is almost no evidence for what those exploring Cyprus were bringing back with them to the mainland. Ammerman (2013b) has suggested that these foragers might have been exploiting sea salt, which is found on the coast of Cyprus, including at one of the proposed Late Epipaleolithic sites that lack radiocarbon determinants (i.e., *Aspros*). McCartney et al. (2010:136, Fig. 13.2) also argue that sea-turtles (and their eggs) might also have been exploited by the earliest inhabitants. The location of currently known early coastal sites in Cyprus are almost all located in proximity to sea-turtle nesting sites. While nesting zones are abundant in the eastern Mediterranean, there is limited evidence for Mesolithic/Epipaleolithic sites near these areas on the mainland; although it is possible that these mainland sites are now submerged (McCartney et al. 2010:136, Fig. 13.2). Thus, Cyprus might have provided two important (and perhaps rare) resources for those living on the mainland.

There are also hints of inter-island exchange by the Akrotiri Period. High quality translucent chert and picrolite beads were recovered from Akrotiri (Chapter 2); neither of these materials are found in the Akrotiri Peninsula, indicating that the site's inhabitants either had far greater knowledge of the island's landscape or were in contact with those that did. The location of *Roudias* in the interior of the island suggests that the latter was plausible.

During the Cypro-PPNA, there is more substantial evidence of island-mainland and inter-island exchange, which makes sense given sites are more substantial in contrast to those in the Late Epipaleolithic. Throughout occupation at *Asprokremnos*, there is a clear focus on craft production of ground stone and chipped stone industries and red and yellow ochre (pigment) processing. The quantity of material exceeded what the site's inhabitants could have utilized. This surplus, coupled with evidence for repeated abandonments, suggests that at least some of the site's occupants were craft specialists who exported their goods (McCartney 2017; McCartney et al. 2010). It is possible that the goods were exchanged with other inhabitants on the island; although current evidence for this is limited with comparatively smaller ochre finds from *Klimonas*. Another equally plausible scenario is that the crafts, particularly the ochre, were being exported to the mainland. McCartney notes, "one possible mainland client is suggested by a couple of red coloured arrowheads from Göbekli Tepe that would be at home in the *Asprokremnos* assemblage" (2017:57). McCartney (2017:56) also suggests that the tanning of pig skins was also being done at the site; similarly, these could have been used in exchanges with other island inhabitants or mainlanders.

At *Klimonas*, three obsidian bladelets and one blade were found. As noted in Chapter 2, obsidian is not natural to Cyprus, but typically has been sourced to central Anatolia. While we see much greater volumes of this import during the Cypro-PPNB, it appears that exchange network between the island and this region began at least by the Cypro-PPNA.

Inter-island exchange (and therefore movement of at least some people around the island) is attested with obsidian and picrolite during the Cypro-PPNB. Inhabitants of Akanthou, which has the greatest amount of obsidian (Chapter 2), likely served as "gate-keepers" for Anatolian obsidian on the island. Inhabitants in other parts of the island might have traded picrolite, amongst other items, in exchange for the obsidian (Peltenburg et al. 2001:42). Miniature picrolite cups, in particular, seem to have served as an item of exchange for imported obsidian. This conclusion is based on similar miniature picrolite cups from Akanthou and *Shillourokambos* and the large quantity of obsidian found at the latter site (particularly in comparison to other Cypro-PPNB sites, outside of Akanthou).

There is some evidence that inhabitants in the Cypro-PPNB maintained relatively intense and frequent contact with the mainland (Vigne et al. 2013b:166). The best evidence comes from domestic mice (*Mus m. domesticus*). Their dental morphology remained relatively stable at *Shillourokambos* for approximately two millennia. If the gene flow from the continent was interrupted or slowed down, the dental morphology would have diversified rapidly. There is thought to have been at least two successful arrivals of mice populations each year (Cucchi and Vigne 2006; Cucchi et al. 2012; Vigne et al. 2013:166). The introduction of new lineages of domestic animal species at *Shillourokambos* also supports stable connections with inhabitants on the mainland (Vigne et al. 2013b:166). The chipped stone assemblage on the island at this time also suggests wider contact with the mainland. Similar to the Levantine PPNB, industries on Cyprus also have Byblos and Amuq points (albeit often poor examples), tools made on prismatic blades, and naviform core technology (McCartney 2007:217; Simmons 2007:235).

Obsidian also clearly shows exchange between the mainland and island. There is some debate as to whether raw materials were worked on the island (Brios et al. 1997:104-105) or the bladelets were simply imported as finished products from the mainland (McCartney 2004:112; Şevketoğlu and Hanson 2015:235). The current evidence seems to support the latter hypothesis because there is little evidence of core debris. More than 95% of the material is also in the form of bladelets, rather than raw material or pre-formed cores (Şevketoğlu and Hanson 2015:235). McCartney (2004:112) has suggested that the bladelets could have been brought to the island in a single bag. This is perhaps supported by obsidian bladelets from Akanthou. Şevketoğlu and Hanson (2015:235) argue that the only a specific type of obsidian core could produce the bladelets seen at the site. These cores are currently only found in the Kömürcü-*Kaletepe* area. However, there is evidence of obsidian from *Klimonas*, implying that obsidian was brought to the island more than once during the Early Neolithic.

The evidence presented above suggests that there was not only two-way traffic between Cyprus and the mainland, but also that exchange networks had been established within the island for several thousand years starting with the first inhabitants of the island. Data from *Ais Giorkis* adds to this body of evidence further supporting the complex and interactive landscape of the Cypriot Neolithic (McCartney et al. 2010:141).

7.4 How Were the *Ais Giorkis* Inhabitants Managing their Landscape?

Prior to this study, the leading hypothesis about *Ais Giorkis* was that it was a seasonally occupied site with evidence for some feasting activities. Based on the isotopic data and our current understanding of the Cypro-PPNB world, I believe that this interpretation should be modified slightly. As noted above, I believe there are two possible scenarios for why people were at the site; both of which are discussed below.

7.4.1 Scenario 1: Animals Left at Site and People Moved Back and Forth to Check on Animals and Collect Key Resources

There is evidence for this scenario in the ethnographic literature from the Mediterranean. For example, in central-eastern Sardinia, herders keep livestock, including cattle, goats, sheep, and pig, on plateaus that are located above permanent villages in the valley. It was common for herders to live in these valley villages, but maintain a temporary shelter on the plateau. They would periodically move between these locations to tend the livestock on the plateau, but the livestock would always stay there (Albarella et al. 2011). There are examples from this area of Sardinia of herders walking about 12 km to a plateau that was located around 500 m higher in the mountains than their village. In the pre-motorization days, this distance and altitudinal range could not be covered every day. As such, herders would spend extended periods (at least a week or more) on the plateau. Shelter consisted of built huts, which are still seen in the central Sardinian highlands today. The movement of men between the village and plateau was not seasonal; rather, it occurred throughout the year (Albarella et al. 2011:145, 148, Fig. 15.3). The plateau was considered communal land. Albarella et al. (2011:149) argue that this type of land is what made this husbandry regime possible because the animals were free to pasture wherever they liked. Agricultural cultivation also did not occur on the plateau, but rather in the valley. This prevented the clash of farmers and herders, because crop damage caused by livestock was not an issue (Albarella et al. 2011:149). Albarella et al. note that:

> In addition, we should consider that many of the animals living on the plateau were eventually consumed in the main village in the valley, which means that this is where their remains are expected to be found. This represents a further reminder of the important distinction between production and consumption that we should make in the interpretation of the zooarchaeological evidence (2011:157).

In regard to Cyprus, I could not find any ethnographic information pertaining to herders leaving livestock in the uplands and traveling back and forth between the lowland villages and the uplands to tend to domestic animals. Agricultural plots, however, were typically located miles away from the village. For example, Christodoulou (1959:85) found that an average of 22.3% of land farmed by villagers in 1946 was located outside of their village boundaries. Farmers would travel back and forth between their village and agricultural plots regularly in order to cultivate, sow, and harvest their lands. Often, they would stay on the plots for a few days (Christodoulou 1959:85). The land distribution patterns are primarily the result of the laws of inheritance. Similar to other places in the Mediterranean, these laws on Cyprus required that all children inherited equal portions of both the paternal and maternal land holdings. For example, in 1926, 238 villagers in Kholetria owned 1037 parcels of land, but by 1982, 426 people owned 1299 parcels (Marks 1999:121-122). Given the laws of inheritance, it is difficult to extrapolate these land distribution patterns to the much more distant past when there was far more available land for agriculture near permanent settlements both in the lowlands and uplands.

There is evidence in modern Cyprus of specialist craftsmen traveling to exploit preferred raw material sources. One of the best-known examples of this pattern pertains to the *dhoukani* (threshing sledge) industry. For example, at the modern village of Panayia (Paphos region), chert was readily available at a number of sources within about 1 km from the village; however, craftsmen of the *dhoukani* would travel up to 25 km for chert collection. This was tied to both location of superior chert sources as well as the need to generate and maintain commercial contacts in villages throughout the region (Pearlman 1984:124). The craftsmen would sit in the shade of olive trees to reduce the cores and knapp blades. They would then load them in sacks for transportation to workshops in Panayia and elsewhere (Pearlman 1984:163). This means that primary and secondary debitage would be located at or close to chert sources, given that this where most of the work occurred. These accounts are interesting because they do not include information on these craftsmen staying at or near the source of raw material (i.e., no type of structure was built at these sources). Stewart (2006) found similar knapping sites with evidence for *dhoukani* manufacture. Many of these were located on hill slopes near the chert source, and did not provide evidence of any type of structure.

In spite of having evidence of herders leaving their domestic animals in the uplands in other parts of the Mediterranean, we do not have examples of this in the Cypriot ethnographic record. Rather, it seems that agricultural plots were dispersed (sometimes in the uplands relatively far from the home village) and that craftsmen would travel into the uplands to exploit preferred raw material sources. While this lack of evidence from the Cypriot ethnographic record does not necessarily mean that this scenario did not occur during the Neolithic, I do not believe the current evidence from *Ais Giorkis* supports this. Based on accounts from other parts of the Mediterranean, structures would be built on the plateau/uplands to provide shelter to the herders. While we have evidence for structures at *Ais Giorkis*, none of these ethnographic accounts mention other types of activities (e.g., chipped stone or ground stone industries) occurring within or near these huts. This is simply not the case with *Ais Giorkis*, where the huge quantity of material suggests that other activities played a key role in the inhabitants' everyday life. The volume of material also suggests that people were not simply there to collect raw materials, work them a bit, and then leave, which is the case for the *dhoukani* industry.

In addition, the above quote by Albarella et al. (2011:157) is particularly striking to me. They mention that most animal remains that were consumed would not be found on the plateaus, but within the villages in the valleys. Again, *Ais Giorkis* does not fit this pattern. As noted in Chapter 2, the volume of animal bone recovered from the site is extremely large with an amount totaling almost a ton (Croft 2017). The scale of herding suggested by the isotopic data also points to domestic animal management not being a key priority for the inhabitants of the site.

To summarize, I do not believe that the people were using *Ais Giorkis* simply as a temporary shelter for their trips to the uplands to manage domestic animals. The sheer quantity of material (artifacts and fauna) recovered from the site, the presence of substantial structures, and the isotopic data all suggest a divergence from patterns that are seen in the ethnographic record for this type of scenario.

7.4.2 Scenario 2: Ais Giorkis Inhabitants are Craft Producers Enabling Them to Participate in Exchange Networks

In the absence of formalized workshops and factories, it is not uncommon for people in small-scale societies to be provisioned with large quantities of socially valued goods through specialized production and long-distance exchange (Spielmann 2002:197-198). As discussed above, we see evidence for both production and exchange at the Cypro-PPNA site of *Asprokremnos* and throughout the Cypriot sites during the Late Epipaleolithic and Early Neolithic. While there are discussions about production sites during the Cypro-PPNA (e.g., McCartney 2017), we have yet to have such discussions for the Cypro-PPNB. I believe that, similar to *Asprokremnos*, *Ais Giorkis* provides substantial evidence for a site whose inhabitants were focused on craft production, rather than agriculture, although some herding did occur, and the herding was embedded in hunting activities.

7.4.2.1 Volume of Material at Ais Giorkis. There are not many substantial structures, including domestic, at *Ais Giorkis*. As a result, it has been assumed that perhaps a few families lived at the site. In contrast to the number of structures, however, we have recovered over 300,000 pieces of chipped stone, over 700 ground stone artifacts, and nearly one ton of animal bone. In addition, there is evidence of specialized activities occurring at the site, including possible processing of condiments or medicines and vessel fragments manufactured from picrolite. The actual amount of material is likely even greater given that the sampling strategy was usually 20% (Chapter 2). It seems clear that the inhabitants were producing surpluses of some material. This surplus implies that at least some of the occupants were craft producers who likely operated within the broader inter-island and island-mainland network.

7.4.2.2 What Crafts or Goods were the Inhabitants Producing? The abundant chipped stone and ground stone and the location of the site near high-quality raw material sources for each, suggests that these were two important production foci for the *Ais Giorkis* inhabitants. The chipped stone assemblage shows a high degree of skill that was utilized to produce a large amount of lithic waste, tools, and cores. There are also possibly dump areas for the lithic waste production (Keach 2014). The combination of the intensity of the amount of material worked, the types of objects created, and specialized areas for lithic waste dump imply specialized production (Barsilia and Goring-Morris 2007; Gebel 2010; McCartney 2017:55).

One interesting aspect of the ground stone industry is the variety of small cupules that have been recovered. It was hypothesized that these might be for mixing spices, pigments, or medicines, because they were too small to have been used for food preparation. While ochre has not been recovered from the site in substantial quantities, residue analysis has recovered mustard, which could be used as a condiment or medicinal purposes. Cypriots, today, still use plants in the mustard family for medicinal purposes (Della et al. 2006). While perishable goods such as condiments or medicines are far harder to trace the movement of in the archaeological record, it seems highly plausible that these items could have been exchanged during the Neolithic.

Elaborate vessels, including some platters or bowls, manufactured from picrolite also seem to be unique goods produced by the inhabitants of *Ais Giorkis*. Most picrolite artifacts in the Cypriot Neolithic and Chalcolithic were restricted to ornaments (Peltenburg 1991), which we also have at *Ais Giorkis*. Jarvi (2015) wrote a master's thesis on experimental picrolite crafting, using ornaments found at *Ais Giorkis* as his baseline categories. One of his conclusions was that it does not take particular skill or expertise to procure the raw material or craft the ornaments. This conclusion is in contrast to Swantek (2006) and Peltenburg (1991) who argued that picrolite artifacts were a critical marker of social identity (i.e., internal site hierarchies) across the island. Jarvi (2015:51) instead suggests that there was a "shared, island-wide valuation of picrolite as a marker of island identity." I think in some ways both are right. Clearly certain sites had easier access to picrolite sources than others, which enabled them to either exchange nodules or actually craft the finalized product that was then exchanged. In addition, picrolite during the Cypro-PPNB does appear to be part of an island-wide identity, because it is found at most of the sites, even those that are not near picrolite sources. While there are not many of these picrolite platters or bowls at *Ais Giorkis*, the fact that they are rare and unique suggests they served a particular function. In addition, based on current archaeological evidence, we do not see their manufacture outside of *Ais Giorkis*, further supporting that these were specialized products crafted by the site's inhabitants.

Given the size of these vessels, it is likely that raw material for them would have been procured from sources in the Troödos, rather than the Kouris riverbed (Chapter 2). *Ais Giorkis* is closer to this source than other Cypro-PPNB sites. Perhaps this is what enabled the inhabitants to produce these larger vessels? Of note, Şevketoğlu and Hanson (2015) comment that their chisels made from picrolite likely would have been sourced from the Troödos Mountains. While there might not have been direct exchanges between inhabitants of *Ais Giorkis* and Akanthou, the former's proximity to sources in the Troödos suggest that they could have been one of the original sources for the picrolite found at Akanthou.

It is also interesting that some of the caprine individuals appeared to be moved to higher elevations than *Ais Giorkis* seasonally. While these elevations were located relatively close to the site, it is also possible that movement of some caprine individuals to higher elevations was also tied to exploitation of resources, such as picrolite.

Perishable items were also likely produced at the site, but there is a dearth of evidence for them. For example, skins were likely important given the large number of faunal remains, particularly those of deer and pig. Skins could be tanned to create a finished hide. Common tools (either stone or bone) used in tanning include scrapers, blades, and perforators. Blades are used to create holes along the hide and to cut the hide from the rack. Scrapers are used to remove hair, fat, and flesh from the hides (Richter and Dettloff 2002:303-304). Both blades (around 20% of the chipped stone assemblage) and scrapers (around 10% of the tools) were recovered from *Ais Giorkis*. In addition, deer cranium are present, which is in contrast to other Cypro-PPNB sites. This might be explained by the fact that *Ais Giorkis* inhabitants were likely closer to deer foraging areas than other Neolithic peoples in the island and could bring the entire carcass back to the site relatively easily. However, brain can also be used in the tanning process. A hide needs to have some type of oil-based substance rubbed into it, in order for the fibrous structures to be lubricated. There are examples of deer brain being used for this purpose (e.g., Richter and Detloff 2002), thus it is possible that the *Ais Giorkis* inhabitants were tanning some skins.

Leather typically only survives in the archaeological record under conditions of extreme aridity and cold, in peat bogs, or where there is excessive salinity (Rifkin 2011:134); thus, it is unlikely that we would ever recover leather from Neolithic Cyprus. Residual traces of blood, hair, and collagen have been detected on lithic scrapers from the Levant (Rifkin 2011:134), although I am not aware of any such studies on Cyprus. However, I do not think it is implausible that tanning was occurring at *Ais Giorkis*. Based on the recovery of scrapers, blades, red ochre, and chalk slabs that were “cutting boards”, McCartney (2017:56) suggests that tanning of pig skins also took place at *Asprokremnos*. In addition, if some of the inhabitants were living year-round near *Ais Giorkis*, they would have needed warm clothes for the fall and winter months.

The preferential treatment afforded to the hulled barley samples, at least based on the nitrogen stable isotope data from this study, raises the question: what was being done with the hulled barley? This question is difficult to answer for a number of reasons, but the main one is that we do not know where the cereal crops found at *Ais Giorkis*, and for that matter most other Cypro-PPNB sites, were grown. At *Ais Giorkis*, the macrobotanical evidence suggests that the inhabitants were further processing the cereal remains into flour. It is difficult to determine based on the current evidence whether they were producing a surplus of this good. With the flour, the inhabitants could have made bread; bread made of barley was a relatively common practice in Cyprus (Baker 2011[1879]). Indeed, bread is one of the most basic elements of daily Cypriot diet, even today. Unfortunately, when bread was first produced remains relatively contested within the discipline of archaeology. Bread is only one way of consuming cereals. Other cereal foods include porridge, gruel, and bulgur. Unfortunately, we do not have substantial evidence for hearths, ovens, or fire-pits at *Ais Giorkis*. With the current archaeological evidence, we cannot say with any degree of confidence what the inhabitants were doing with the barley and wheat flour and why barley appears to have been given preferential treatment.

The final item that the inhabitants of *Ais Giorkis* might have been producing for exchange is milk and/or cheese. A good deal of evidence for Early Neolithic milk exploitation has already been collected from the Near East, Africa, and Europe (e.g., Helmer et al. 2007; Vigne and Helmer 2007; Gillis et al. 2013). Analyses in support of this idea have been based on sequential analyses of stable isotopes (e.g., Balasse and Tresset 2002; Gillis et al. 2013), culling profiles of caprines and bovids (e.g., Helmer et al. 2007; Vigne and Helmer 2007; Vigne et al. 2017), and lipid residues from ceramic vessels (e.g., Evershed et al. 2008). Based on current evidence, it seems unlikely that Early Neolithic peoples would have been able to consume fresh milk in large quantities due to their inability to process lactase at this point (Burger et al. 2007; Itan et al. 2009). However, they would have been able to digest processed milk (e.g., cheese and other fermented products; Kovačikova et al. 2012). Cheese making, in fact, has been documented during the 6th millennium cal BC in eastern Poland (Salque et al. 2013). There is also evidence of milk exploitation at *Shillourokambos* (Chapter 3; Vigne et al. 2017). Unfortunately, the final zooarchaeological report for *Ais Giorkis* is not yet available; thus, it is difficult to say whether these products were possibly being exploited at the site. It seems plausible that milk/cheese might have been important products, given the site's location in the uplands. The cooler temperatures might have helped prevent spoiling.

7.4.2.3 What Goods were the Inhabitants of Ais Giorkis Exchanging For? Based on current archaeological evidence, the inhabitants likely exchanged for obsidian, marine shell, and carnelian bead. In regard to obsidian, *Ais Giorkis* was not a "hotspot." By this, the site did not have large quantities of this import, compared to Akanthou and to a lesser extent *Shillourokambos*. This suggests that *Ais Giorkis* perhaps did not have as great of participation in the obsidian trade network (Robb and Farr 2005:37). However, I do not think this means the inhabitants valued it any less. In fact, the only possible grave good associated with the human burial at the site was an obsidian bladelet, although the association is somewhat speculative. While obsidian was likely not a commonly sought-after good, it probably did hold social value to the site's inhabitants.

Marine shells (total 982) were used both as a food source and as personal ornaments at *Ais Giorkis* (personal communication Dr. D. Reese, 12/7/17). Due to the site's location in the uplands, marine shell must have come from elsewhere. It is possible that the site's inhabitants traveling to coastal parts of the island might have simply picked up some of the marine shell and brought them back to the site. Additionally, the site's inhabitants likely exchanged some items for the shells. Perhaps one possible network is with the inhabitants of *Shillourokambos*. Over 90% of marine mollusk shells at *Shillourokambos* served as ornaments or other types of artifacts (i.e., containers, tools, and pebbles). About half of these were worked and the other half were collected as ready to use artifacts, which means that they could have been used as beads and suspended (Mayer 2017). There are similarities in species between the two sites, which could be a product of exchanges made between both sites' inhabitants.

The carnelian beads, of which there are 2, are an interesting import and likely came from Egypt. Carnelian beads are currently not found at other Cypro-PPNB sites, but they are found at *Klimonas* and in the succeeding period at Khirokitia (personal communication Dr. D. Reese, 12/6/17). They likely were used as body ornaments. Because there are only a few beads, it is difficult to say much about them. To the best of my knowledge, there is no evidence for Egyptian/North African connections during the Aceramic Neolithic. Thus, it seems more likely that carnelian beads were part of a large exchange network that included North Africa, the Levant, and Anatolia. Through connections with mainlanders from the Levant and/or Anatolia, some individuals on Cyprus were able to acquire carnelian beads.

Perishable items were also likely being exchanged for. One example appears to be the cereal crops, since current evidence does not support that they were grown at or near the site. We have evidence of cereal crops arriving at sites possibly via exchange on the mainland. For example, at the PPN site of Jerf el Ahmar, located in present-day Syria, two observations are made about the botanical data: primary threshing of cereal crops might have occurred off-site and grain was stored hulled with limited weed seed admixtures (Asouti and Fuller 2013:319). It appears that the earlier and later steps of the crop processing cycle were separated by time and space. It is unknown if the former was practiced simply away from the buildings at the site or if crops in the later stages of the cycle were brought to the site via exchange. Final preparation and consumption appears to be a household centered activity at the site (Asouti and Fuller 2013:319-320).

The inhabitants of *Ais Giorkis* might also have been trading for domestic animals. It is thought that the cattle at the site represent a second lineage, different than the original domestic lineage brought to the island as evidenced from *Shillourokambos* (Chapter 3). Cattle husbandry is believed to have persisted at *Ais Giorkis* and other areas of western Cyprus for several centuries up to a millennium after their disappearance from sites such as *Shillourokambos* (Croft in Peltenburg 2003:50). The cooler temperatures and likely easier access to preferred forage and water perhaps made the upland locations ideal areas for cattle herding. Unfortunately, the limited data prevents a better understanding of this hypothesis.

It is also possible that milk products or other ante-mortem products (e.g., fibers and cheese) were items the *Ais Giorkis* inhabitants exchanged for. At *Shillourokambos*, the culling profile of goats in the recent phases of site occupation suggest that their exploitation had shifted towards milk. Sheep, from the earliest occupation phases, were bred for both meat and milk production, although during the later phases a new lineage appears to have been introduced and was exploited for its hair and meat (Chapter 3; Vigne et al. 2017). In contrast to *Ais Giorkis*, caprine herding dominates at *Shillourokambos* by the later phases of site occupation (Hadjikoumis et al. forthcoming), suggesting that the inhabitants of the site focused on domestic herd animals. Perhaps *Shillourokambos* inhabitants focused on domestic animal products, whereas *Ais Giorkis* inhabitants focused on the production of other crafts.

In some ways, I wonder if the situation on Cyprus during the Early Neolithic is similar to David Ricardo's Law of Comparative Advantage, which concludes that one country can have a comparative advantage in some product over its trading partner even if it is less efficient at making it (Ridley 1996:207; Ruffin 2002). Ridley summarizes Ricardo's insight using the following example:

> Suppose there are only two commodities being traded: spears and axes. One tribe, called – for the sake of argument – Japan, is good at making spears and very good at making axes; the other, called Britain, is bad at making spears and very bad at making axes. Superficially, it seems to make sense for the first lot to make their own spears and axes and not indulge in trade at all. But hold on. A spear is worth a certain number of axes. Let us say one spear is worth one axe. So every time the first tribe makes a spear, it is making something it could buy from the other tribe by making an axe. Since it takes this tribe less time to make an axe than a spear, it would be sensible to make an extra axe, instead of a spear, and swap it for a spear made by the second tribe. The second tribe reasons likewise (Ridley 1996:207).

Ultimately, the two groups realize that they are both better off in this situation than if each tries to be self-sufficient (Ridley 1996:208). While Ricardo's comparative advantage often pertains to market systems, it also seems highly plausible for non-market economies. Division of labor between groups would be more productive than one within a group. While sharing between individuals reduces the risk of shortages faced by each individual, it is still more likely that resources for one whole group would be short at the same time than for distant groups or groups specializing in some activity (Ridley 1996:208). By groups specializing in particular activities, they can exchange for products that they do not specialize in from other groups. There is currently limited evidence at *Ais Giorkis* for domestic herd products. While the inhabitants do have domestic animals, their management was not the focus of the inhabitants. They likely were able to get meat relatively easily from these animals. Milk and other ante-mortem products were likely goods that were sought after. The inhabitants at *Ais Giorkis* could have exchanged their crafts for these products produced by the inhabitants of *Shillourokambos* or others on the island. The inhabitants of *Ais Giorkis* would have had to specialize in the production of some goods in order to participate in these inter-island exchange networks. These exchanges would also not just entail goods, but information and marriage partners as well (discussed below).

7.4.2.4 Who were the Ais Giorkis Inhabitants Exchanging with? With the current archaeological evidence, this question is nearly impossible to answer. The obsidian and picrolite exchange networks on the island tell us how these items moved around, but not how the people moved across the landscape. I doubt that inhabitants of the island traveled solely between the current excavated Cypro-PPNB sites. Based on survey data, we know there were other sites across the island, but whether these were more permanent villages or activity areas remains to be seen. At the very minimum, the people of *Ais Giorkis* were producing a surplus of some goods, implying that at least some of them were craft producers who likely operated within the broader inter-island and perhaps island-mainland network.

7.5 Conclusion

Hunting was a key activity at the site, irrespective of whether it was related to tanning or not. Besides contributing to diet, hunting plays an important social role, particularly among men

(Hildebrandt and McGuire 2002; Speth 2010). Data from the mainland hints that craft production was typically embedded in hunting and/or herding activities, particularly in remote areas (Wright et al. 2008:155). Throughout mainland Southwest Asia during the Early Neolithic, there is the presence of wild animal iconography and symbolism (e.g., Goring-Morris and Horwitz 2007; Hodder and Meskell 2011; Twiss and Russell 2009; Twiss 2006). While there is limited evidence of similar items from Cyprus, the fact that wild animals were introduced to Cyprus during the Late Epipaleolithic, reaffirms their importance in the ritual and cosmological structure of Early Neolithic communities (Arbuckle 2014:69).

In some ways, I wonder if *Ais Giorkis* was also a meeting place, akin to fairs that Marks (1999) documented in the area in the recent past. Surplus items by members of the modern-day village of Kholetria were exchanged and sold at local fairs. Christodoulou also noted the existence of similar gatherings prior to the Roman period (Christodoulou 1959:102). Fairs were one of the most important forms of internal exchange throughout Cyprus. They typically took place in the open air and the same trades occupied the same spot every year (Christodoulou 1959:102). Besides goods, marriage partners and information were also exchanged at these gatherings. It is likely that some type of gatherings took place during the Early Neolithic.

A cross cultural look at marriage practices among a wide range of foraging societies found that signaling by a man seeking a marriage partner was not just directed at the potential mate but also at her parents (Apostolou 2007). One way that men could signal their marriage potential is through hunting successes (Speth 2010). Thus, perhaps the focus we see on hunting at *Ais Giorkis* goes hand-in-hand with gatherings or fair like activities. Hunting perhaps also served as a male-bonding experience (Simmons 2009a). *Ais Giorkis* as a gathering place or early fair parallels the argument made by Simmons (2012) who suggests that feasting, which includes the gathering of people, was a key activity at the site.

There is still the question of whether *Ais Giorkis* was inhabited year-round. The current consensus is no based on both the lack of postholes associated with the structures and limited evidence for hearths or firepits. In some ways, the isotopic evidence contradicts this, because there does not appear to be seasonal movement of at least the domestic animals, which indicates they were kept close to the site. However, it is also plausible that the inhabitants of *Ais Giorkis* lived near the site, and simply used it as a place for craft production and hunting activities. It is interesting that we have evidence for blade and ground stone caching, which can suggest areas were discontinuously inhabited (McCartney 2017). It is tough to comment more on this because we have limited evidence of phasing at the site. Ultimately, I do not think it is implausible that people were living at or near *Ais Giorkis* throughout the year. Since the Late Epipaleolithic, there is evidence that people have been exploring the hinterland of the island, which suggests that by the Cypro-PPNB they would have known how to survive winters at the lower elevations of the Troödos foothills.

Based on current evidence, I believe the most plausible explanation for what the people at *Ais Giorkis* were doing in the landscape relates to the production of crafts and goods that were likely exchanged within inter-island and even possibly island-mainland networks. The choice of site location (access to raw material), object types (e.g., picrolite vessel fragments and small ground stone cupules), the production of large surpluses of chipped stone and ground stone, and the large quantities of faunal remains (over 50% of which are wild species) suggests that stone commodities, hunting, and possibly animal products (leather and maybe milk) were the focus of habitation at *Ais Giorkis*, rather than pasture or agriculture land. The stable isotope data supports this notion; animal management practices at the site are relatively homogenous. Evidence for feasting and the large quantities of hunted wild animal remains also suggests that *Ais Giorkis* might have been a gathering place, akin to modern fairs seen in the area, where products, marriage partners, and information were exchanged.

CHAPTER 8: RE-FRAMING THE CYPRO-PPNB

8.1 Introduction

Since the 12th millennium cal BP, the inhabitants of Cyprus have been actively engaging with the local landscape. During the Late Epipaleolithic, resources such as chert and picrolite are recovered from sites on the island, where they do not occur locally. There are hints that sea-salt and sea-turtles might have been exploited along the coast, and perhaps brought back to mainland Southwest Asia. In addition, wild boar likely were introduced during this time period, suggesting that the inhabitants had begun to stock the island with key resources. These data indicate that people were exploring the hinterlands of the island and inter-island exchange networks were being established by a relatively early date.

During the Cypro-PPNA, some people became craft specialists who operated within the broader Eastern Mediterranean exchange network. These Cypriots produced large surpluses of ochre, chipped stone blades, and projectile points that went beyond the needs of their own community. Other communities in Cyprus resemble more typical early villages. Additional evidence for exchange with the mainland also comes from the recovery of a few obsidian blades.

By the Cypro-PPNB, inter-island and island-mainland exchange networks are more visible in the archaeological record. Humans introduced a wide variety of wild and domestic animal and plant species to the island, perhaps to make a somewhat unfamiliar landscape more familiar. There is also evidence for new lineages of some animals being reintroduced after the original lineage likely died out. Obsidian is being exchanged on the island, and there appears to be at least one particular “hotspot” at Akanthou. Picrolite and other goods were possibly exchanged for obsidian and perhaps even moved beyond the island to the mainland. Some communities seem to be more dependent on an agricultural lifestyle, and others focus on hunting and even craft production.

Despite these data, current definitions of the Late Epipaleolithic and Early Neolithic on Cyprus still use the strict forager/farmer dichotomy. This dichotomy derives from the still prevalent model of island colonization in the Mediterranean. Specifically, many still believe that human populations could only settle on islands with the advent of technologies related to farming (e.g., Cherry and Leppard 2015, 2017). Proponents of this dichotomy argue that once colonizing farmers settle in the island environment, like Cyprus, they lose their knowledge of maritime technology and either become isolated or require outsiders (i.e., middlemen) to transport them to new areas (Peltenburg et al. 2001:56-57; Peltenburg 2003:97).

Current viewpoints are now considering the sea as highway, rather than a barrier, that facilities interactions with the mainland (McCartney et al. 2010; Simmons 2014). However, many still see the inhabitants of Cyprus only trying to gain access to resources or social relationships that are not available to them in an impoverished and challenging environment (Peltenburg 2004c; McCartney et al. 2010:136, citations therein). Focus is not given to two-way interactions between islanders and mainlanders or even interactions by inhabitants within the island (McCartney et al. 2010:136). Partly because of this, as McCartney et al. (2010:141) succinctly noted, “What Neolithic groups were doing in the Cypriot landscape, however, has been little explored.”

In order to address this issue, I adopted a modified niche construction theoretical perspective. I did not collect data that would allow me to discuss environmental modifications from the introduction of animal and plant species as an evolutionary process. However, similar to Smith (2011:837), I believe that human niche construction provides a general unifying perspective for integrating consideration of human efforts at landscape modification. Ultimately, I was interested in plant and animal management strategies by Neolithic peoples in western Cyprus, and what this could potentially allow us to infer about land use.

My primary research question was, how did the earliest permanent human settlers manage the Neolithic landscape of western Cyprus? To address this, I utilized stable isotope ($\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$) analyses of the botanical and faunal remains from the Cypro-PPNB site of *Ais Giorkis.* I had three secondary questions to enable me to examine my primary research question:

1. What are the baseline standards for $\delta^{13}C$*,* $\delta^{15}N$*, and* $\delta^{18}O$ *in the western region of Cyprus?*

2. What were the plant management strategies for two-grained einkorn, hulled barley, and lentil?

3. What were the animal management strategies for deer, sheep, goat, cattle, and pig?

8.1.1 Secondary Question 1

In order to have an idea of the proportions of plant types in western Cyprus, and thus a baseline of regional carbon and nitrogen values, I collected snails from a variety of elevations and geological contexts within the western region. This attempt at producing a baseline ran into several major setbacks. The first was that land snails were not always found in the different geological contexts or elevations, which resulted in several trips back to Cyprus. In addition, Garmin Glo on the Dragon Touch Model E-70 did not work very well in the field. Thus, it was challenging to collect samples from specific areas. The final issue, which in part relates to the first, is that snails were not collected in a systematic manner across the western region. This would have taken far great resources than I had. These limitations leave considerable room for additional researchers to develop carbon and nitrogen (and oxygen) baseline standards; a point that will be returned to below.

I synthesized the oxygen isotope baseline data on the island (Boronina et al. 2005a; IAEA/WMO 2016; Jacovides 1979), which Leon (2016) has also recently done. In addition, there are now several publications/dissertations (Hadjikoumis et al. forthcoming; Lange-Badré and Le Mort 1998; Leon 2016; Scirè Calabrisotto 2017a, 2017b) that utilize stable isotope analyses to shed light on problems of anthropological and archaeological interest. Data from these helped with the interpretation of this study’s results.

The carbon and nitrogen isotope values from the deer provide important information about the environmental setting of the site. The environment of Early Holocene Cyprus is dominated by C_3 plants, and the climate was perhaps wetter than today. However, some plants were still grown under dry conditions. Some of the animals, including deer, might also have been foraging under a light canopy, which was likely located within a few kilometers of the site.

8.1.2 Secondary Question 2

Three tentative conclusions were made for the nitrogen isotope values of the two-grained einkorn wheat and hulled barley samples: 1.) the two-grained einkorn wheat and hulled barley were grown in separate fields; 2.) the soil conditions of the hulled barley were being managed in a way to increase soil fertility, which was in contrast to the two-grained einkorn wheat; and 3.) the inhabitants of *Ais Giorkis* (or whomever they were getting the crops from) appear to be providing barley with greater resources to ensure its growth, possibly at the expense of wheat. Both crop cereals are grouped into the ‘moderately watered band,’ which contrasts with evidence from the mainland. Here, barley was typically grown under drier conditions than wheat. Both the

$\delta^{15}N$ and $\Delta^{13}C$ values in this study imply that people were making strategic decisions about the crop growing strategies between the hulled barley and two-grained einkorn wheat found at *Ais Giorkis*. They seemingly preferred barley, which was a surprising conclusion given that einkorn is the most common species at the site. Based on macrobotanical evidence, the inhabitants of *Ais Giorkis* were not expending resources or labor on cultivation, harvesting, and most post-harvesting crop processing activities.

8.1.3 Secondary Question 3

Evidence for the homogeneity of animal management practices at *Ais Giorkis* is provided by the stable isotope data. There is limited evidence for seasonal movement of the caprines and cattle between the lowlands and uplands. Some caprine individuals were possibly moved farther upland. They even might have foraged under a light canopy. Thus, this study's results indicate that the *Ais Giorkis* inhabitants were practicing small-scale herding of the domestic animals, due to the lack of data supporting seasonal movement. The pig nitrogen values suggest that the animals were consuming a primarily herbivorous diet. It is possible that some of these animals were wild or feral. The inhabitants might also have managed them as a free-range husbandry regime. There is also no evidence for the consumption of marine resources by animals at *Ais Giorkis*.

8.1.4 How Did the Inhabitants Manage the Neolithic Landscape of Western Cyprus?

Based on the carbon, nitrogen, and oxygen isotope data, the inhabitants of *Ais Giorkis* were not focusing resources and labor on agricultural practices. Instead they appear to have exploited certain resources and hunted wild deer and domestic, feral, and/or wild pig. While this provides additional information on how the inhabitants were managing the landscape around *Ais Giorkis*, it does not fully address why they were at the site or how they fit into the broader Cypro-PPNB interaction sphere. I believe the data presented in this dissertation provide two scenarios: 1.) animals were left at the site, and some groups from the lowlands would make seasonal trips to the site to check on the animals and collect key resources and hunt wild (domestic?) animals; and 2.) *Ais Giorkis*' inhabitants focused on craft specialization for inter-island and possibly island-mainland. Ultimately, I argued that the latter was the more likely of the two scenarios. There is evidence for the first scenario in the ethnographic literature from Mediterranean islands; however, the material culture found at *Ais Giorkis* diverges from the pattern seen in this literature. While there is no evidence of this scenario from the Cypriot ethnographic literature, we do know that until relatively recently Cypriots would exploit raw materials, such as chert sources, for the production of *dhoukanis*. However, typically the only material found at these activity areas are from knapping, which again is not the case for *Ais Giorkis*. As a result, I believe that at least some inhabitants appear to be focusing on the production of both ground stone and chipped stone industries, hunting and possibly tanning of animal hides, and picrolite manufacture. The surplus of many of these items found at the site indicate that the inhabitants were producing quantities that exceeded the needs of the community; thus, they had to have been participating in exchange networks. Given that we have evidence of the hinterland being explored for several thousand years, it seems entirely reasonable that by the Cypro-PPNB, inhabitants would have known how to survive year-round in the lower elevations of the Troödos Mountains.

8.2 Limitations

As with any study there are limitations, and I address three of them. The first relates to sample size. As we saw with the lentil seeds, in particular, bulk samples (minimum of 5 grains/seeds per analysis) are necessary to account for natural variation in the plant. When the confidence range extends outside the accepted bounds, the results are too variable to merit interpretation. The animal bone sample size was generally acceptable (8 samples or more); however, the number is based primarily on one study (Pearson and Grove 2015) that only examined caprine stable isotope data (although see Reynard and Tuross 2015 for similar conclusions). Thus, we currently do not know if this minimum is applicable to other animal species. The molar enamel sample was generally comparable to other studies; however, these samples are only capturing specific moments in time, which makes extrapolating the results to larger questions challenging. In addition, stable isotope analyses should be conducted on bone collagen and molar enamel samples taken from a variety of contexts and levels at a site (e.g., Pearson et al. 2015) in order to gain a more accurate picture of the specific question(s) being investigated. While I tried to do this, I was limited by the time that I had in Cyprus to collect the data necessary for this study.

It is also challenging to interpret results due to a lack of island-wide baseline data. There are a number of examples in the literature where such baselines have been established for specific regions or countries (e.g., Bentley and Knipper 2005; Hartman and Danin 2010; Szpak et al. 2013). This would require a large undertaking of labor and financial resources. For example, one way to map regional $^{87}Sr/^{86}Sr$ is to analyze hundreds of water, plant, low-mobility animal species (i.e., snails), and soil leachate samples. An alternative way, and one that more directly measures the biologically available isotope signatures, is to measure $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ in archaeological tooth enamel of low-mobility animal specifies from a variety of excavation sites. Leon (2016) has begun to establish a biologically available strontium baseline for the south-central and south-eastern regions of Cyprus, although, as he notes, additional work needs to be done. Similarly, in order to understand the relationship between plant isotopic values and rainfall in Cyprus, which in turn influences values for animals and humans, plant samples need to be systematically collected from a variety of sites, elevations, and seasons. Surveying the monthly content of oxygen isotopes in precipitation in Cyprus would allow for a reconstruction of both annual weighted mean and mean seasonal δ^{18}O values. These data would allow researchers to produce seasonal curves of δ^{18}O values, which can be used to model the sequential curve of δ^{18}O values of water ingested by animals. In turn, this can provide stronger reconstructions of seasonal movement and birth seasonality. While establishing robust baselines will require labor and financial resources, it will help to make interpretations of stable isotope data far more accurate.

The final limitation relates to the current categorization (i.e., domestic or wild) of animals. As we have seen at *Shillourokambos*, there is evidence of feralization of some animals, which demonstrates the human-animal relationship is quite complex on the island. It is entirely possible that while animals are considered domesticated on the basis of morphology, they perhaps were not necessarily treated as such by people. This is perhaps the case with the pig at our site. They are morphologically domesticated, but the stable isotope data suggest that they were perhaps wild or feral given the herbivorous nature of their diet. It is also possible that wild animals, such as deer, were used in a more domestic sense in Cyprus. There are no morphological changes associated with the deer that would indicate that they had begun to undergo domestication; however, the fact that humans did bring these animals to the island implies some degree of control over them in the wild. There is evidence from the Roman period onwards in Europe of keeping fallow deer in parks, or artificial enclosures. While we currently have limited evidence for this in Cyprus, the human-deer relationship on the island is quite curious, and worthy of continued investigation. Ultimately, it is important to always combine multiple lines of evidence (e.g., stable isotope data and the zooarchaeological analyses) in order to have a more complete understanding of animal management practices.

8.3 Contributions

The contributions from this study are two-fold. The first is that the isotopic data add to the slowly growing body of literature on Cyprus (e.g., Hadjikoumis et al. forthcoming; Lange-Badré and Le Mort 1998; Leon 2016; Scirè Calabrisotto 2017a, 2017b) that demonstrates this type of research can be successfully applied to Cypriot archaeological contexts. This is important because there are aspects of animal and plant management strategies that are less visible through traditional archaeological methods. For example, direct evidence for animal diet (and changes in this diet), weaning patterns, birth seasonality, and movement can be obtained via stable isotopes. Similarly, we can now obtain direct evidence of crop water availability and soil nitrogen composition from stable isotope analyses of archaeobotanical remains. These data should never be interpreted in isolation. Rather combining the results with strategies characterized by zooarchaeological and paleobotanical approaches allows for a better contextualized and more holistic understanding of subsistence strategies and mobility patterns employed by people in the past (Makarewicz and Sealy 2015:154).

The second contribution is that this study reinforces the importance of re-framing our understanding of the Cypro-PPNB. Specifically, not everyone on the island were farmers. While the inhabitants of *Ais Giorkis* had domestic animals and plants, activities related to agriculture did not seem to be the main focus. They also are not strictly hunter-foragers, again because they do have some domestic products. McCartney et al. (2010:141) uses the term “herder-hunters who cultivated.” Rather, the situation for *Ais Giorkis* and early Cyprus is far more complex. Site location ensured that they had access to important raw materials (chert, picrolite, diabase) and good hunting ground, which allowed them to focus on production of both ground stone and chipped stone industries, hunting and possibly tanning of animal hides, and the manufacture of picrolite objects. The quantity of material at the site indicates that the production went beyond the inhabitants’ own need. This surplus combined with the limited focus on domestic resources lends support to the notion that at least some of the *Ais Giorkis* inhabitants were craft specialists.

While the question still remains open on who the *Ais Giorkis* inhabitants were exchanging with, these data demonstrate that there were established exchange networks on the island. In addition, there were likely gathering places where such products, marriage partners, and information could be exchanged. Given the evidence of feasting at the site, *Ais Giorkis* might also have fulfilled this purpose, similar to fairs that are found in the area today. Even the focus on hunting might have been tied into these gatherings. They could have been a way for young men to signal their mating potential to prospective marriage partners and their respective families.

As I noted in Chapter 1, there has been scholarly interest on the mainland in documenting variation in Neolithic lifeways, including the adoption and incorporation of domestic resources into everyday life. Yet, this approach has not been incorporated into most research models in Neolithic Cyprus. Despite the fact that at some sites, there is still a heavy focus on the exploitation of wild resources, the island inhabitants are often viewed as agropastoralists by researchers. This might be the case for some inhabitants at sites (e.g., *Shillourokambos*), but it does not encompass the entire island. To me, what is more interesting is that it appears that sites and people within the landscape specialized in different resources, which seemed to have allowed for a strong inter-island exchange network. In order to better understand this network, however, we as a discipline of archaeologists interested in Early Neolithic Cyprus need to move beyond our current interpretations of the Cypro-PPNB and truly embrace the variation that we see within the archaeological record.

8.4 Future Directions

Stable isotope analyses in conjunction with traditional archaeological methods are contributing to our understanding of animal and plant management strategies, which in turn allow us to infer land use by past peoples. Issues surrounding land use are still significant factors today, including in Cyprus, particularly with climate change. In addition, our current interest in going to Mars and questions that are being asked about how we will get there and what happens when we are actually there, emphasize that we still continue to grapple with issues related to colonization and exploration of unknown lands. These same questions were likely being asked and solved by the earliest people in Cyprus.

Going forward, I believe that there are several important areas of future research. The first, which I mentioned above, is establishing a robust stable isotope baseline for the island. In so doing, we will be able to use stable isotope analyses to the fullest of its capabilities.

Related to this, incorporating strontium analysis into questions of archaeological interest will greatly allow us to expand our understanding of past peoples on Cyprus. For example, strontium analyses of crops can provide us with a better understanding of where crops were grown, which remains unknown for the Cypro-PPNB. As I noted in Chapter 5, the barley does have an enriched nitrogen signal. Based on current evidence, I believe that it is tied to anthropogenic reasons; however, if the barley is actually coming from coastal areas, then sea-spray of nitrates could be the cause of the enrichment. Similarly, strontium can shed light on the actual movement of people and animals, specifically whether they are locals or from other parts of the island. These data have been used to support hypotheses about sites being gathering or meeting areas on the mainland. We also still have relatively limited data on island-mainland interactions. Again, strontium can shed light on this by identifying signatures that are not from the island, which would tell us that they likely came from elsewhere.

Far more archaeological projects in Cyprus should incorporate stable isotope analyses of plant, animal, and human remains. While there are a number of reasons, I think one of the most important is that this would allow us to identify island-wide trends and changes in these trends. For example, I noted in Chapter 5 that barley is typically grown in drier conditions on the mainland than wheat. This pattern is seen from the Neolithic through the Bronze Age. While the data from this study suggests the opposite for barley grown in the Cypro-PPNB, this hypothesis is based on a small sample from a single site. Adding to this initial database will allow us to see if there are local and regional differences in plant and animal management strategies, and trends through time.

As Robb and Farr (2005:25) note, “We have lost the human stories of lives being lived, journeys made, and social relations established.” To begin to better understand humans living during the Early Cypriot Neolithic, we need to move beyond our archaeological obsession with documenting the earliest colonization event and seeing the island’s inhabitant solely as farmers. Incorporating stable isotope analyses into traditional archaeological research frameworks will help us reframe the Cypro-PPNB, particularly by providing new evidence of human activity during this important period in human history.

APPENDIX A: RADIOCARBON CALIBRATED DATES

This appendix provides the radiocarbon calibrated dates used in this dissertation. ^{14}C dates from charcoal and charred botanical samples were primarily considered, because radiocarbon dates on bone or tooth samples from the earliest known sites on Cyprus are usually incorrect. Specifically, the results do not appear to offer robust, reliable age estimates. In addition, marine shells or snail shells are typically regarded as less reliable because of the uncertain marine ^{14}C reservoir offsets for sites from the late Epipaleolithic/early Holocene. The geology of Cyprus also includes calcareous areas that also have the high possibility of introducing dead carbon to marine and snail shells (Manning 2014:9).

For the main sites discussed in this study, I recalibrated, if available, original uncalibrated radiocarbon ages using Oxcal 4.3 (Bronk Ramsey 2009, 2017) and the Intcal 09 calibration curve (Bronk Ramsey 2009, 2017; Reimer et al. 2009). As I noted in Chapter 1, there are two reasons for why I chose to use an earlier calibration curve. The first is so that dates in this dissertation are directly comparable to Levi Keach's dissertation (2018), which includes research questions related to the inhabitants of *Ais Giorkis* and early Cyprus. The second reason is to ensure that the dates are comparable to those used in the most recent synthesis of the archaeology of Cyprus (Knapp 2013; Manning 2013). I first present the data in tabular form for all sites (Table A.1). This is followed by the calibration plots which are presented alphabetically by site. The lay out of this appendix is similar to Levi Keach's (2018) Appendix I.

Table A.1 Radiocarbon Dates

Site Name	Reference	Radiocarbon Date	Error	From (BC)	To (BC)	%
Abu Hureyra				**11974**	**6534**	
	OxA-882*	6100	120	5310	4729	95.4
	OxA-1931	7890	90	7056	6534	95.3
	BM-1724R	8020	100	7293	6646	95.4
	OxA-1930	8180	100	7496	6831	95.4
	BM-1424	8190	77	7455	7049	95.4
	OxA-2167	8270	100	7521	7072	95.4
	OxA-1227	8320	80	7541	7090	95.4
	OxA-2168	8330	100	7573	7085	95.4
	BM-1425	8393	72	7586	7198	95.4
	BM-1721R	8490	110	7788	7190	95.4
	OxA-1190	8500	120	7934	7186	95.4
	OxA-2169	8640	110	8181	7496	95.5
	BM-1722R	8640	100	8170	7515	95.4
	BM-1120	8666	66	7939	7581	95.4
	BM-1423	8676	72	7949	7582	95.4
	BM-1719R	9100	100	8608	7979	95.4
	BM-1122	9374	72	9107	8350	95.4
	OxA-1228	9680	90	9288	8807	95.4
	OxA-397	10420	140	10671	9866	95.4
	OxA-171	10600	200	10992	9876	95.4
	OxA-170	10600	200	10992	9876	95.4
	BM-1121	10792	82	10936	10616	95.4
	OxA-386	10800	160	11153	10461	95.4
	BM-1723R	10820	510	11826	9297	95.4
	OxA-172	10900	200	11296	10476	95.4
	BM-1718R	11140	110	11313	10783	95.4
	OxA-883	11450	300	11974	10739	95.4
	BM-1720R*	22020	200	25557	23905	95.4
Ain Ghazal				**8528**	**6651**	
	AA-5202	8310	70	7530	7143	95.4
	AA-5206	7990	80	7081	6651	95.4
	GrN-12972	8165	50	7316	7060	95.4
	GrN-12971	8460	90	7656	7199	95.4
	Bta-19907	8520	110	7937	7311	95.4
	GrN-12969	8510	80	7723	7360	95.4
	UCR-1722	8040	230	7518	6483	95.4
	GrN-12970	8650	200	8282	7316	95.4
	OxA-1743	8700	80	8170	7579	95.4
	GrN-12965	9050	80	8528	7967	95.4
Akanthou *Arkosykos*/Tatlısu *Çiftlikdüzü*				**8234**	**7748**	
	OxA-13996	8820	38	8201	7748	95.4
	OxA-27791	8911	35	8234	7963	95.4

Table A.1 Radiocarbon Dates

Site Name	Reference	Radiocarbon Date	Error	From (BC)	To (BC)	%
Akrotiri *Aetokremnos*				**12181**	**9293**	
	Beta-41405	10190	230	10598	9293	95.4
	Beta-41000/ETH7188	10420	85	10619	10096	95.4
	Beta-41407	10480	300	10998	9356	95.4
	Beta-41406/ETH-7331	10485	80	10644	10166	95.4
	Beta-40382/ETH-7160	10560	90	10708	10193	95.4
	Beta-41408/ETH-7332	10575	80	10726	10209	95.4
	Beta-41002/ETH-7189	10770	90	10938	10603	95.4
	Beta-40655	10840	270	11351	10116	95.4
	Beta-40380	11720	240	12181	11163	95.4
Atlit Yam				**7481**	**6256**	
	PITT-622	7550	80	6568	6237	95.4
	RT-944C	7610	90	6641	6256	95.4
	RT-944A	7670	85	6680	6390	95.4
	Pta-3950	8000	90	7165	6649	95.4
	RT-707	8140	120	7481	6712	95.4
Ayia Varvara *Asprokremnos*				**9141**	**8569**	
	Hd-27170/ ETH-35142	9465	46	9119	8624	95.4
	Hd-27180/ ETH-35155	9477	43	9119	8633	95.3
	Hd-27217/ ETH-35157	9525	49	9141	8724	95.4
	Hd-27227/ ETH-35183	9452	25	8807	8639	95.4
	Hd-27228/ ETH 35170	9432	49	9107	8569	95.3
	Hd-27242/ ETH-35158	9497	46	9126	8640	95.4
Ayios Tchonas *Klimonas*				**9156**	**7746**	
	AA-88544	9200	52	8551	8296	95.4
	AA-88547	9087	70	8546	8015	95.3
	AA-88545	9122	63	8538	8244	95.4
	AA-88548	8966	52	8283	7967	95.4
	AA-88546	8852	51	8222	7788	95.4
	AA-88549	8831	55	8211	7746	95.4
	AA-88541*	7741	46	6646	6476	95.4
	AA-88542*	7716	47	6637	6469	95.4
	AA-88539*	7823	46	6816	6510	95.4
	AA-88543*	7760	47	6677	6477	95.4
	AA-88550	9460	54	9121	8616	95.3
	AA-88551	9544	53	9156	8743	95.4
	AA-88540	9085	52	8450	8229	95.4
Catalhöyük East				**7588**	**5768**	
	AA-27983	7015	55	6005	5768	95.4
	PL-9800526B	7180	80	6226	5901	95.4
	P-1361	7499	93	6565	6105	95.4

Table A.1 Radiocarbon Dates

Site Name	Reference	Radiocarbon Date	Error	From (BC)	To (BC)	%
	P-781	7524	90	6588	6221	95.4
	P-774	7531	94	6591	6223	95.4
	P-772	7572	91	6596	6240	95.4
	AA-19344	7620	50	6591	6406	95.4
	AA-19345	7626	52	6592	6414	95.4
	P-797	7629	90	6648	6262	95.4
	P-776	7640	91	6656	6262	95.4
	P-1375	7661	99	6698	6257	95.4
	AA-19346	7670	50	6605	6436	95.4
	P-1366	7684	90	6744	6377	95.4
	P-777	7704	91	6768	6394	95.4
	AA-18105	7710	100	6902	6379	95.4
	P-1365	7729	80	6751	6429	95.4
	PL-980559A	7730	80	6752	6429	95.4
	AA-19351	7747	65	6693	6456	95.4
	P-1374	7757	92	7002	6431	95.4
	AA-27976	7780	55	6748	6472	95.4
	PL-980410A,B	7815	60	6983	6478	95.4
	P-1371	7844	102	7038	6498	95.4
	P-1367	7853	97	7037	6506	95.4
	P-1362	7904	111	7068	6506	95.4
	PL-980558A	7910	80	7049	6610	95.4
	P-1363	7911	103	7071	6530	95.4
	P-770	7912	94	7064	6591	95.4
	P-1372	7915	85	7051	6607	95.4
	AA-19350	7918	54	7031	6652	95.4
	P-1364	7936	98	7080	6592	95.4
	P-1369	7937	109	7139	6531	95.4
	AA-19349	7944	65	7046	6660	95.4
	---	7950	80	7056	6651	95.4
	AA-19348	7982	52	7055	6699	95.4
	AA-19347	7998	54	7063	6700	95.4
	P-1370	8036	104	7301	6653	95.4
	P-775	8037	96	7295	6657	95.5
	---	8060	80	7296	6696	95.4
	AA-18104	8065	50	7179	6817	95.4
	PL-972425A	8070	80	7306	6700	95.4
	P-782	8092	98	7343	6697	95.4
	P-779	8190	99	7514	6842	95.4
	AA-27982	8195	80	7457	7050	95.4
	PL-980525A	8390	90	7588	7188	95.4
Catalhöyük West				**6007**	**5674**	
	PL-980524A	6940	80	5989	5674	95.4
	AA-27981	7040	40	6007	5842	95.4
Erimi *Laonin tou Porakou*				**2131**	**1316**	

Table A.1 Radiocarbon Dates						
Site Name	**Reference**	**Radiocarbon Date**	**Error**	**From (BC)**	**To (BC)**	**%**
	T228_1	3145	40	1501	1316	95.4
	T230_1_fa	3500	65	2017	1666	95.4
	T230_1_o	3450	55	1903	1625	95.4
	T230_2	3240	40	1612	1433	95.4
	T248_1	3620	40	2131	1886	95.4
	T248_2	3570	55	2117	1750	95.4
Göbekli Tepe				**9175**	**8559**	
	Hd-20025	9452	73	9131	8559	95.4
	Hd-20036	9559	53	9175	8759	95.4
Kalavasos *Tenta*				**9120**	**4851**	
	P-2972	9240	130	9108	8224	95.4
	P-2976*	8870	500	9453	6686	95.4
	P-2785*	8720	400	9120	6819	95.4
	P-2554	8480	110	7751	7189	95.4
	P-2548	8350	200	7937	6772	95.4
	P-2974	8020	90	7181	6651	95.4
	P-2973	8010	360	7937	6107	95.4
	P-2782	7600	100	6639	6250	95.4
	P-2555	7430	90	6446	6092	95.4
	P-2978	7400	260	7000	5735	95.3
	P-278	7380	100	6432	6061	95.4
	P-2552	7250	100	6368	5924	95.4
	P-2550	7180	90	6236	5881	95.4
	P-2551	7140	90	6221	5841	95.4
	P-2783	7130	410	7038	5317	95.4
	P-2779	7120	90	6213	5811	95.4
	P-2553	7110	90	6211	5790	95.4
	P-2975	6970	310	6463	5324	95.4
	P-2977	6580	290	6062	4851	95.4
	P-2781	6300	80	5470	5061	95.4
	P-2549*	5630	260	5207	3956	95.3
Khirokitia *Vouni*				**7175**	**4795**	
	Ly-4309	6230	160	5485	4795	95.4
	Ly-4306	6310	170	5613	4848	95.4
	Ly-3716	7000	150	6208	5631	95.4
	BM-852	7294	78	6361	6015	95.4
	BM-855	7308	74	6363	6027	95.4
	BM-854	7442	61	6440	6125	95.4
	St-416	7445	160	6601	6010	95.4
	BM-853	7451	81	6460	6101	95.3
	Ly-4308	7470	140	6592	6062	95.4
	St-414	7515	125	6598	6095	95.4
	Ly-3719	7540	180	6823	6019	95.4
	St-415	7655	160	7029	6223	95.4

Table A.1 Radiocarbon Dates						
Site Name	**Reference**	**Radiocarbon Date**	**Error**	**From (BC)**	**To (BC)**	**%**
	Ly-3717	7700	150	7030	6254	95.4
	Ly-4307	7930	130	7175	6500	95.4
	Ly-3718*	7930	320	7597	6119	95.4
	Ly-4785*	8850	650	10032	6496	95.4
Kholetria *Ortos*				**6560**	**5838**	
	Beta-56869*	6480	230	5875	4910	95.4
	Beta-56868	7550	70	6560	6240	95.3
	Beta-82074	7500	60	6454	6243	95.4
	Beta-82075	7080	60	6066	5838	95.4
	Beta-82076	7360	60	6376	6080	95.4
	Beta-86688	7280	60	6249	6018	95.4
Kissonerga *Mosphilia*				**4681**	**2215**	
	GU-2537	4020	110	2881	2215	95.3
	BM-2279R	4180	130	3265	2350	95.4
	GU-2968	4240	100	3264	2496	95.4
	GU-2155	4250	170	3369	2351	95.4
	OxA-2161	4290	80	3312	2626	95.3
	OxA-2162	4300	80	3322	2635	95.3
	OxA-2963	4520	80	3498	2930	95.4
	OxA-2964	4860	80	3910	3378	95.4
	GU-3397	5320	90	4334	3978	95.4
	GU-2967	5540	110	4681	4070	95.4
	GU-2966	5620	60	4585	4343	95.4
	AA-10495	7255	60	6231	6016	95.4
Kissonerga *Mylouthkia*				**8735**	**6696**	
	OxA-7460	9315	60	8735	8347	95.4
	AA-33128	9235	70	8624	8297	95.4
	AA-33129	9110	70	8543	8229	95.4
	OxA-7461	8185	55	7346	7060	95.4
	AA-33130	8025	65	7132	6696	95.4
Kouphovouno				**5634**	**4997**	
	OxA-20957	6585	35	5615	5479	95.4
	OxA-20956	6647	35	5634	5514	95.4
	OxA-20947	6328	34	5374	5218	95.4
	OxA-20976	6326	33	5369	5220	95.4
	OxA-20952	6360	34	5469	5229	95.3
	OxA-20955	6276	32	5321	5211	95.4
	OxA-20954	6300	33	5342	5214	95.4
	OxA-21281	6394	37	5470	5316	95.4
	OxA-21110	6391	36	5470	5315	95.4
	OxA-20959	6284	34	5326	5209	95.4
	OxA-21280	6365	35	5470	5231	95.4

Table A.1 Radiocarbon Dates						
Site Name	**Reference**	**Radiocarbon Date**	**Error**	**From (BC)**	**To (BC)**	**%**
	OxA-20821	6143	36	5212	4997	95.4
	OxA-20951	6251	34	5314	5076	95.4
Kritou Marottou *Ais Giorkis*				**7956**	**7058**	
	Beta-183649	8480	40	7587	7498	95.4
	Beta-183650	8600	40	7722	7554	95.4
	Beta-183651	8580	40	7678	7538	95.4
	Beta-203857	8530	40	7597	7529	95.4
	Beta-213412	8510	50	7599	7499	95.4
	Beta-213413*	6840	40	5809	5642	95.4
	Beta-213414	8590	50	7722	7541	95.4
	Beta-213415	8450	60	7592	7359	95.4
	Beta-213417	8720	60	7956	7596	95.4
	Beta-220596	8620	40	7726	7580	95.4
	Beta-220598	8190	60	7447	7058	95.3
	Beta-243928	8390	50	7570	7342	95.4
	Beta-256039	8470	50	7593	7470	95.4
	Beta-256040	8440	60	7589	7356	95.3
	Beta-256041	8430	50	7584	7359	95.4
Kömürcü-*Kaletepe*				**8250**	**7680**	
	GifA-99090	8850	90	8250	7680	95.4
Parekklisha *Shillourokambos*				**8751**	**6829**	
	Ly-292	8125	70	7345	6829	95.4
	GifA-95032	8230	90	7485	7061	95.4
	GifA-95033	8340	100	7577	7090	95.4
	GifA-95034	8390	90	7588	7188	95.4
	Ly-928	8495	80	7676	7351	95.4
	Ly-291	8655	65	7938	7576	95.4
	Ly-930	8670	80	7964	7550	95.4
	Ly-1262	8670	80	7964	7550	95.4
	Ly-929	8700	70	7963	7585	95.4
	Ly-6	8725	100	8202	7585	95.4
	Ly-1261	8735	75	8181	7591	95.4
	Ly-289	8760	80	8201	7599	95.3
	Ly-5	8825	100	8236	7615	95.4
	Ly-931	8860	90	8257	7684	95.4
	Ly-574	8930	75	8283	7827	95.4
	Ly-573	9110	90	8611	8001	95.4
	Ly-572	9205	75	8611	8286	95.4
	Ly-290	9310	80	8751	8318	95.4
Sha’ar Hagolan				**6442**	**5673**	
	OxA-7884	6980	100	6029	5673	95.4
	OxA-7920	7245	50	6221	6022	95.4

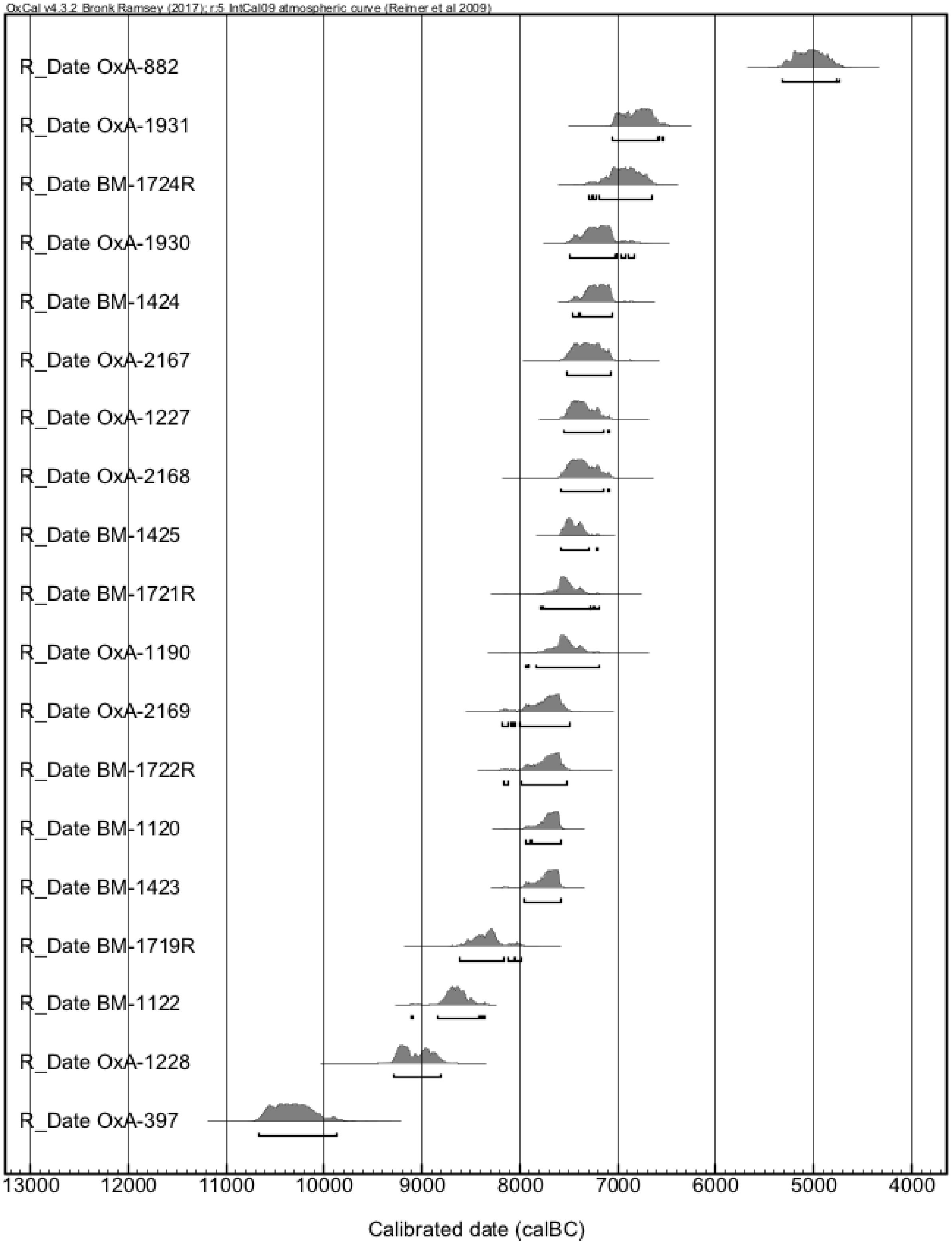
Table A.1 Radiocarbon Dates

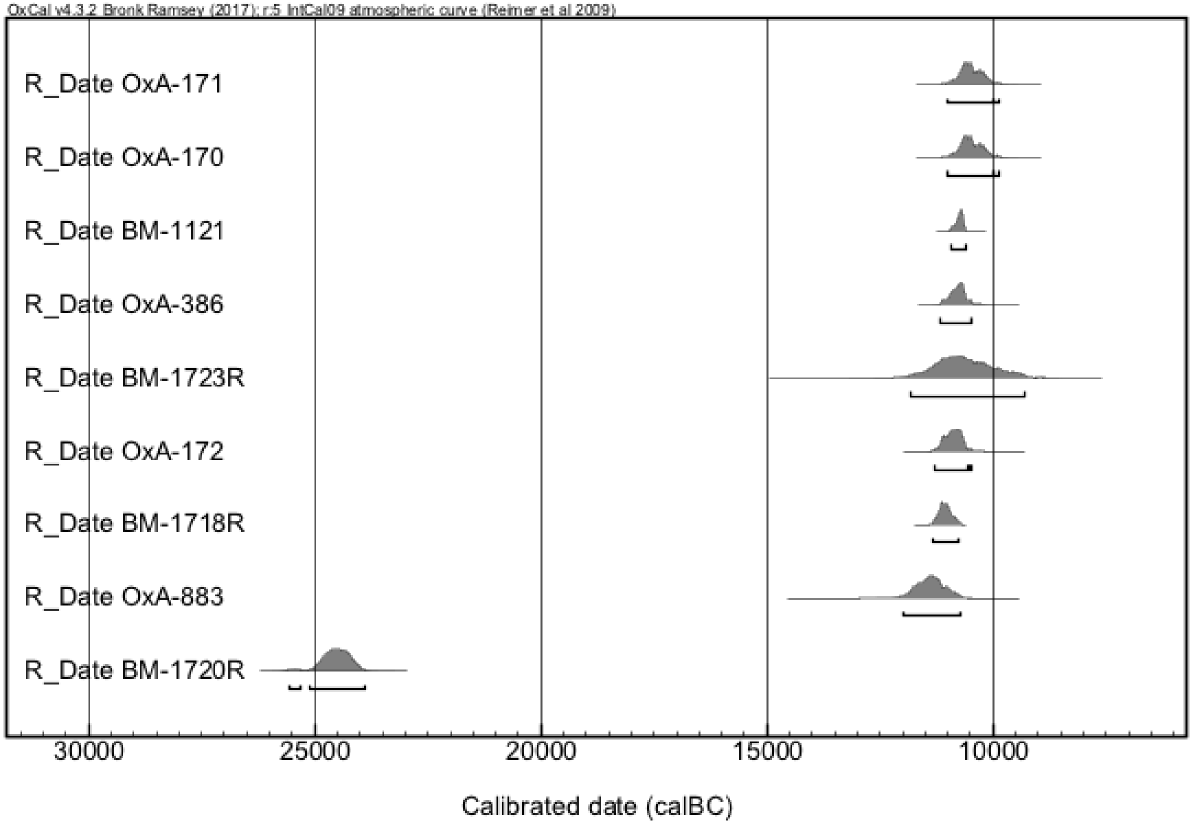
Site Name	Reference	Radiocarbon Date	Error	From (BC)	To (BC)	%
	OxA-7885	7270	80	6354	5995	95.3
	OxA-7917	7410	50	6416	6109	95.4
	OxA-7918	7465	50	6427	6238	95.4
	OxA-7919	7495	50	6442	6247	95.4

Abu Hureyra

Abu Hureyra is located on the southern bank of the Euphrates river in modern Syria. It spans the transition from a hunter-forager to farming economy (Moore et al. 2000). Based on calibration of the dates published by Böhner and Schyle (2006), site occupation occurred between 11,974 – 6534 cal BC. Two determinants (OxA-882 and BM-1720R) were excluded because, given their context (Natufian and PPNB, respectively), their dates were suspect.

Figure A.1 Abu Hureyra Radiocarbon Calibration

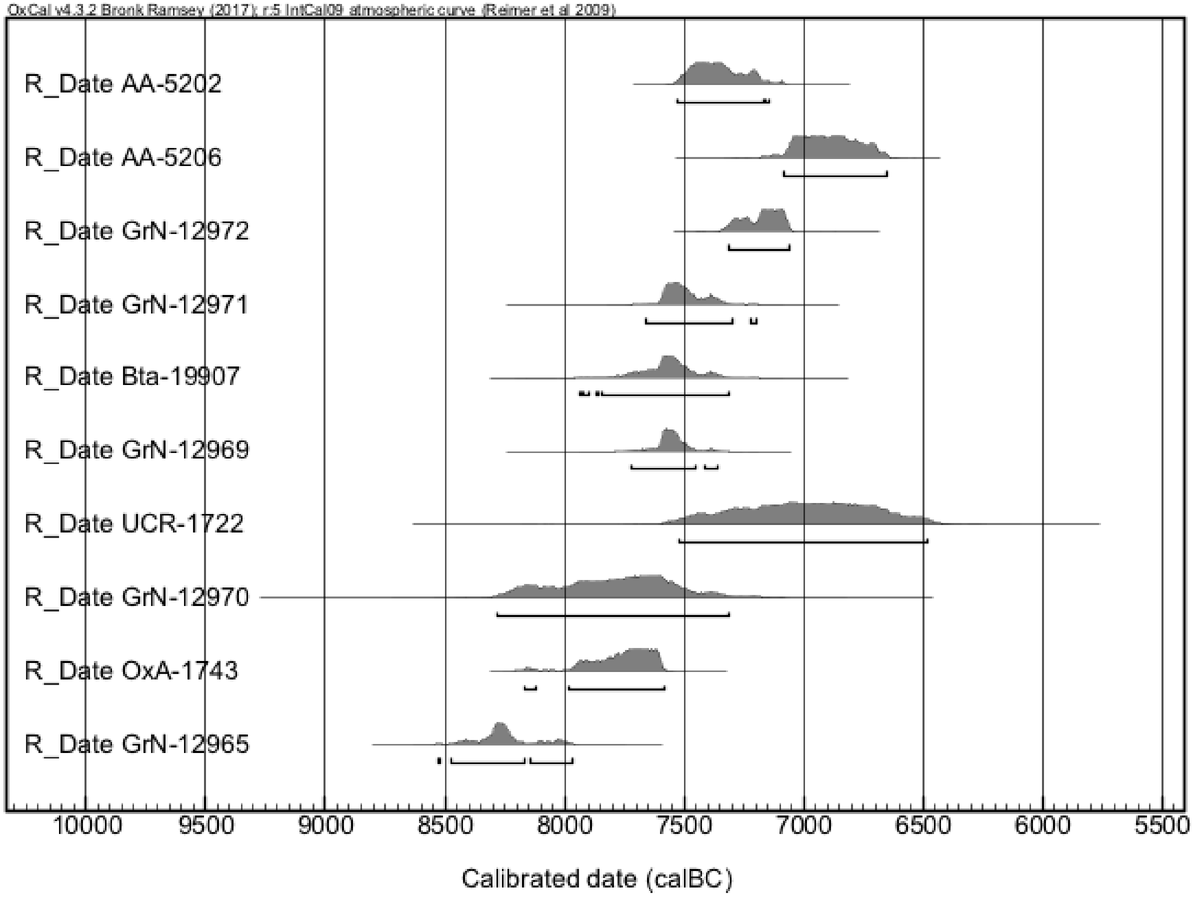




‘Ain Ghazal

‘Ain Ghazal is located on the northeast outskirts of modern Amman, Jordan, adjacent to the Wadi Zarqa, which likely would have been a permanent steam at the time of the site’s occupation (Rollefson et al. 1992; Simmons et al. 1988). The site was occupied successively from the middle Pre-Pottery Neolithic B through the Yarmoukian Pottery Neolithic. Based on calibration of the pre-Yarmoukian dates published by Rollefson et al. (1992), site occupation occurred between 8528 - 6651 cal BC.

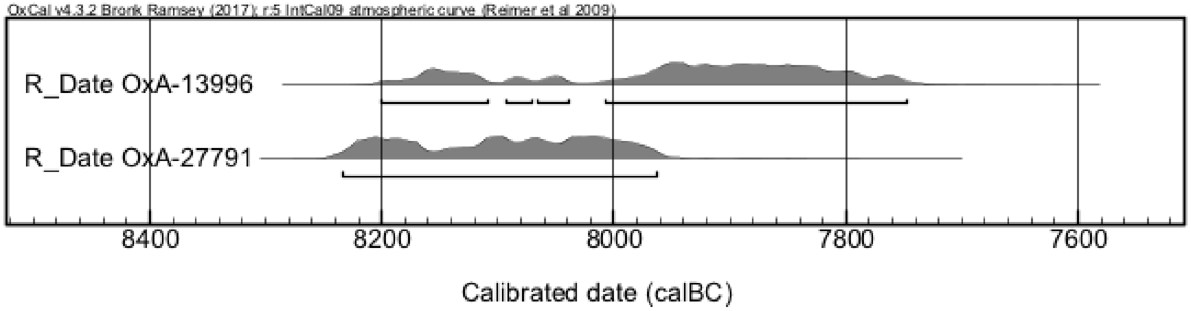
Figure A.2 'Ain Ghazal Radiocarbon Calibration



Akanthou Arkosykos/Tatlısu Çiftlikdüzü

Akanthou is a Cypro-PPNB site located on the north coast of Cyprus. Two radiocarbon dates have been published by Şevketoğlu and Hanson (2015), which produce a range of 8234 – 7748 cal BC.

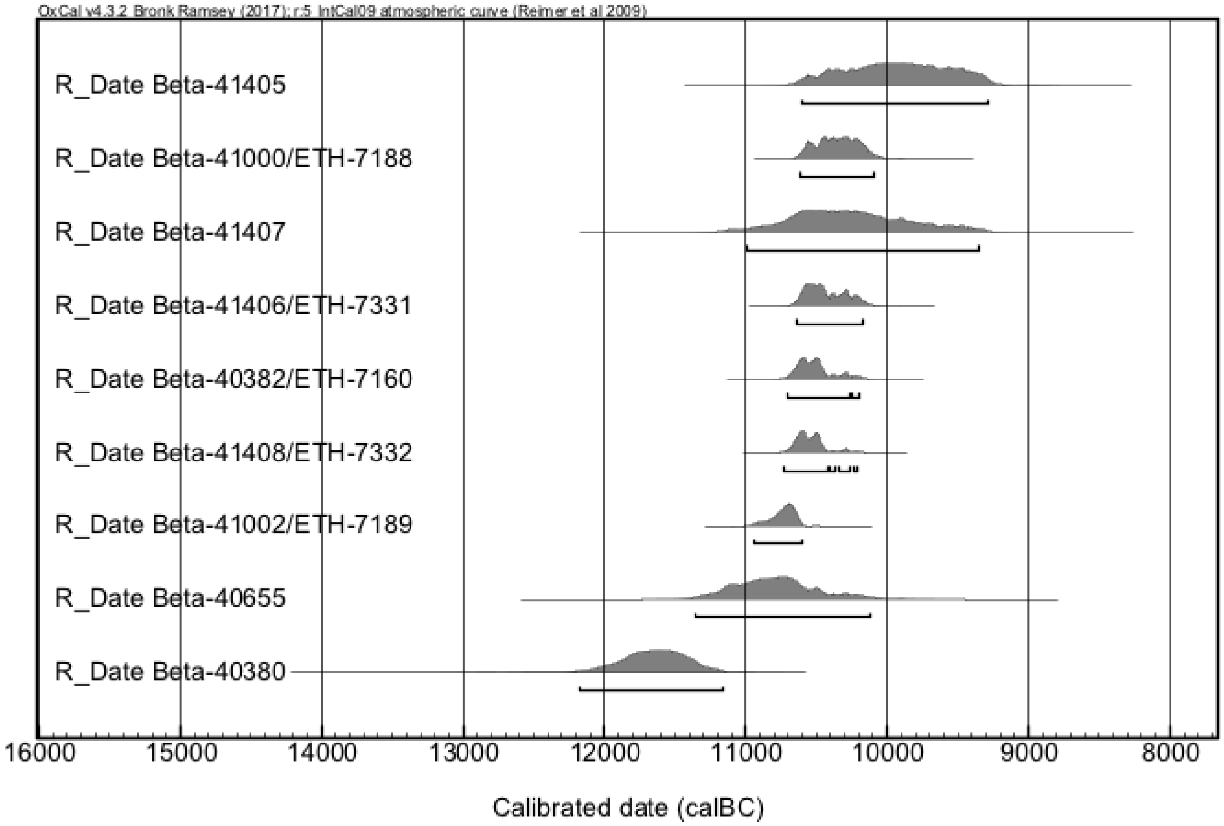
Figure A.3 Akanthou Arkosykos/Tatlısu Çiftlikdüzü Radiocarbon Calibration



Akrotiri *Aetokremnos*

Akrotiri is a collapsed rock shelter located on the southern coast of Cyprus (Akrotiri Peninsula), dating to the Late Epipaleolithic. Currently, it is the oldest archaeological site on the island. Based on only the charcoal dates presented by Simmons and Wigand (1994), the site was occupied between 12,181 – 9293 cal BC.

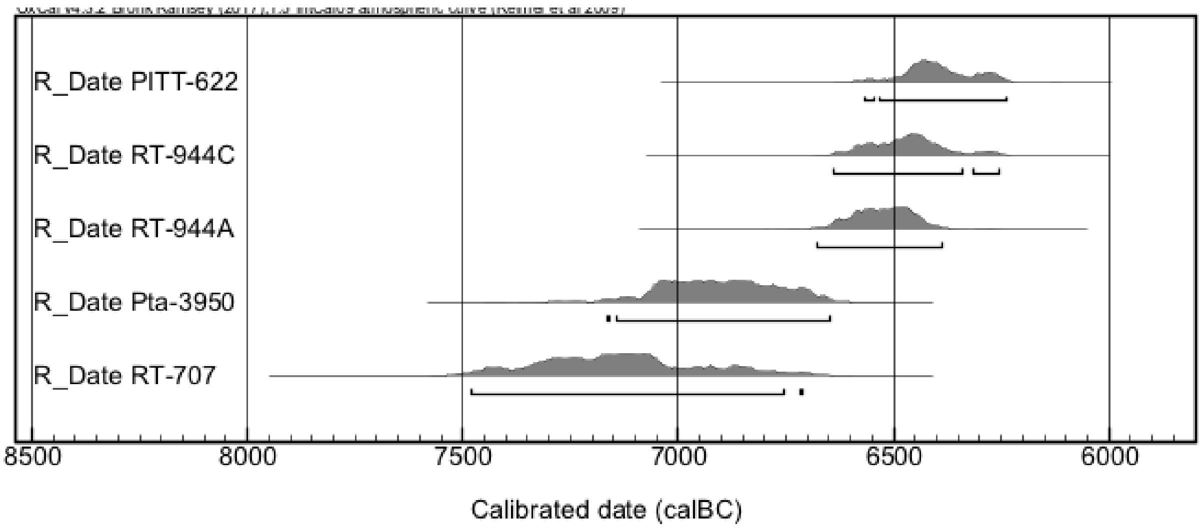
Figure A.4 Akrotiri Aetokremnos Radiocarbon Calibration



‘Atlit Yam

‘Atlit Yam is a now under-water Pre-Pottery Neolithic C site, situated off the coast of modern Haifa, Israel. The site dates between 7481 – 6256 cal BC, based on charcoal dates presented by Galili et al. (1993).

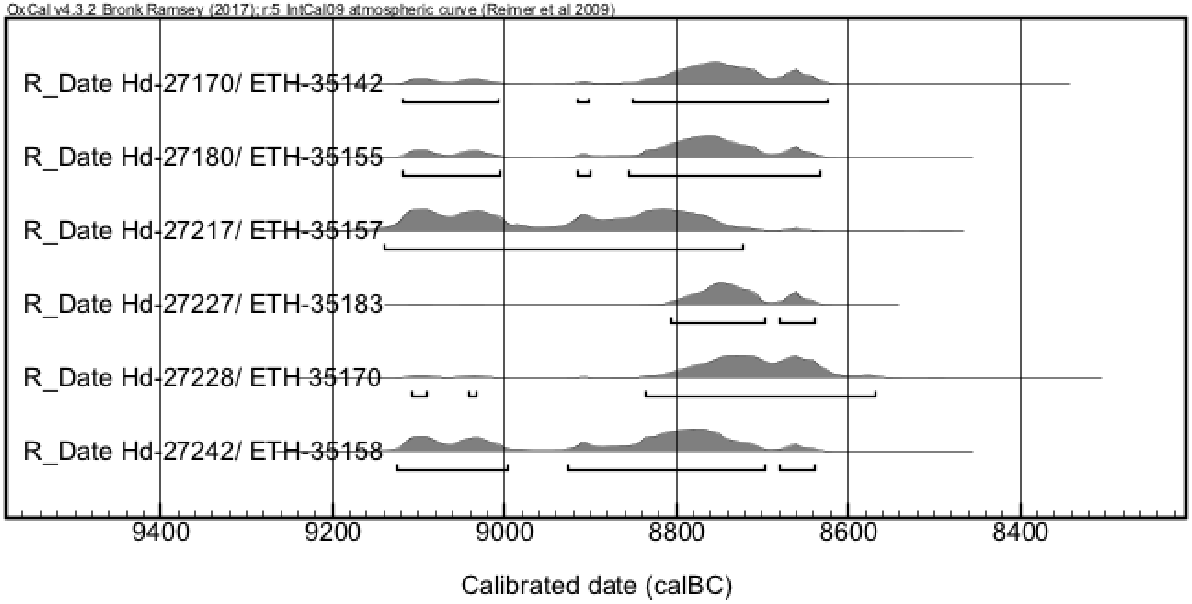
Figure A.5 ‘Atlit Yam Radiocarbon Calibration



Ayia Varvara *Asprokremnos*

Ayia Varvara *Asprokremnos* is a Cypro-PPNA site located in central. Based on the recalibration of dates presented in Manning et al. (2010), it was occupied between 9141 – 8569 cal BC.

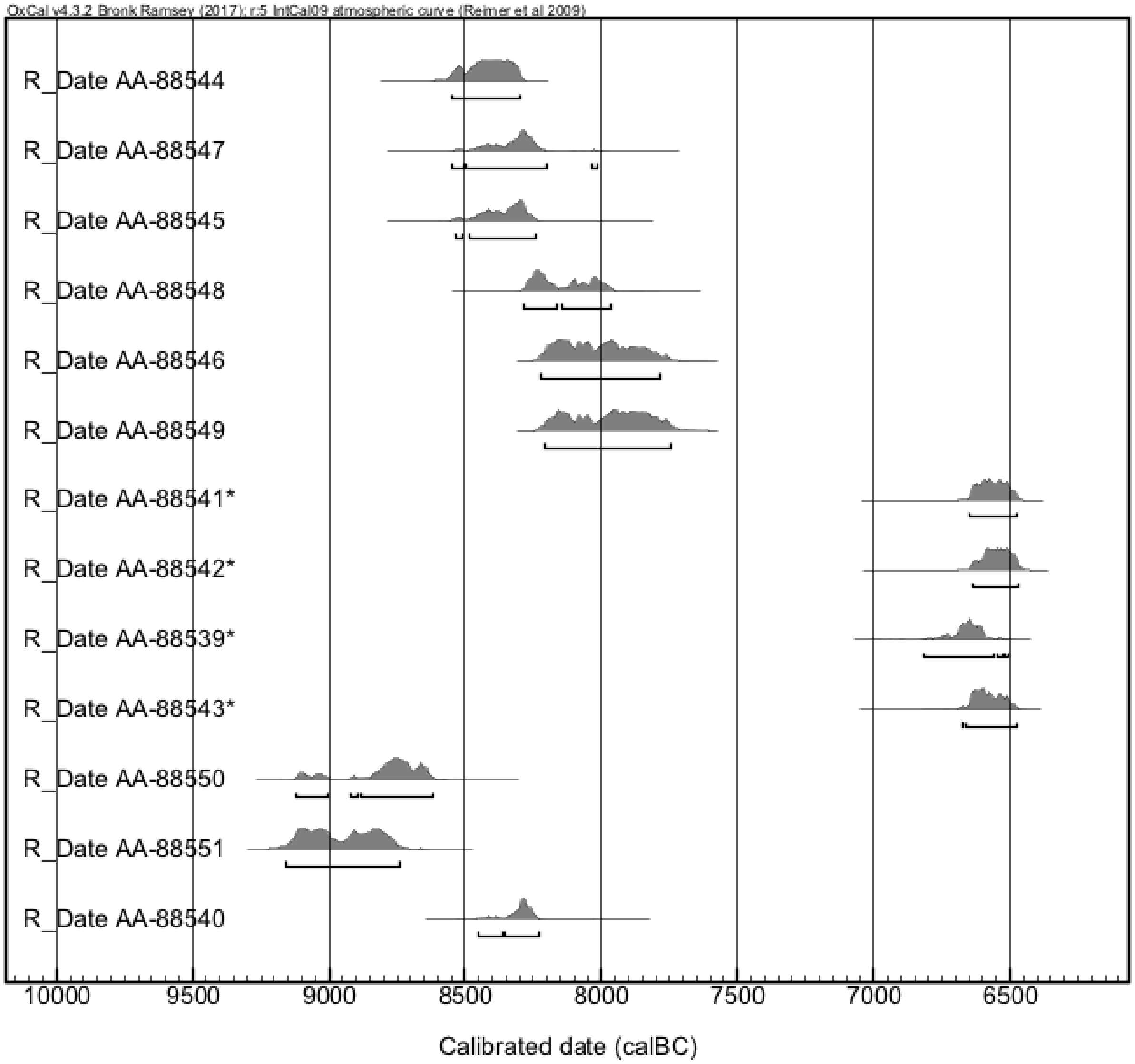
Figure A.6 Ayia Varvara Asprokremnos Radiocarbon Calibration



Ayios Tchonas *Klimonas*

Ayios Tchonas *Klimonas* is a Cypro-PPNA site, which is situated on the south-central coast. Thirteen dates were recalibrated from Vigne et al. (2011b). The majority of the samples were from burnt bone. Only one was on charcoal (AA88551). The four samples that yielded anomalously late dates were from teeth (AA-88541, AA-88542, AA-88539, AA-88543). Removing these samples, the nine samples recalibrate to 9156 – 7746 cal BC. Of note, Manning (2014), using the Bayesian processing method, suggested a shorter period of around 100 years for occupation (ca. 8800 cal BC).

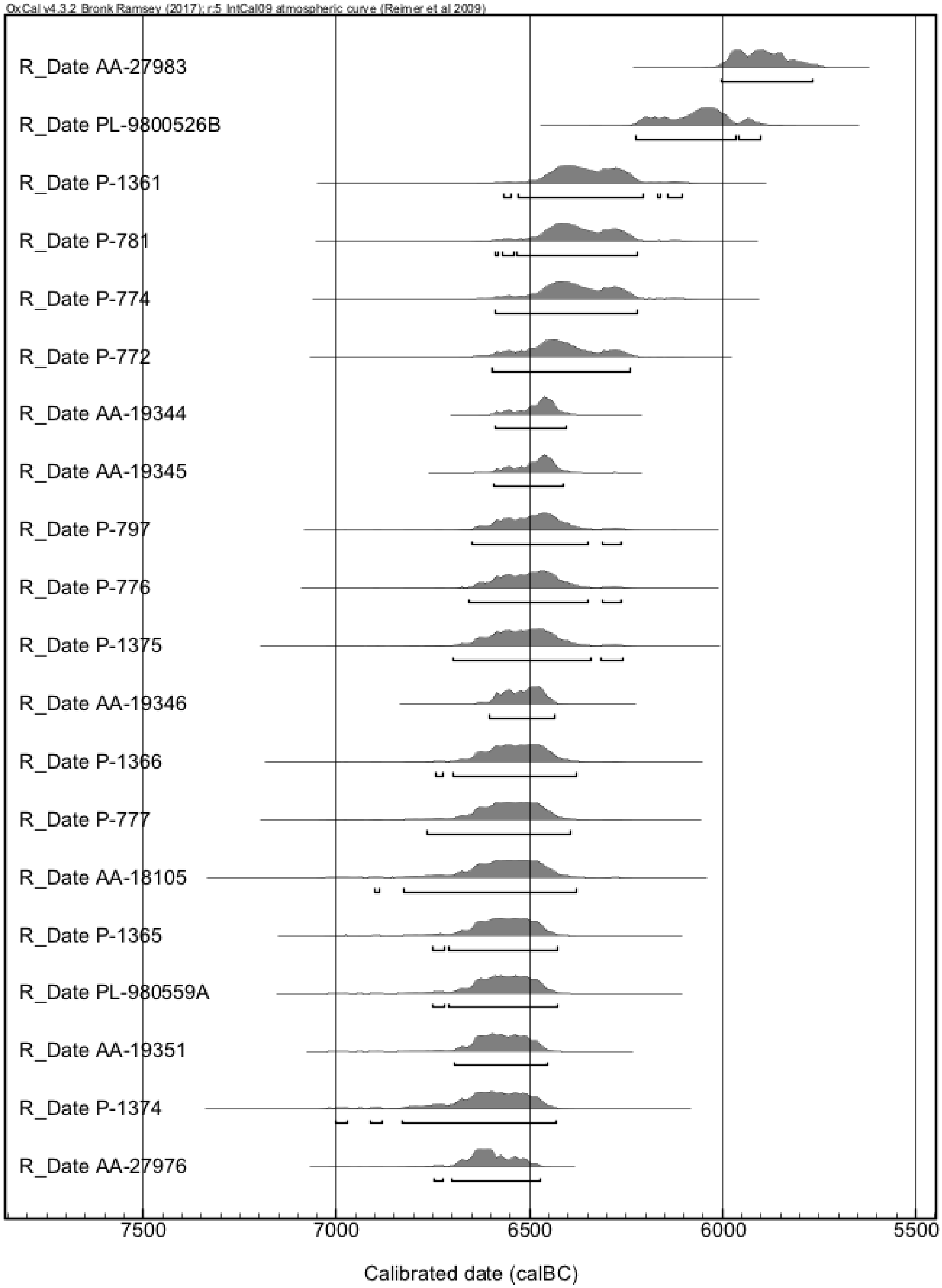
Figure A.7 Ayios Tchonas *Klimonas* Radiocarbon Calibration

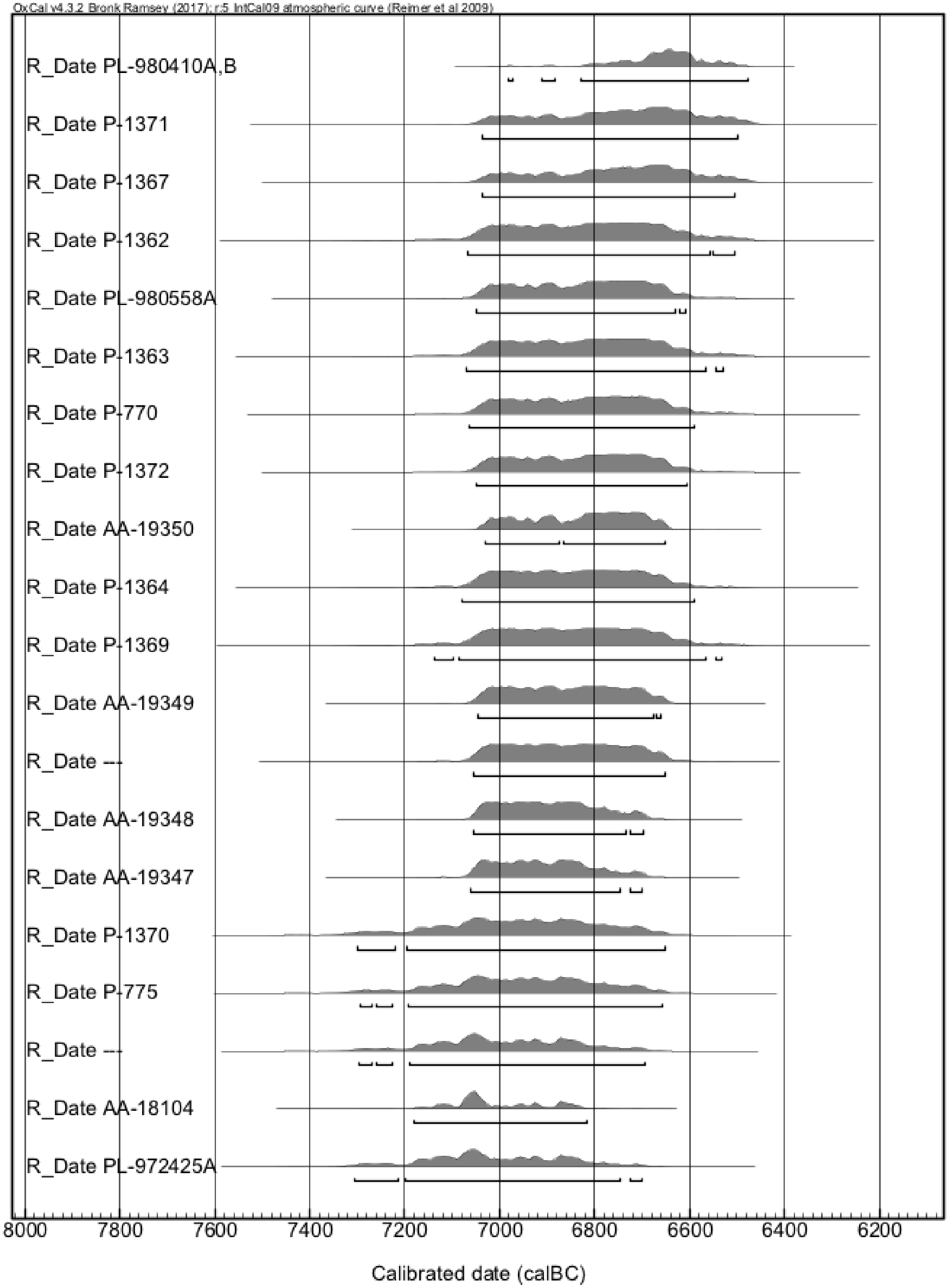


Catalhöyük

Catalhöyük is an early agricultural village located in central Anatolia and primarily dates to the Pottery Neolithic. The site has a remarkably dense settlement: it has been estimated that between 3500 to 8000 people lived in 13.5 ha space. People initially lived on the Neolithic East mound for roughly 1400 years before moving to the other side of the Çarsamba Çay river to the West mound during the early Chalcolithic (Hodder 2007). Based on only the charcoal and charred seeds dates presented by Böhner and Schyle (2006), the site's East and West mounds were occupied between 7588 – 5768 cal BC and 6007 – 5674 cal BC, respectively.

Figure A.8 Catalhöyük East Mound Radiocarbon Calibration




OxCal v4.3.2 Bronk Ramsey (2017); r:5 IntCal09 atmospheric curve (Reimer et al 2009)
R_Date PL-980410A,B
R_Date P-1371
R_Date P-1367
R_Date P-1362
R_Date PL-980558A
R_Date P-1363
R_Date P-770
R_Date P-1372
R_Date AA-19350
R_Date P-1364
R_Date P-1369
R_Date AA-19349
R_Date ---
R_Date AA-19348
R_Date AA-19347
R_Date P-1370
R_Date P-775
R_Date ---
R_Date AA-18104
R_Date PL-972425A
8000
7800
7600
7400
7200
7000
6800
6600
6400
6200
Calibrated date (calBC)

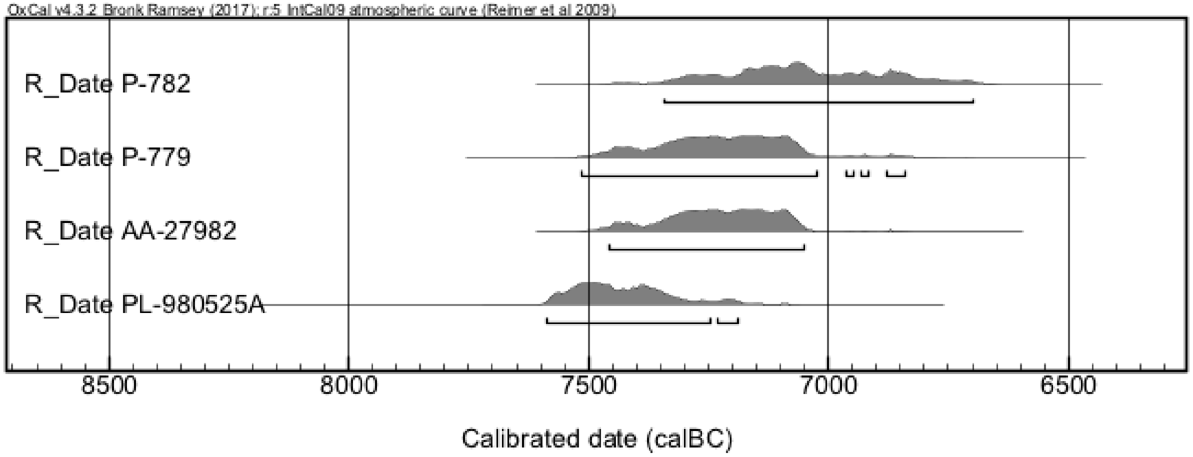
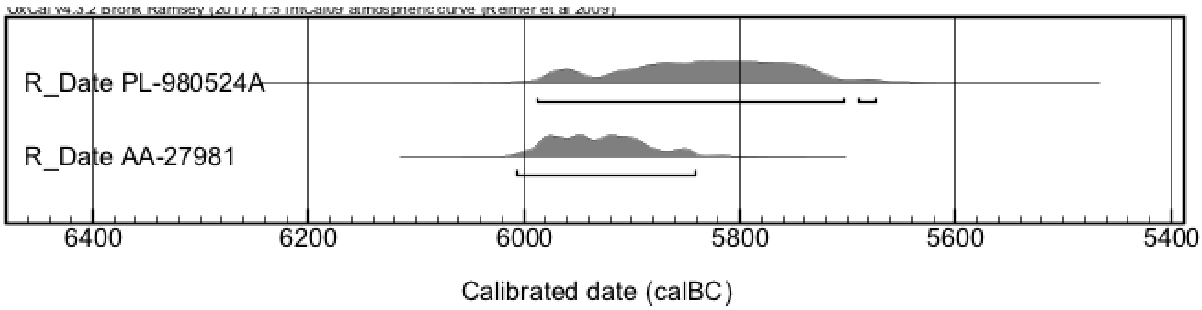


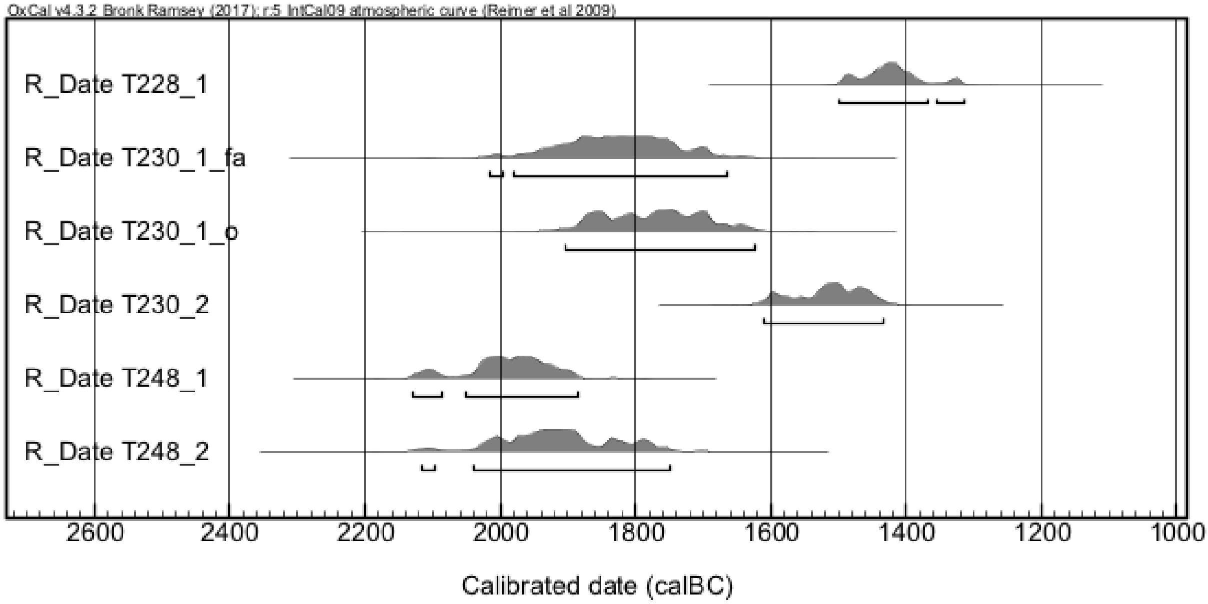
Figure A.9 Catalhöyük West Mound Radiocarbon Calibration



Erimi *Laonin tou Porakou*

Erimi *Laonin tou Porakou* is a Bronze Age settlement located on the southern coast of Cyprus in the Limassol District. The radiocarbon samples were published by Scirè Calabrisotto et al. (2013). All samples were from human bone collected from 3 tombs. I only present the dates that had reliable C/N ratios and yielded dates within the expected time frame. Based on these samples, the site dates between 2131 – 1316 cal BC.

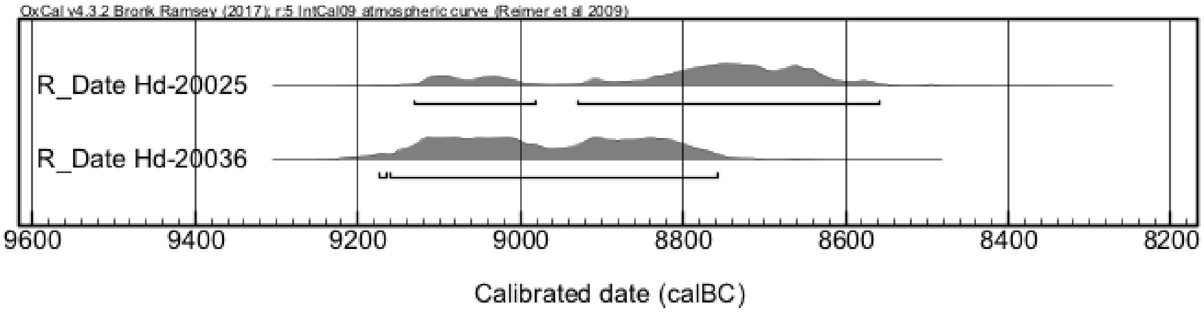
Figure A.10 Erimi *Laonin tou Porakou* Radiocarbon Calibration



Göbekli Tepe

The mound of Göbekli Tepe is located northeast of the modern-day town of Şanlıurfa in Upper Mesopotamia (southeastern Turkey). It is best known for its megalithic architecture and large-scale stone sculptures. Four dates for the site were collected from various sources by Böhner and Schyle (2006), but I also recalibrated the ones from charcoal. Based on a recalibration of these, the site ranges from 9175 – 8559 cal BC.

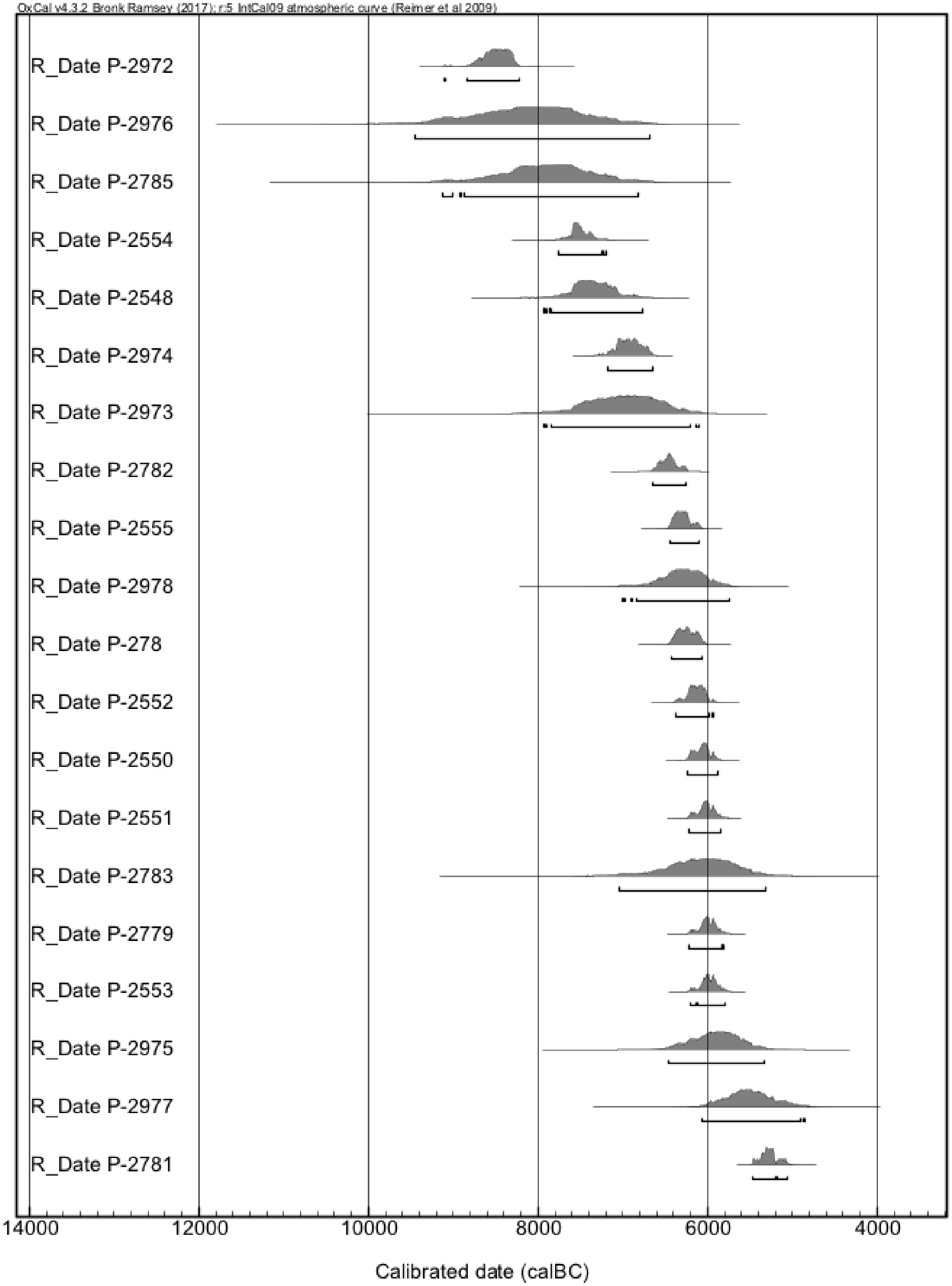
Figure A.11 Göbekli Tepe Radiocarbon Calibration

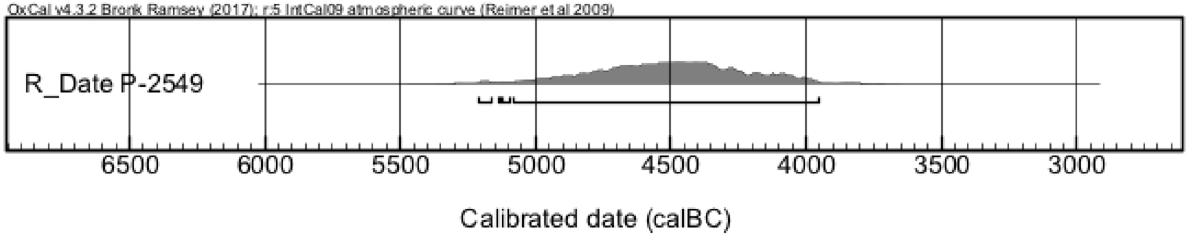


Kalavasos *Tenta*

The site of Kalavasos *Tenta* dates from the Cypro-PPNB to KC period. Most of the early dates have large error ranges, which make it difficult to comment on the length of site occupation. P-2976, in particular, has a large error range and was not included in the discussion. Based on the radiocarbon dates, all of which were on charcoal, presented in Knapp (2013) and Manning (2013), the site dates between 9120 – 4851 cal BC, with the majority clustering around 6000 cal BC.

Figure A.12 Kalavasos *Tenta* Radiocarbon Calibration

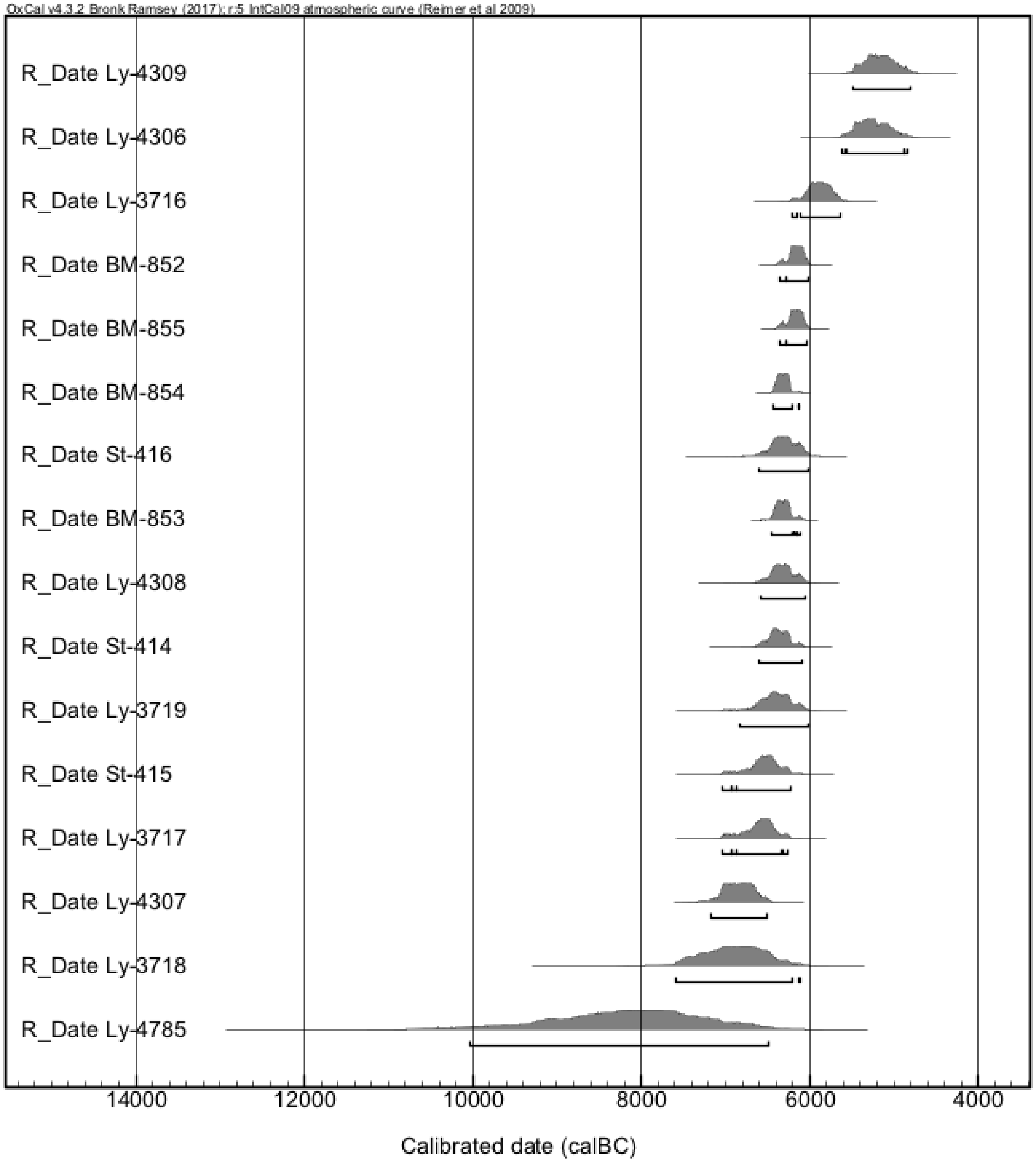




Khirokitia *Vouni*

Khirokitia *Vouni* dates to the Late Aceramic Neolithic or Khirokitia Culture (KC) on Cyprus and the site is one of two that has been full excavated for this time period. In fact, it is the type site for the KC period. I did not include two determinants (LY-3718 and LY-4785) because their error ranges were large. Based on the radiocarbon dates presented in Knapp (2013) and Manning (2013:Sub-Appendix I), site occupation ranges from 7175 – 4795 cal BC.

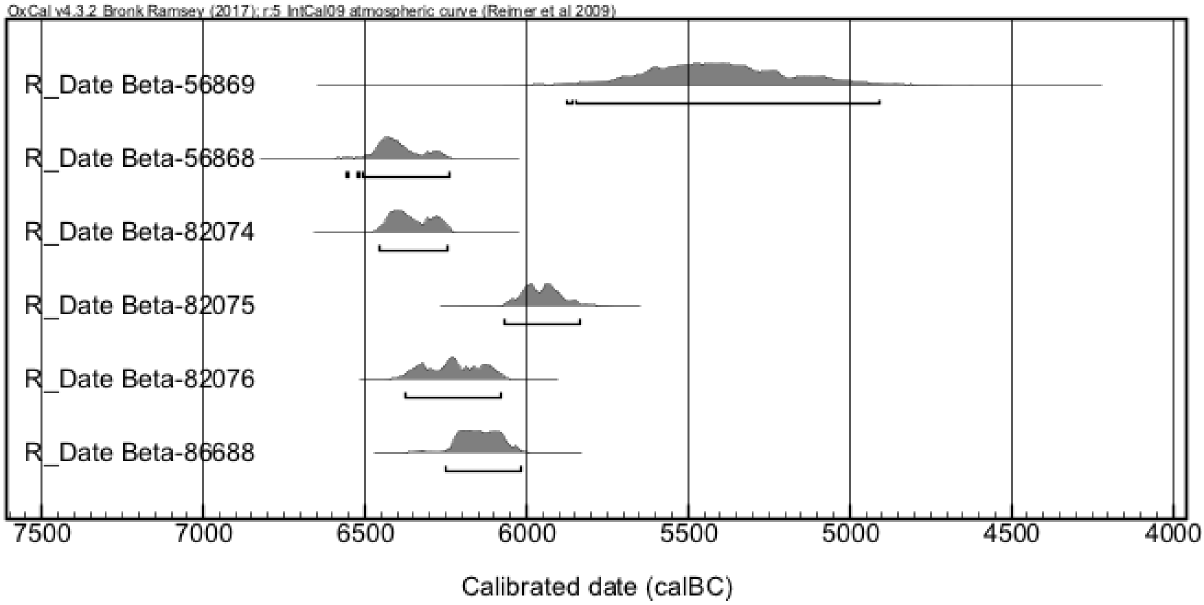
Figure A.13 Khirokitia Vouni Radiocarbon Calibration



Kholetria *Ortos*

Kholetria *Ortos* is a KC period site on Cyprus located approximately 20 km east of Paphos on a hill above the Xeros river. Simmons (1994) published two radiocarbon determinants, both of which were on bone: Beta-56869 and Beta-56868. The rest of the dates were published by Cooper (1997). I also consulted Levi (2018:Appendix I) because he consulted the original returns from Beta Analytics as well. Excepting one determinant because the range was large (Beta-56869), the dates ranges from 6560 – 5838 cal BC.

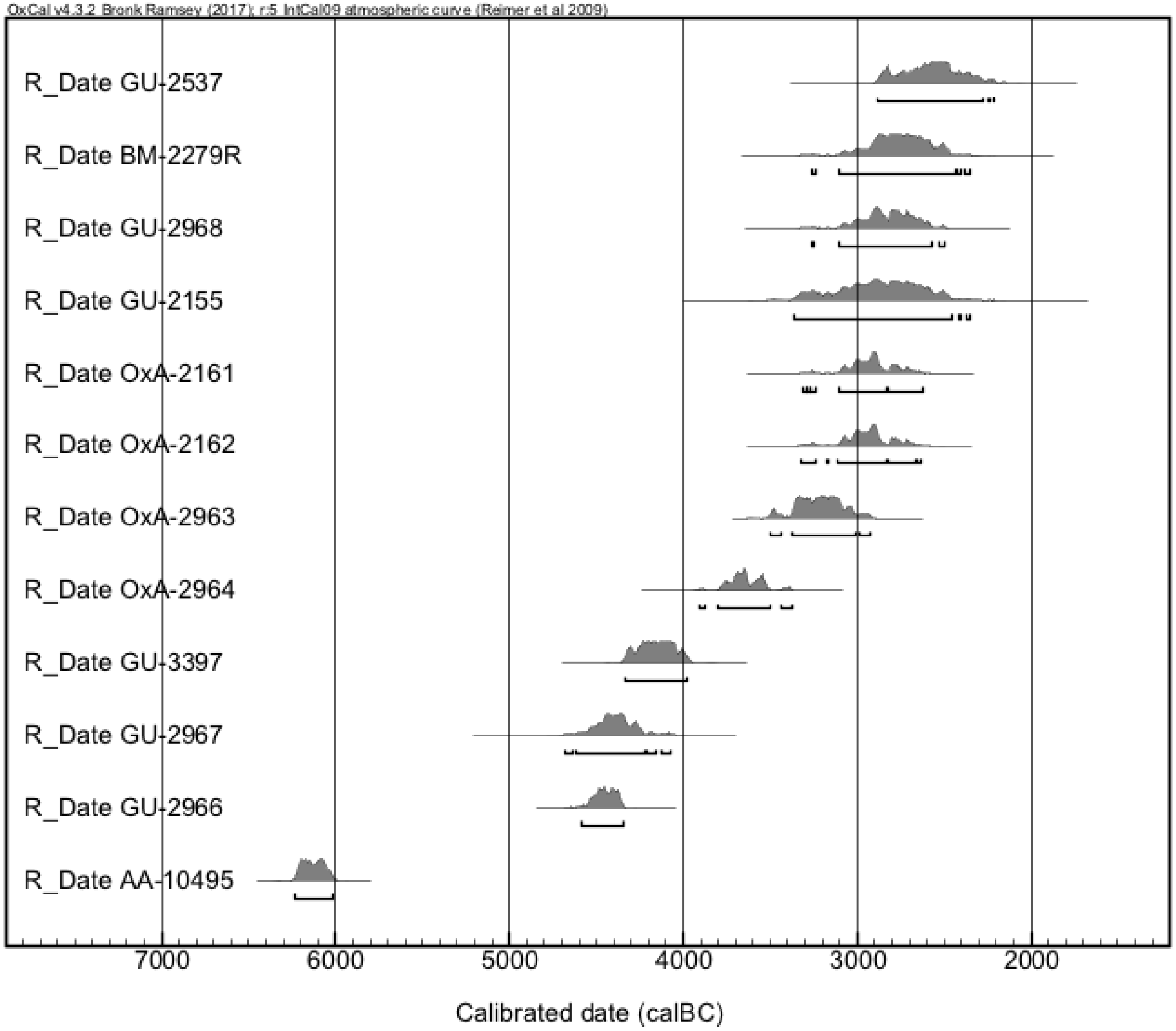
Figure A.14 Kholetria Ortos Radiocarbon Calibration



Kissonerga *Mosphilia*

Kissonerga *Mosphilia* is primarily a Chalcolithic site located north of the Skotinis River, about 1 km from the southwestern coast of Cyprus. Based on the radiocarbon dates, all of which were on charcoal or seed, collected from various sources by Böhner and Schyle (2006) and published in Knapp (2013) and Manning (2013:Sub-Appenidx I), the site dates between 4681 – 2215 cal BC. There is also perhaps an Aceramic Neolithic component, as noted by Knapp (2013) and Manning (2013:Sub-Appendix I), based on the radiocarbon determinant (AA-10495): 6231-6016 cal BC.

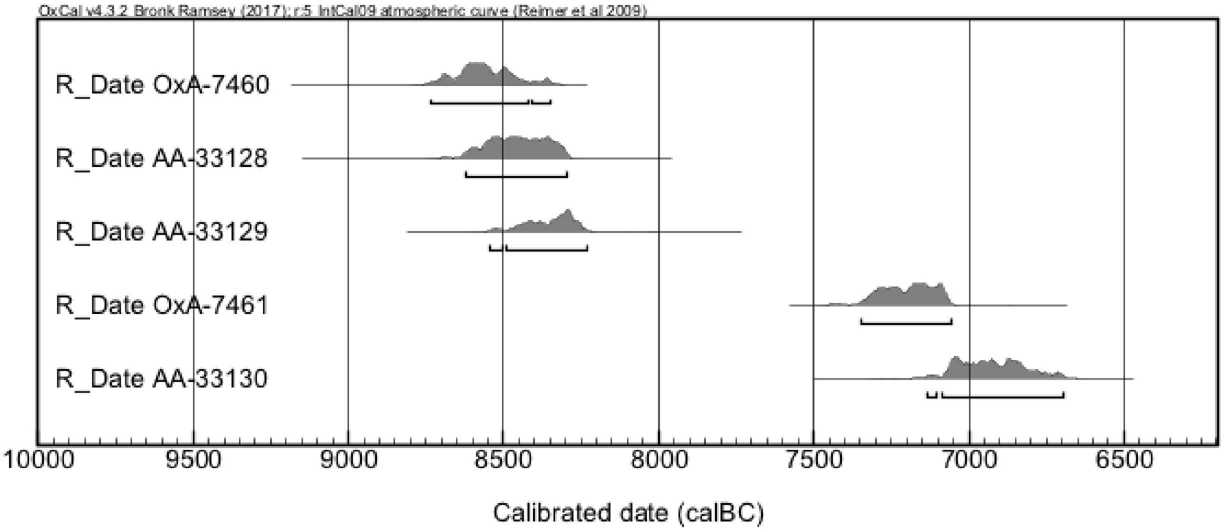
Figure A.15 Kissonerga Mosphilia Radiocarbon Calibration



Kissonerga *Mylouthkia*

Kissonerga *Mylouthkia* is a Cypro-PPNB site located around 100 m from the current coastline, north of Paphos, at the northern end of the Ktimi Lowlands. The occupation dates range from 8735 – 6696 cal BC, based on the recalibration of dates presented in Peltenburg 2003:83, Table II.I. Dates from shell were not included in the recalibration. Mylouthkia dates were collected from 2 separate well contexts: Period 1 A, the earlier context, comes from Well-116; and Period 1B comes from Well 133.

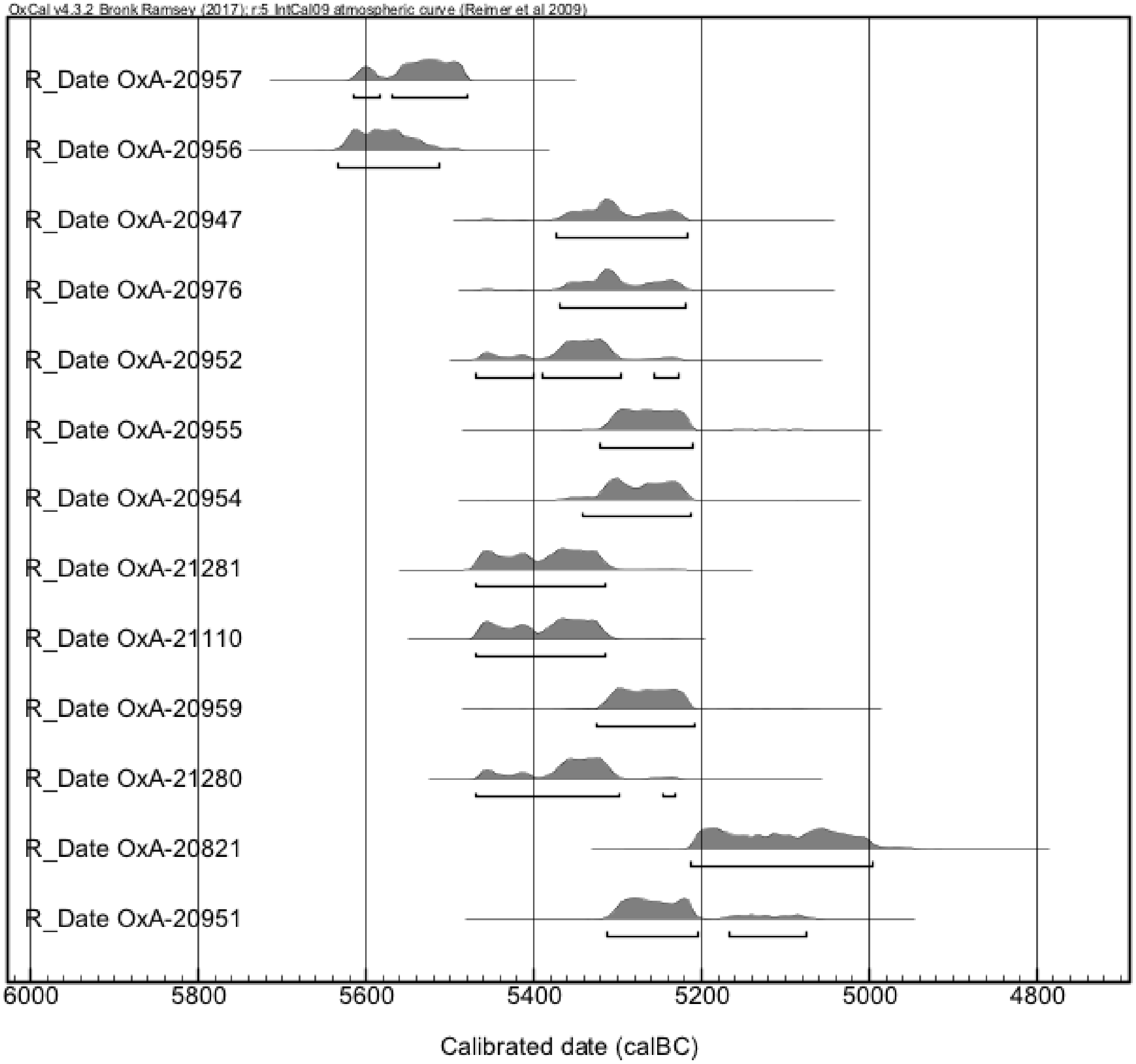
Figure A.16 Kissonerga Mylouthkia Radiocarbon Calibration



Kouphovouno

Kouphovouno is a middle-late Neolithic village situated in mainland southern Greece, around 2.5 km southwest of Sparta on the Peloponnesian Peninsula. Radiocarbon dates for this site were published in Mee et al. (2014:Fig 10). Based on recalibration of these dates, the site was occupied between 5634 – 4997 cal BC.

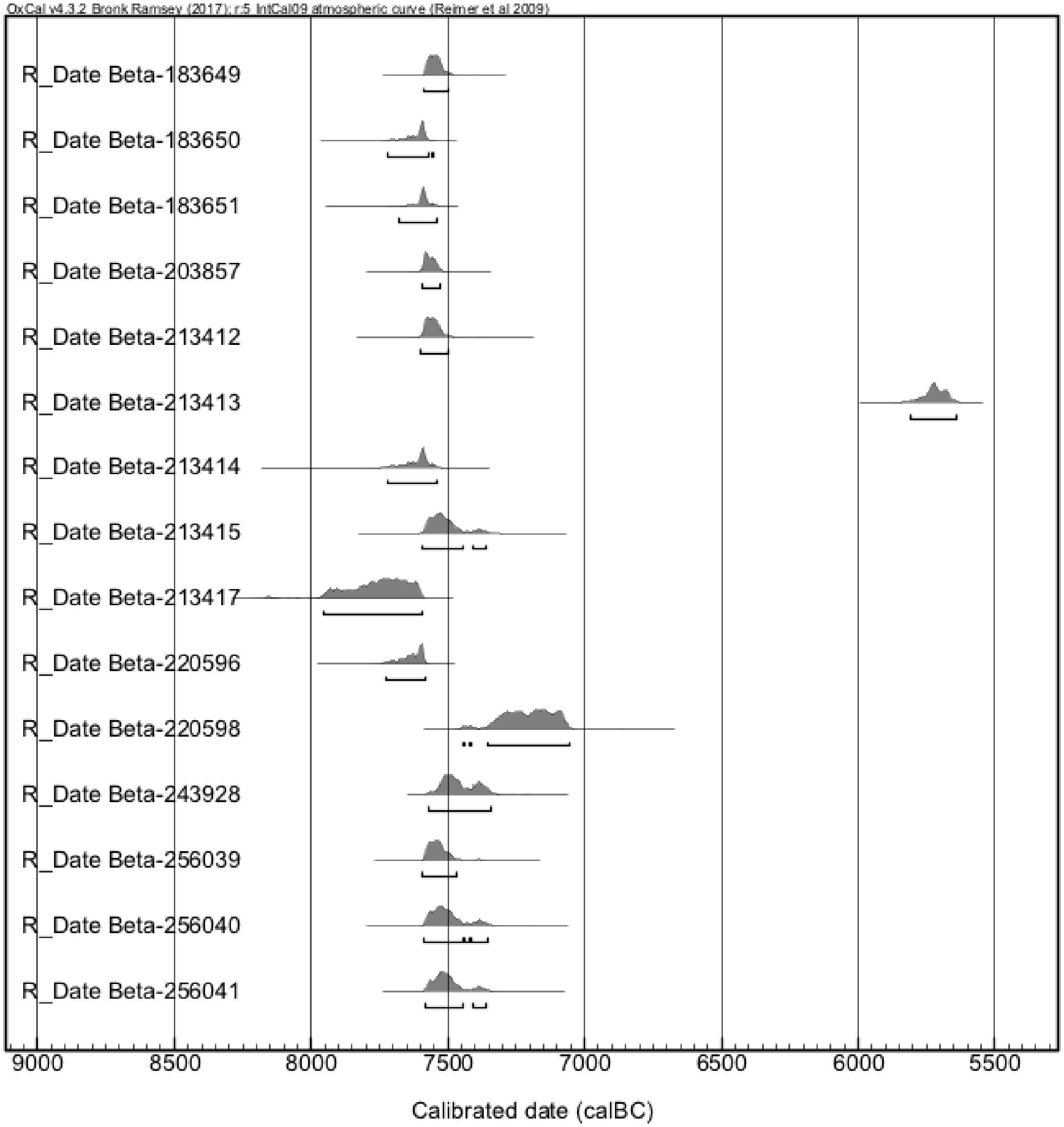
Figure A.17 Kouphovouno Radiocarbon Calibration



Kritou Marottou *Ais Giorkis*

Ais Giorkis is a Cypro-PPNB site located 480 m above sea level on an east-southeast facing slope of the upper Ezousa River Valley in the Paphos region. It is the primary site focused on in this dissertation. Radiocarbon dates were from Simmons (2012), although I chose to only recalibrate those derived from charcoal. Based on these dates, excluding Beta-213413 which provided an anomalously late date, site occupation ranged from 7956 – 7058 cal BC. This range corresponds to the middle and late Cypro-PPNB.

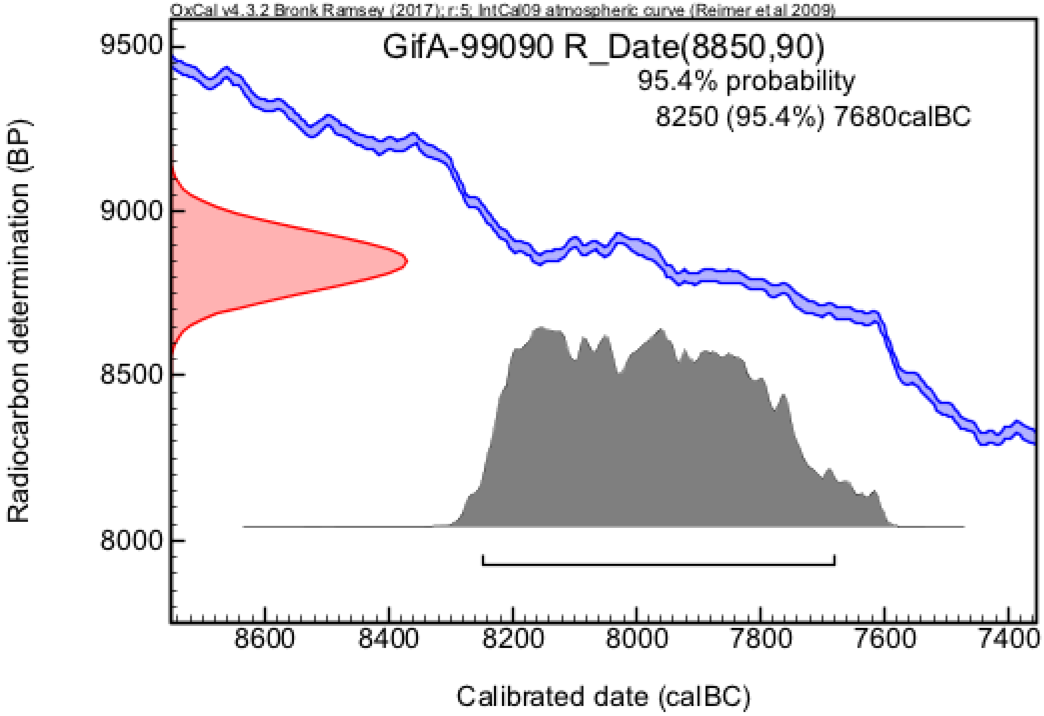
Figure A.18 Kritou Marottou *Ais Giorkis* Radiocarbon Calibration



Kömürcü-*Kaletepe*

Kömürcü-*Kaletepe* is situated on the northern slope of the Göllüdağ in Cappadocia, Turkey. It was one of the primary sources for obsidian in the Near East during the PPNB, including on Cyprus. Radiocarbon dates are presented in Balkan and Binder (2000), although only one date pertains to the time period under investigation in this study (GifA-99090). Recalibrated the date is between 8250 – 7680 cal BC.

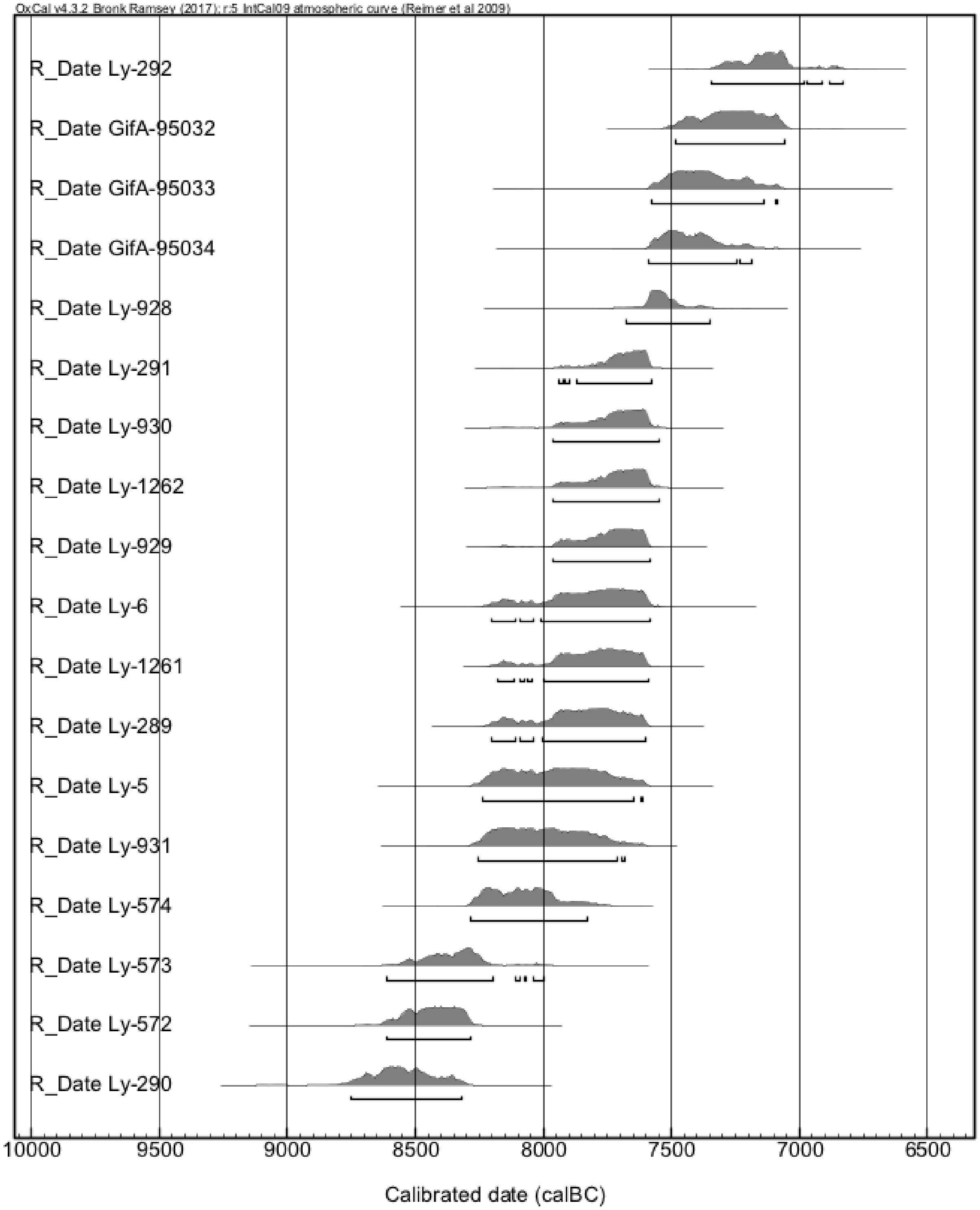
Figure A.19 Kömürcü-*Kaletepe* Radiocarbon Calibration



Parekklisha *Shillourokambos*

Parekklisha *Shillourokambos* is a Cypro-PPNB site located on the coastal plain northeast of Limassol. It has been assigned four chronological phases, all of which fall within the Cypro-PPNB, based on over 50 radiocarbon dates: Early A, Early B, Middle, and Late. It is, in fact, one of the earliest of the securely-dated Cypro-PPNB sites. Dates are published by Guilaine 2003b, although I collected them from Böhner and Schyle (2006). Based on the recalibration, site occupation ranges 8751 and 6829 cal BC.

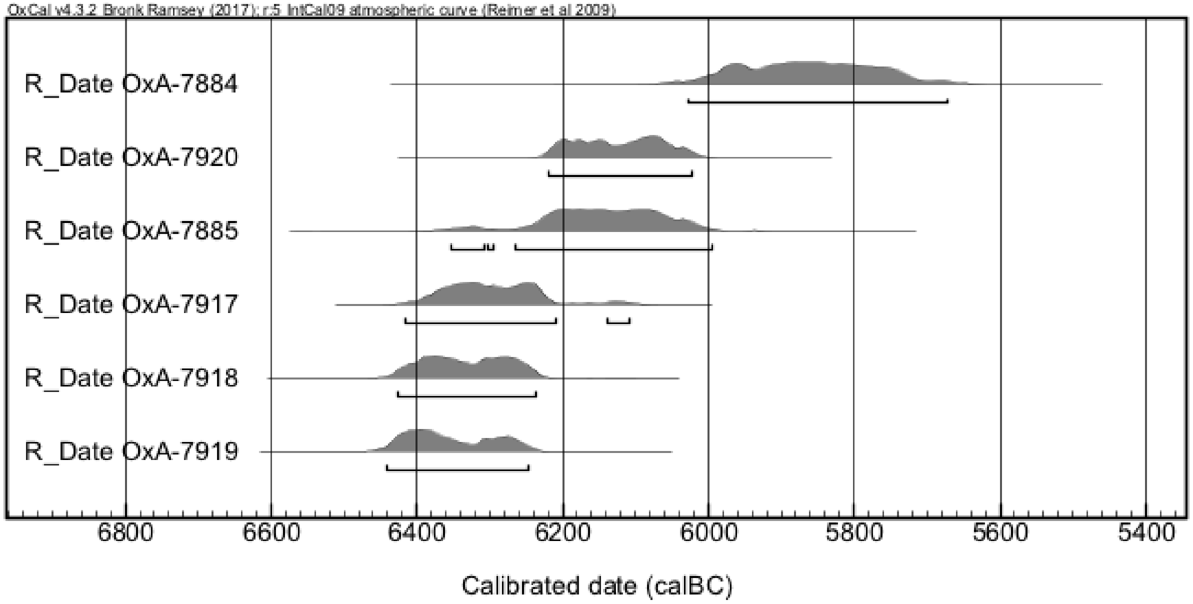
Figure A.20 Parekklisha Shillourokambos Radiocarbon Calibration



Sha’ar Hagolan

Sha’ar Hagolan is a Pottery Neolithic site of the Yarmukian Culture. It is located on the bank of the Yarmuk River in the Jordan Valley (Israel). Dates are published in Garfinkel 1999, but I accessed them via Böhner and Schyle (2006). The dates ranged between 6442 – 5673 cal BC.

Figure A.21 Sha’ar Hagolan Radiocarbon Calibration



APPENDIX B: PREPARATION AND LABORATORY METHODOLOGY FOR BASELINE SAMPLES

Preparation

The snail shells were boiled in distilled water to clean them and the shell was finely ground using an agate mortar and pestle. The ground shell was then put into capsules. This part of the process took place on Cyprus.

Laboratory Methodology

Samples were rinsed with weak acetic acid six times and decanted each time. Next, samples were rinsed in deionized water. They were then dissolved in 1ml of 3N HNO_3. This process was done by the Cornell Isotope Laboratory (COIL). Data are the result of analyses performed at COIL on a Thermo Delta V isotope ratio mass spectrometer (IRMS) interfaced to a NC2500 elemental analyzer. To ensure the accuracy and precision of the instrument in-house standard is analyzed after every 10 samples. For this analytical sample run, the overall standard deviation for the internal Deer standard (animal tissue) was 0.08‰ for $\delta^{15}N$ and 0.04‰ for $\delta^{13}C$. They also quantify the ability of the instrument to measure samples across a gradient of amplitude intensities using a chemical Methionine standard. Based on the results of these samples, delta values obtained between the amplitudes of 140mV and 14000mV for $\delta^{15}N$ have an error associated with linearity of 0.12‰ and between 140mV and 10000mV for $\delta^{13}C$ error is 0.39‰. Isotope corrections are performed using a two-point normalization (linear regression for all $\delta^{15}N$ and $\delta^{13}C$ data using two additional in-house standards (KCRN and CBT) (personal communication Kim Sparks, Facility Manager of COIL, 12-21-16).

APPENDIX C: SAMPLE CONTEXT INFORMATION

The tables below provide additional archaeological context information for all samples in this study.

Table C.1 Archaeological Context for Botanical Samples

Lab Sample Number	SFN Number	Unit	Level	Feature	Year	Species	Weight
PL-1	SFN 65	20N 45W SEQ			2006	Lentil	0.013g
PL-2	SFN 32	20N 40W SWQ	7	4	2005	Barley	0.012g
							0.015g
							0.012g
							0.013g
PL-3	SFN 83	20N 50W SEQ	3	21	2006	Einkorn	0.016g
							0.020g
							0.013g
							0.012g
							0.019g
PL-4	SFN 79	20N 45W SEQ	10	4	2006	Lentil	0.007g
PL-5	SFN32	20N 40W SEQ	7		2005	Barley	0.019g
							0.017g
							0.012
PL-6	SFN 43	20N 40W SWQ	6		2005	Einkorn	0.014
							0.014
							0.006
							0.009
							0.007
PL-7	SFN 83	20N 30W SEQ	3	21	2006	Lentil	0.013
PL-8	SFN 37	20N 40W	3	4	2005	Barley	0.024

Table C.2 Archaeological Context for Animal Collagen Samples

Lab ID	Identification Number	Species	FN	Area/Context	Quad	Level	Feature	Element	Portion
Lab ID 1	11-Dama	*Dama dama mesopotamica*	1987	15n20w		3		tibia R	d
Lab ID 2	13-Dama	*Dama dama mesopotamica*	1987	15n20w		3		tibia R	d
Lab ID 3	15-Dama	*Dama dama mesopotamica*	2316	15n25w	SWQ SW part	7		tibia R	d
Lab ID 4	19-Dama	*Dama dama mesopotamica*	2351	15n30w	SEQ	3		tibia R	d
Lab ID 5	23-Dama	*Dama dama mesopotamica*	2397	15n30w	SEQ	4		tibia R	d
Lab ID 6	29-Dama	*Dama dama mesopotamica*	1140	20n45w	NE/NWQ	1	9	tibia R	d
Lab ID 7	2-Dama	*Dama dama mesopotamica*	2064	5n30w	NEQWside	8		tibia R	d
Lab ID 8	32-Dama	*Dama dama mesopotamica*	1140	20n45w	NE/NWQ	1	9	tibia R	d
Lab ID 9	40-Dama	*Dama dama mesopotamica*	2696	30n40w	NWQ W1/2 S part	5	50	tibia R	d
Lab ID 10	42-Dama	*Dama dama mesopotamica*	2673	30n40w	SWQ	3	28	tibia R	d
Lab ID 11	44-Dama	*Dama dama mesopotamica*	2024	30n45w	SWQ	1	39	tibia R	d
Lab ID 12	47-Dama	*Dama dama mesopotamica*	2300	30n45w	NWQ/50wNEQ	2	39	tibia R	d
Lab ID 13	5-Dama	*Dama dama mesopotamica*	1760	5n30w	eastern 1.65m	3		tibia R	d
Lab ID 14	48-Dama	*Dama dama mesopotamica*	2047	30n45w	NWQ/50WNEQ	2	39	radius R	d
Lab ID 15	50-Dama	*Dama dama mesopotamica*	2125	30n45w	SEQ	2	28	radius R	d
Lab ID 49	3-Dama	*Dama dama mesopotamica*	2064	5n30w	NEQWside	8		humerus R	d
Lab ID 50	4-Dama	*Dama dama mesopotamica*	2064	5n30w	NEQWside	8		humerus R	d
AY0084	9-Dama	*Dama dama mesopotamica*	2560	10n30w	NEQ	2		tibia L	d
AY0085	7-Dama	*Dama dama mesopotamica*	2299	10n30w	Npart	1	46	tibia L	d
AY0086	10-Dama	*Dama dama mesopotamica*	1987	15n20w		3		tibia L	d
AY0087	14-Dama	*Dama dama mesopotamica*	2316	15n25w	SWQ Swpart	7		tibia L	d
AY0088	16-Dama	*Dama dama mesopotamica*	2216	15n25w	NWQ	7		tibia L	d
AY0089	18-Dama	*Dama dama mesopotamica*	2216	15n25w	NWQ	7		tibia L	d
AY0090	20-Dama	*Dama dama mesopotamica*	2418	15n30w	SEQ	1	47	radius R	d
AY0091	31-Dama	*Dama dama mesopotamica*	1140	20n45w	NE/NWQ	1	9	tibia L	d
AY0092	34-Dama	*Dama dama mesopotamica*	2354	25n25w	SWQ	2		radius L	p
AY0093	38-Dama	*Dama dama mesopotamica*	2670	25n45w	NEQNEsubQ	3	28	tibia L	d
AY0094	39-Dama	*Dama dama mesopotamica*	2696	30n40w	NWQW1/2Spart	5	50	radius L	d

Table C.2 Archaeological Context for Animal Collagen Samples

Lab ID	Identification Number	Species	FN	Area/Context	Quad	Level	Feature	Element	Portion
AY0095	33-Dama	*Dama dama mesopotamica*	1140	20n45w	NE/NWQ	1	9	radius R	d
AY0096	41-Dama	*Dama dama mesopotamica*	2696	30n40w	NWQW1/2Spart	5	50	radius L	p
AY0097	45-Dama	*Dama dama mesopotamica*	2024	30n45w	SWQ	1	39	radius L	d
AY0098	49-Dama	*Dama dama mesopotamica*	2125	30n45w	SEQ	2	28	tibia L	d
AY0099	26-Dama	*Dama dama mesopotamica*	2165	20n25w	NWQ	3		radius L	p
AY0100	27-Dama	*Dama dama mesopotamica*	2307	20n25w	SEQNpart	5		radius L	p
Lab ID 16	55-Caprine	Caprine	2076	15n20w		4		tibia R	d
Lab ID 17	59-Caprine	Caprine	2272	15n25w	SWQ SWpart	6		tibia R	d
Lab ID 18	65-Caprine	Caprine	2546	15n30w	SWQ Npart	3		tibia R	d
Lab ID 19	68-Caprine	Caprine	2284	20n25w	SEQ Npart	4		tibia R	d
Lab ID 20	70-Caprine	Caprine	2165	20n25w		3		tibia R	d
Lab ID 21	72-Caprine	Caprine	2210	20n25w	SWQ	2		tibia R	d
Lab ID 22	80-Caprine	Caprine	2210	20n25w	SWQ	2		tibia R	d
Lab ID 23	96-Caprine	Caprine	2064	5n30w	NEQ Wside	8		tibia R	d
Lab ID 24	82-Caprine	*Ovis aries*	1140	20n45w	NE/NWQ	1	9	radius R	d
Lab ID 25	92-Caprine	*Capra hircus*	2300	30n45w	NWQ/50wNEQ	2	39	humerus R	d
Lab ID 26	56-Caprine	*Ovis aries*	2316	15n25w	SWQ SWpart	7		radius R	p
Lab ID 27	57-Caprine	*Capra hircus*	2316	15n25w	SWQ SWpart	7		humerus R	d
Lab ID 28	78-Caprine	*Capra hircus*	2027	20n25w	SEQ Spart	4		humerus R	d
Lab ID 29	58-Caprine	*Capra hircus*	2272	15n25w	SWQ SWpart	6		humerus L	d
Lab ID 30	64-Caprine	*Ovis aries*	2445	15n30w	SEQ	2	47	humerus L	d
Lab ID 47	81-Caprine	*Capra hircus*	1140	20n45w	NE/NWQ	1	9	humerus R	d
Lab ID 48	83-Caprine	*Capra hircus*	1140	20n45w	NE/NWQ	1	9	humerus R	d

Table C.2 Archaeological Context for Animal Collagen Samples

Lab ID	Identification Number	Species	FN	Area/Context	Quad	Level	Feature	Element	Portion
AY0067	73-Caprine	*Capra hircus*	2160	20n25w	NWQ	2		humerus L	d
AY0068	75-Caprine	*Capra hircus*	2455	20n25w	SWQ	3		humerus L	d
AY0069	79-Caprine	Caprine	2210	20n25w	SWQ	2		tibia L	d
AY0070	54-Caprine	*Capra hircus*	1987	15n20w		3		humerus L	d
AY0071	60-Caprine	*Ovis aries*	2498	15n30w	NWQ	3		radius R	p
AY0072	52-Caprine	Caprine	1987	15n20w		3		tibia L	d
AY0073	85-Caprine	*Ovis aries*	1140	20n45w	NE/NWQ	1	9	humerus L	d
AY0074	89-Caprine	*Ovis aries*	2448	25n30w	SWQ	1	52	humerus L	d
AY0075	87-Caprine	*Ovis aries*	1140	20n45w	NE/NWQ	1	9	radius R	p
AY0076	88-Caprine	*Capra hircus*	1140	20n45w	NE/NWQ	1	9	humerus R	d
AY0077	69-Caprine	*Capra hircus*	2464	20n25w	SWQ	4		humerus R	d
AY0078	62-Caprine	*Capra hircus*	2224	15n30w	SWQ	1		radius L	d
AY0079	67-Caprine	*Capra hircus*	2280	15n35w	NEQ	1		radius L	d
AY0080	93-Caprine	Caprine	2125	30n45w	SEQ	2	28	tibia L	d
AY0081	94-Caprine	Caprine	2125	30n45w	SEQ	2	28	humerus L	d
AY0082	95-Caprine	Caprine	1824	35n50w	Squads	1		humerus L	m
AY0083	98-Caprine	Caprine	1788	5n30w	eastern 1.65m	4		humerus L	m
Lab ID 31	105-Sus	*Sus Scrofa*	2498	15n30w	NWQ	3		radius R	p
Lab ID 32	107-Sus	*Sus Scrofa*	2546	15n30w	SWQNpart	3		radius R	p
Lab ID 33	111-Sus	*Sus Scrofa*	2445	15n30w	SEQ	2	47	radius R	p
Lab ID 34	112-Sus	*Sus Scrofa*	2445	15n30w	SEQ	2	47	radius R	p
Lab ID 35	113-Sus	*Sus Scrofa*	2257	15n30w	SWQ	2		radius R	p
Lab ID 36	117-Sus	*Sus Scrofa*	2165	20n25w	NWQ	3		tibia R	d
Lab ID 37	119-Sus	*Sus Scrofa*	1140	20n45w	NE/NWQ	1	9	tibia R	d

Table C.2 Archaeological Context for Animal Collagen Samples

Lab ID	Identification Number	Species	FN	Area/Context	Quad	Level	Feature	Element	Portion
Lab ID 38	127-Sus	*Sus Scrofa*	2300	30n45w	NWQ/50wNEQ	2	39	radius R	p
Lab ID 39	128-Sus	*Sus Scrofa*	2413	30n45w	SEQ	1	42	tibia R	d
Lab ID 40	131-Sus	*Sus Scrofa*	2047	30n45w	NWQ/50WNEQ	2	39	tibia R	m
Lab ID 41	135-Sus	*Sus Scrofa*	1800	5n30w		3		tibia R	d
Lab ID 42	136-Sus	*Sus Scrofa*	1853	5n30w	E 1.65 m	6		tibia R	d
AY0058	121-Sus	*Sus Scrofa*	2696	30n40w	NWQW1/2Spart	5	50	humerus L	d
AY0059	122-Sus	*Sus Scrofa*	2696	30n40w	NWQW1/2Spart	5	50	tibia L	d
AY0060	124-Sus	*Sus Scrofa*	2662	30n40w	NWQW1/2	2		humerus L	d
AY0061	125-Sus	*Sus Scrofa*	2300	30n45w	NWQ/50wNEQ	2	39	humerus L	d
AY0062	115-Sus	*Sus Scrofa*	2464	20n25w	SWQ	4		humerus R	d
AY0063	102-Sus	*Sus Scrofa*	1987	15n20w		3		tibia L	m
AY0064	101-Sus	*Sus Scrofa*	2124	10n25w	NWQN1/2	1		humerus L	d
AY0065	108-Sus	*Sus Scrofa*	2511	15n30w	NEQ	2		humerus L	d
AY0066	109-Sus	*Sus Scrofa*	2498	15n30w	NWQ	3		humerus R	m
Lab ID 43	139-Bos	*Bos taurus*	2560	10n30w	NEQ	2		humerus R	m
Lab ID 44	143-Bos	*Bos taurus*	1987	15n20w		3		tibia R	d
Lab ID 45	149-Bos	*Bos taurus*	2165	20n25w	NWQ	3		tibia R	m
Lab ID 46	150-Bos	*Bos taurus*	1986	20n25w	SEQ	3		humerus R	m
AY0051	148-Bos	*Bos taurus*	2292	20n25w	SEQ			radius L	d
AY0052	147-Bos	*Bos taurus*	2113	15n30w	NEQ	1		femur L	m
AY0053	152-Bos	*Bos taurus*	1800	5n30w		3		humerus L	m
AY0054	146-Bos	*Bos taurus*	2076	15n20w		4		humerus L	m

Table C.2 Archaeological Context for Animal Collagen Samples

Lab ID	Identification Number	Species	FN	Area/Context	Quad	Level	Feature	Element	Portion
AY0055	137-Bos	*Bos taurus*	2124	10n25w	NWQN1/2	1		radius L	m
AY0056	140-Bos	*Bos taurus*	2560	10n30w	NEQ	2		femur L	m
AY0057	151-Bos	*Bos taurus*	2662	30n40w	NWQW1/2	2		radius R	p

Table C.3 Archaeological Context of Molar Samples

Lab ID	Identification Number	Unit	Quad	Level	Feature	FN	Species	Molar	M3
AY0101	159-Molar	20n45w	NE/NWQ	1	9	1140	Caprine	M3	r
AY0102	160-Molar	20n45w	NE/NWQ	1	9	1140	Caprine	M3	r
AY0103	161-Molar	20n45w	NE/NWQ	1	9	1140	Caprine	M3	r
AY0104	156-Molar	20n25w		3		2165	*Capra hircus*	M2	r
AY0105	158-Molar	20n25w	SEQNpart	5		2307	Capring	M2	r
AY0106	162-Molar	20n45w	NE/NWQ	1	9	1140	Caprine	M2	r
AY0107	167-Molar	5n30w	eastern1.65m	4		1788	*Ovis aries*	M2	r

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