Πανεπιστήμιο Κύπρου
University of Cyprus

ΤΜΗΜΑ ΙΣΤΟΡΙΑΣ ΚΑΙ ΑΡΧΑΙΟΛΟΓΙΑΣ
DEPARTMENT OF HISTORY AND ARCHAEOLOGY

Μάστερ στη Χερσαία και Υποβρύχια Αρχαιολογία Πεδίου
Master in Field Archaeology on Land and Under the Sea

Mineral resource exploitation in the Early Cypriot Neolithic: The provenance and use of ochres at Ayia Varvara-Asprokremnos

Διατριβή Μάστερ
Master's Thesis

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ΛΕΥΚΩΣΙΑ / NICOSIA 2024

Except where otherwise acknowledged, all the work presented here is my own. The research undertaken here has not been presented as part of the requirements for any other degree.

Niamh Shulmeister 3rd March 2024

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Abbreviations

AVA: Ayia Varvara-Asprokremnos, the archaeological site studied in this paper.

CAARI: the Cyprus American Archaeological Research Institute, an archaeological unit based out of Nicosia. CAARI hosted a talk by Fulbright Artist Elisabeth Heying on her use of earth pigments on the 16th April 2024.

EENC: Elaborating Early Neolithic Cyprus, the name of the project responsible for both the excavations at Ayia Varvara-Asprokremnos and surface surveys in the surrounding area.

PCA: Principal Component Analysis, a statistical technique used to simplify and display the results of multivariate analysis in two dimensions without losing significant amounts of data.

PPNA: The Pre-Pottery Neolithic A, the earliest stage of the pre-pottery Neolithic. In Cyprus it lasts from around 9200-8600 cal. BC.

PPNB: The Pre-Pottery Neolithic B, the central phase of the pre-pottery Neolithic. In Cyprus it lasts from around 8400-7000 cal. BC.

PPNC: The Pre-Pottery Neolithic C, the latest phase of the pre-pottery Neolithic. In Cyprus it lasts from around 7000/6800-5500 cal. BC.

p-XRF: Portable X-Ray Fluorescence, an analytical technique used to identify the elemental composition of a sample. It operates by firing an x-ray beam of known energy at the sample, and recording the energy of the x-rays emitted in response.

UCY: The University of Cyprus.

Abbreviations in figures only:

AA: Reference material collection site Agrokipia A.

KG: Reference material collection site Kambia Gossan.

KP: Reference material collection site Kokkinopezoula.

KV: Reference material collection site Kokkinovounaros.

MN: Reference material collection site Mathiatis North.

MS: Reference material collection site Mathiatis South.

The locations of all of these sites are shown in Figure 26.

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Abstract

At present, very little is known about the earliest phases of the Cypriot Neolithic: only two PPNA sites, Ayios Tychonas-Klimonas and Ayia Varvara-Asprokremnos, have been excavated thus far. Despite being contemporary in age, these two sites demonstrate very different patterns of occupation and use, with Klimonas likely serving as a permanent settlement and Asprokremnos as a temporary, perhaps seasonal, campsite. The artefact assemblage from Ayia Varvara-Asprokremnos suggests that it served primarily as a production site for lithics, with few structures identified but several thousand kilograms of stone tools and debitage recovered. In addition, a large amount of ochre was found at the site, often in association with ground stone tools in the "workshop" structures. In this study, the potential uses of this material- as pigment; in ritual practice; and in the process of tanning leather- are discussed. A provenance study is also performed through the use of p-XRF analysis in an attempt to associate the ochre from Ayia Varvara-Asprokremnos with specific geological formations in the surrounding landscape. While no exact source is identified, it is likely that the Asprokremnos ochre was collected to the west of the settlement, probably from outcrops along the banks of the Gialias River. Future research in this area would be welcome, particularly in regards to more precise geochemical analytical methods, comparisons with ochre from other PPNA sites such as Klimonas, and a more detailed study of both the lithic and faunal assemblages of Asprokremnos in order to better reconstruct past human activity.

Acknowledgments

My deepest gratitude goes to Professor Ourania Kouka for her support on this project, particularly given the logistical difficulties we frequently faced. Without her support and encouragement this thesis would not have been possible. I am also hugely grateful for the help of Dr Miltiadis Polidorou, who went above and beyond the call of duty in supporting me throughout this thesis. I would like to express many thanks to Professor Lina Kassianidou, partner of the excavations at Ayia Varvara-Asproklemnos for entrusting me with the study and publication of the ochres. Moreover, I need to acknowledge the contributions of Dr Andreas Charalambous for his assistance in the earliest phases of this project and his support in the field, as well as technician Constantinos Prastitis for his help at the Archaeological Research Unit.

All the staff at the Department of Antiquities and the Cyprus Museum were incredibly supportive of this work, but particular thanks must go to Dr Giorgos Georgiou, Eftychia Zachariou, Efthymia Alphas, George, John, and Dimitris for their help in accessing storeroom material. Professor Sturt Manning and Dr Lindy Crewe provided access to the excavation database for Ayia Varvara-Asprokremnos. The site was originally excavated by Dr Carole McCartney, who passed away in 2021. Without the organisation and support of the wider archaeological community of Cyprus, the excavation data for this site would have been lost.

In addition, Fulbright Fellow artist Elisabeth Heying's talk about her work collecting earth pigments in Cyprus proved to be central in shaping the conclusions of this thesis. My thanks to both Heying and the Cyprus American Archaeological Research Institute for organising this talk.

I need to thank my classmates- Juan, Nicole, Elsa, and Jules- for their friendship and support throughout my time in Cyprus. I also want to thank my parents, for occasional proofreading and constant emotional support; and all of my friends, but particularly Aaron, Raine, Reyni, and Charlotte- y'all are the reason I'm still sane. Finally, I want to say a huge thank you to all the stray cats in Nicosia, for being soft and adorable willing to accept pats.

1. Introduction

Ayia Varvara-Asprokremnos is an archaeological site located in Central Cyprus (Figure 1), excavated in the early 2000s as part of the Elaborating Early Neolithic Cyprus (EENC) Project led by the late Carole McCartney. Radiocarbon ages have dated the site to around 8900-8600 BC (Manning et al. 2009). These dates prove Asprokremnos to be one of the oldest known occupation sites on Cyprus, placing it within the Pre-Pottery Neolithic A (PPNA), the earliest phase of the Neolithic period.

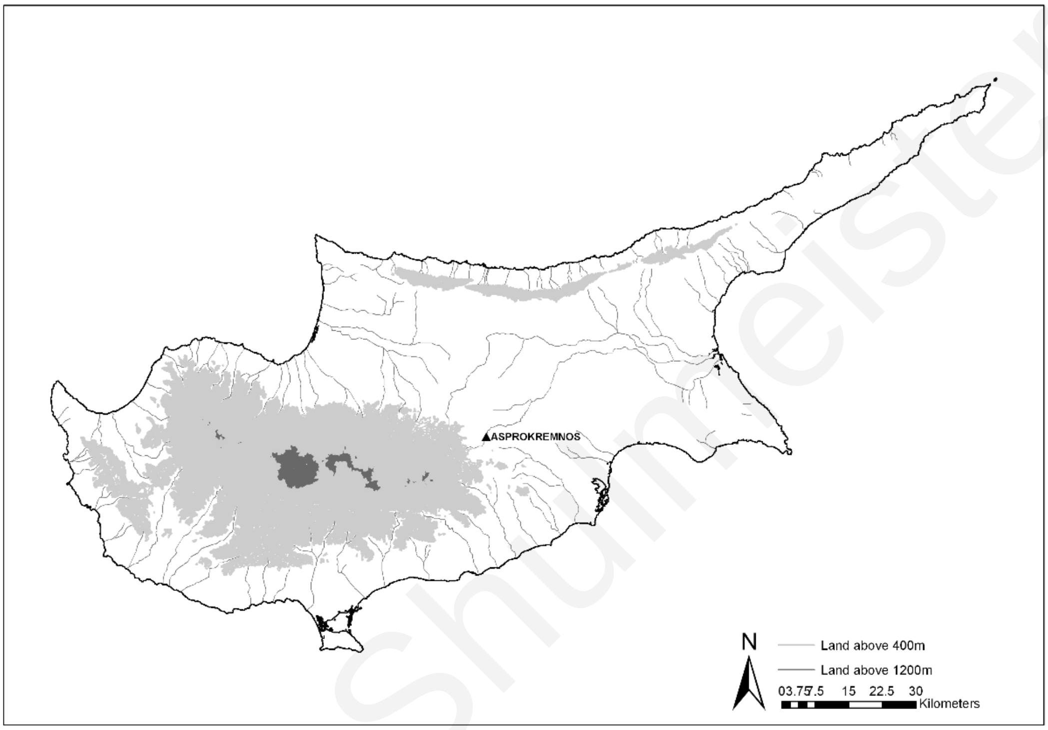


Figure 1: Map of Cyprus with the location of Ayia Varvara-Asprokremnos. © C. McCartney: Ayia Varvara-Asprokremnos Excavation Archive.

In the Levant, the Neolithic period is divided into three phases (A, B, and C) with approximate dates of 12 000 – 10 800 BP, 10 800 – 8 500 BP, and 8 500 – 6 500 BP respectively (Rollefson 2008). These distinctions were first formalized by K. Kenyon's excavations at Jericho in the 1950s (Kenyon 1954) and define the phases by a number of factors including geographical distribution, architecture and settlement types, burial styles, tool technologies, and the presence or absence of certain domesticated animals and crops. While Cyprus has historically been considered to be on the periphery of the (early) Neolithic, recent excavations at the other PPNA site on the island – Ayios Tychonas-Klimonas – found a high level of overlap between their chronologically-dated PPNA site and the cultural complex associated with the PPNA in the Levant (Guilaine 2023). Ayia Varvara-Asprokremnos is contemporary to Klimonas, and while there are a number of unique aspects of the site, it is part of the same broader cultural tradition as Klimonas.

However, there are some differences in the chronology between Cyprus and the mainland. In Cyprus, the Epipalaeolithic occurs around 10 500 BC. The PPNA is from around 9200-8600 cal. BC, the PPNB from 8400-7000 cal. BC, and the PPNC from 7000/6800-5500 cal. BC

(Rousou 2022). Thus, the Cypriot Neolithic starts slightly later than its mainland counterpart, and the PPNA is somewhat shorter (Figure 2).

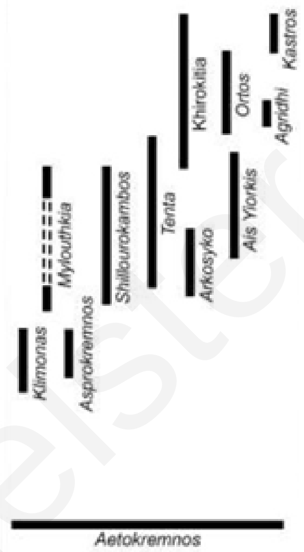
Continental period	Date (cal BC)	Cyprus	Cyprus occupations
	5000	?	
Ceramic Neolithic			
		Late Aceramic	
	6000	Neolithic	
Final PPNB/PPNC			
	7000	Early Aceramic	
		Neolithic	
PPNB			
	8000	?	
PPNB			
PPNB		Initial Aceramic	
	9000	Neolithic	
PPNA			
		?	
Khamian	10 000		
		Late Epipalaeolithic	
Natufian			
	11 000		

FIGURE 2: Chronology of the Epipalaeolithic and Neolithic on both Cyprus and the mainland, with occupation periods for Cypriot sites shown. Figure adapted from: Rousou 2022, fig. 14.

Ayia Varvara-Asprokremnos is an important keystone in understanding not only the Cypriot Pre-Pottery Neolithic, but also the occupation of the island in the first place, its association and links with the mainland, and the spread of Neolithic culture and technology more broadly in the Eastern Mediterranean. Lithics and ochre material is particularly prevalent in the archaeological assemblage of Asprokremnos. The site likely served as a production centre for stone tools during the PPNA, and may have been a processing site for animal hide and leather as well, given the prevalence and context of ochres found within the assemblage. Thus, the geological context of the site and the use of mineral resources within its boundaries is an area which deserves particular attention.

2. Geology of Cyprus

Cyprus is an island which has never been connected by land to any of the continental shelves around it. Geologically, its formation can largely be traced to the subduction of the African plate under the Eurasian plate, with seafloor spreading from this process causing the creation of what would become the Troodos ophiolite complex (Robertson & Xenophontos 1993). This is a formation of plutonic and basaltic rocks which forms the core of the Troodos Mountains. It is characterised by its mafic and ultramafic rocks, particularly harzburgite and serpentinite, which only form under certain conditions involving metamorphosed upper mantle material (Schuiling 2011). The harzburgite/serpentinite "core" of the Troodos is surrounded by a number of other volcanic units, including the upper and lower pillow lavas. The formation as a whole is known to geologists as one of the most complete ophiolite formations on the planet, and as such, its formation and uplift has garnered a great deal of attention.

Despite the initial formation of this structure occurring during the Late Cretaceous, around 92 million years ago (Geological Survey Department, 2017), the formation was not uplifted to the oceans' surface until substantial tectonic activity occurred far more recently: perhaps during the middle Miocene or Pleistocene (Robertson 1977), or even the Late Pliocene, either between 2.14 and 1.95 Ma or immediately prior to 1.77 Ma (Kinnaird et al. 2011).

The Pentadaktylos Range in the north, also known as the Keryneia Range, originated from an older formation, with the basal layers consisting of limestones that developed in a large shallow sea to the south of Cyprus' current location. The oldest formations in this range date to between 250 and 135 million years (Geological Survey Department 2017b). However, these are allochthonous units- that is, material which has been shifted from its original point of deposition by tectonic activity. This material was fractured and frequently subducted during the Triassic by the formation of the Neotethyan Ocean- the same ocean basin which the Troodos complex emerged from. The limestone units which were not destroyed by this process form the foundations of the Pentadaktylos Range, with several subsequent layers of both sedimentary and igneous material deposited over them afterwards: volcanic eruptions occurred around 74 Ma, and carbonate platforms formed at several points throughout the Mesozoic (Chen & Robertson 2021). However, it was not until the Upper Miocene (i.e. within the last 10 million years) that the Pentadaktylos Range were thrust into their present position (Geological Survey Department, 2017b).

The formation of the rest of the island occurred in relatively quick succession in geological terms once the Troodos and Pentadaktylos Ranges had reached their modern positions. The Mamonia Terrane in southwest Cyprus is another allochthonous formation, consisting of both volcanic and igneous material. The initial deposits likely formed during the Upper Triassic to Late Cretaceous, and likely formed at the continental margins of the Tauride Block, in modern-day Turkey, before being shifted west or southwest as oceanic basins closed (Bragin 2023). A number of additional tectonic events occurred throughout the Late Cretaceous to modify this unit further, including its collision with the western edge of the Troodos complex, which brought it fully into the scope of Cyprus' geological history (Bailey et al. 2000).

The Circum-Troodos Sedimentary Succession, meanwhile, is an array of sedimentary deposits that formed around the Troodos formation. It dates primarily to the Pliocene and Pleistocene, and consists primarily of limestones, formed from material deposited in the shallow marine environment surrounding the mountain ranges described above. The largest feature within this unit is the Mesaoria plain, which refers to the area bounded by the Troodos to the south, the Pentadaktylos to the north, and the Mediterranean Sea to the east and west (Calon et al. 2005). Another important feature is the Pachna formation, a deposit of chalks and marls dating to the Miocene which underlies the Akrotiri peninsula on the south of the island (Polidorou & Evilpidou 2017). This is overlain by Quaternary sediments, largely marine and aeolian sediments, alongside alluvial material from the Kouris river. Most of Cyprus outside of the Troodos and Pentadaktylos follows this general trend, with deep-sea marine sedimentary rocks such as limestones and chalks overlaid by Quaternary sediments of either alluvial or aeolian origin. Coastal processes and tectonic activity have also played a substantial role in the formation and alteration of coastal areas, including those which have been occupied by humans (Galili et al. 2016).

Overall, the geological history of Cyprus is complicated, and has produced multiple distinct units with differing histories and very different lithological characteristics (Figure 3).

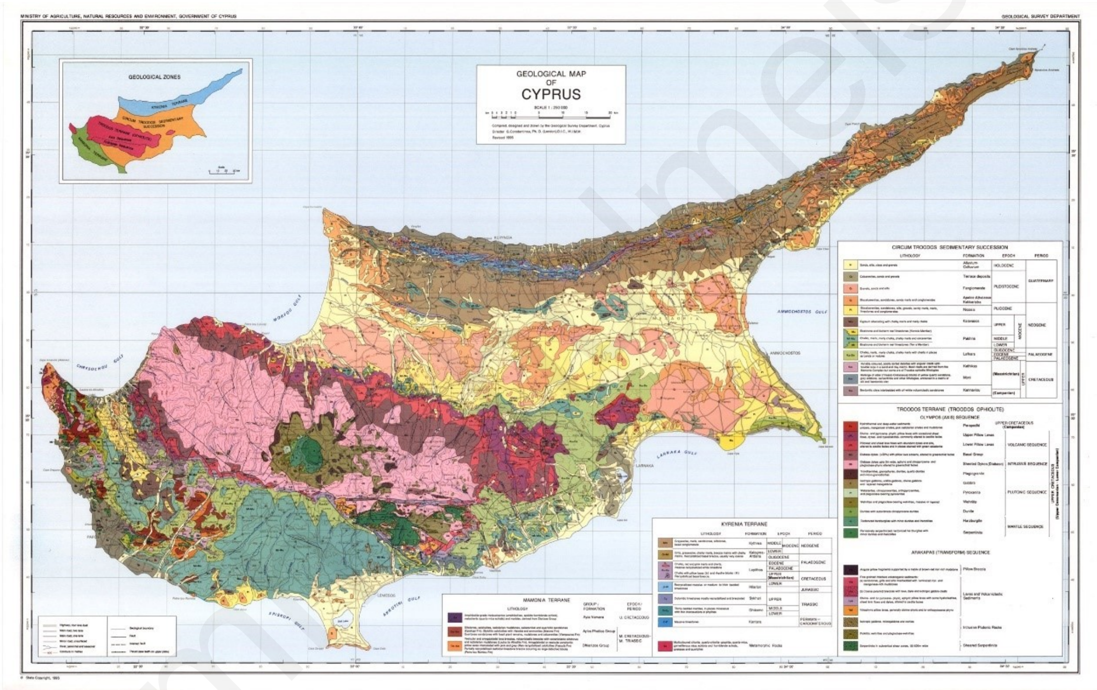


FIGURE 3: Geological map of Cyprus. Figure from: Geological Survey Department, Ministry of Agriculture, Natural Resources, and Environment, 1995. Downloaded 15th March 2024, https://www.moa.gov.cy/moa/gsd/gsd.nsf/page32_en/page32_en?OpenDocument&Start=1&Count=1000&Expand=1.

2.1 Cypriot Geology and Archaeology

The complex geological history of Cyprus has resulted in the availability of a wide variety of mineral resources. Many of these have been exploited by human populations in the past, including throughout prehistory. These include igneous stones from the Troodos; ochres and jasper from the lower pillow lavas and sedimentary boundaries; and chalks, cherts, limestones, and chalcedony from sedimentary contexts at lower elevations. How this material was used, and where it was collected, are both questions that archaeological work must take into consideration.

While there is a wide variety of igneous material available within the Troodos mountains, most of the artefacts recovered from archaeological sites were probably collected from secondary deposits in riverbeds and streams, rather than from the mountains themselves. The macrolithic assemblage from Ayios Tychonas-Klimonas features a wide variety of diabases, grano-diorites, gabbros, and microgabbros (Robitaille 2023, 289). Basalts are also particularly common, with seventy-three of 186 identified handstones at this site formed from basalts. Quern stones, meanwhile, were predominantly made of gabbro, as were pestles. Overall, the grinding stone assemblage of this site was dominated by igneous material associated with various aspects of the Troodos formations. However, the vast majority of the recovered tools are hammerstones or other small pieces, and could have been collected from secondary fluvial contexts such as the Amathous River, located less than 4km from the site. Despite being of lower quality for this purpose, local limestones were also utilised as slabs and anvils, likely because of the proximity of quarry sources for these larger tools (Robitaille 2023, 292). Likewise, the ground stone tool assemblage for Ayia Varvara-Asprokremnos is dominated by volcanic materials, particularly in regards to hammerstones and pounders (e.g. Figure 4), yet the grinding slabs and bowls are almost all composed of local chalks and limestones (e.g. Figure 5).

FIGURE 4: A grinding stone recovered from the excavations at Ayia Varvara-Asprokremnos. © N. Shulmeister.

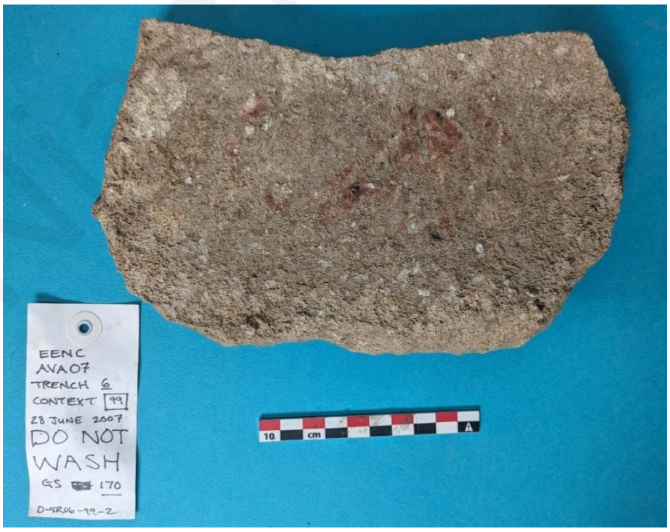


FIGURE 5: A chalk slab recovered from the excavations at Ayia Varvara-Asprokremnos. © N. Shulmeister.

Some of the most iconic artefacts from the Cypriot Neolithic and Chalcolithic are composed of picrolite, a very soft metamorphic rock with a distinctive green colour and a soft, “soapy” or “waxy” texture (Xenophontos 1991). While the Chalcolithic-era cruciform figurines are the most well known picrolite artefacts (Figure 6), this material was utilised in earlier periods as well, and has been found at Akrotiri-Aetokremnos, which is currently the earliest known site on the island (Moutsiou et al. 2022). Picrolite is too soft to be worked effectively for stone tools, and is instead used almost solely for decorative purposes.

FIGURE 6: Examples of cruciform Figures made from picrolite, dating to the Chalcolithic period. Figure from: Bolger et al. 2019. Souskiou-Laona Excavation Project, Accessed 3rd May 2024, https://doi.org/10.5284/1057535.

Primary sources for picrolite are located within the Troodos mountains, near the summit of Mount Olympus, where it can be found in veins with serpentinised harzburgite (Moutsiou et al. 2022). While there are known sources in other areas around the Troodos Massif, particularly in the Limassol area, these are generally small and heavily deformed in ways that prevent simple access and use of this material. Thus, during the Epipalaeolithic and Neolithic, picrolite was probably collected directly from sources in the Troodos mountains, or recovered as pebbles from the Kouris or Karkotis rivers.

Ochres are naturally occurring, brightly coloured soils which generally get their colours from compounds of iron oxides (Dayet 2021). They are sedimentary rocks formed by the weathering of other materials, and as such, their chemical composition is highly dependent on the underlying geology of the region. In Cyprus, most ochres occur around the lower edges of the Troodos Massif. In the modern day, many of the most visible outcrops are associated with mine sites such as Mitsero (Figure 7).

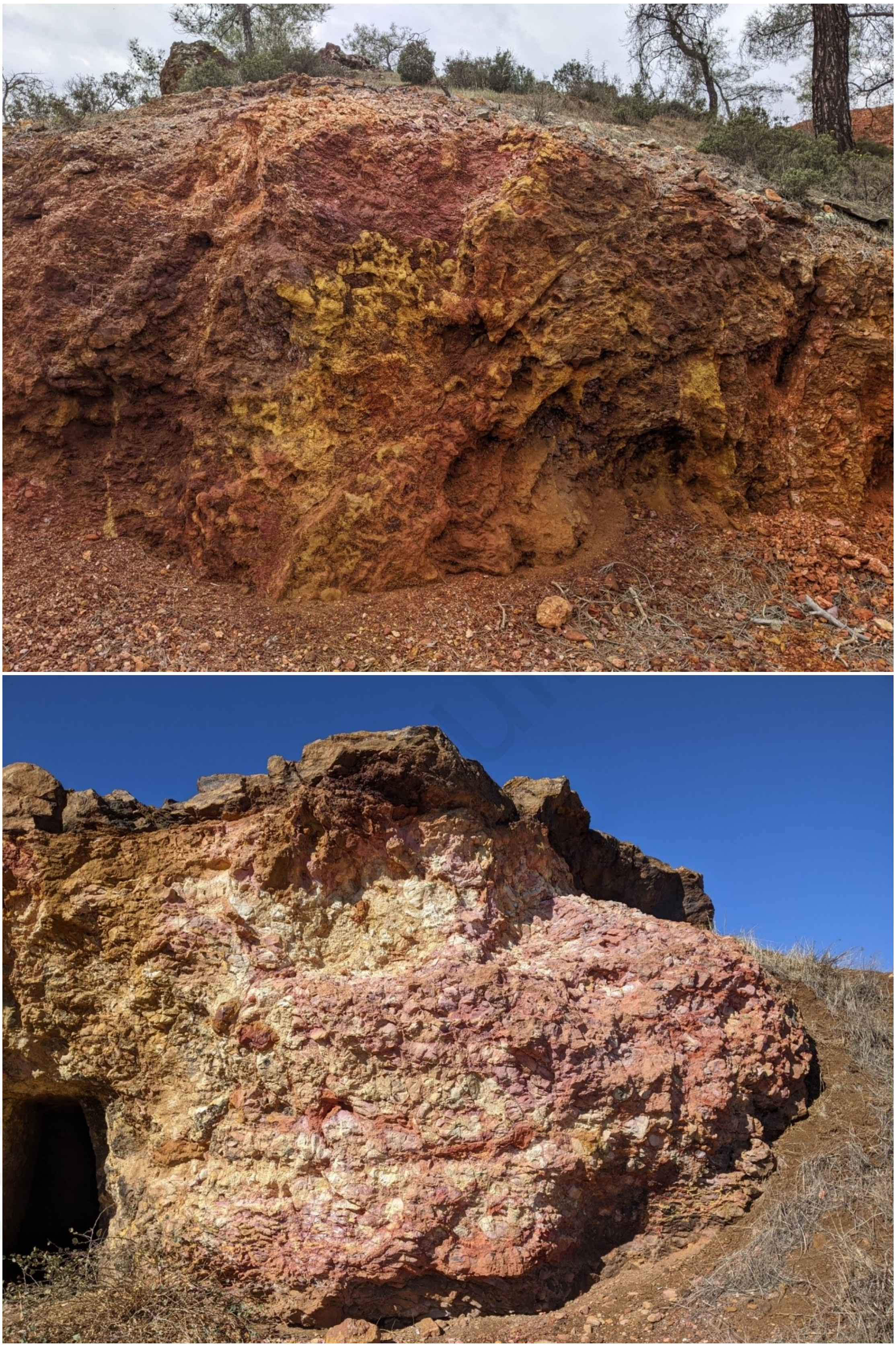


FIGURE 7: Ochre outcrops in the area of the Mitsero (top) and Kokkinovounaros (bottom) mines, both in the Troodos foothills. © N. Shulmeister.

The archaeological use of ochres is well-attested to globally, with evidence dating back at least 100 000 years (Balter 2009). It is most well known for its use as a pigment, although a number of other purposes have been attested to archaeologically and ethnographically. These are described in more detail in a later section. In Cyprus specifically, ochres appear in early Neolithic contexts both as individual pieces of ochre and as residues on grinding tools. It has been hypothesised that it was used as a pigment, but also for cleaning and softening hides in the tanning process (McCartney & Sorrentino 2019).

Cyprus' geology also provides an abundance of sources of good lithic material for stone knapping, many of which were utilised during the early Neolithic. Jasper appears in the lower pillow lavas of the Troodos, and occasionally turns up in chipped stone assemblages from this period (Stewart et al. 2020), as does silicified umber. This material outcrops in some locations in the Tremithos Valley, but is most well-known from the Perapedhi formation on the west of the island (Bragina 2012). Flint and chalcedony both form in silica-rich environments such as chalks; and both were utilised for chipped stone tools at the site of Ayios Tychonas-Klimonas (Vigne et al. 2011). Chert nodules from the Lefkara chalk formation specifically were utilised for stone knapping at multiple sites across southern Cyprus (e.g. Stewart et al. 2020).

The Lefkara chalk beds themselves are of particular interest here, given that the site of Ayia Varvara-Asprokremnos rests on this feature specifically. It is a sedimentary feature dating to the Late Cretaceous, and represents some of the earliest sedimentary deposits on and around the Troodos ophiolites (Kähler & Stow 1998). Both the chalks and cherts from this formation are found in archaeological contexts. In particular, chalk appears to have been used for the production of macrolithic tools in those cases where it was a common local material. Multiple chalk slabs have been recovered from Ayia Varvara-Asprokremnos (McCartney n.d.), which is located on the Lefkara formation itself. However, the other major PPNA site on the island, Ayios Tychonas-Klimonas, does not appear to have used this material, instead relying on local limestones (Robitaille 2023 pp. 287).

2.2 Geology of Ayia Varvara-Asprokremnos

The archaeological site of Ayia Varvara-Asprokremnos is located in an area which is geologically complex. It sits on the boundary between the lowest aspects of the Troodos pillow lavas and the Lefkara formation chalks/cherts (Figure 8), meaning that both igneous and sedimentary material is readily available in the surrounding landscape.

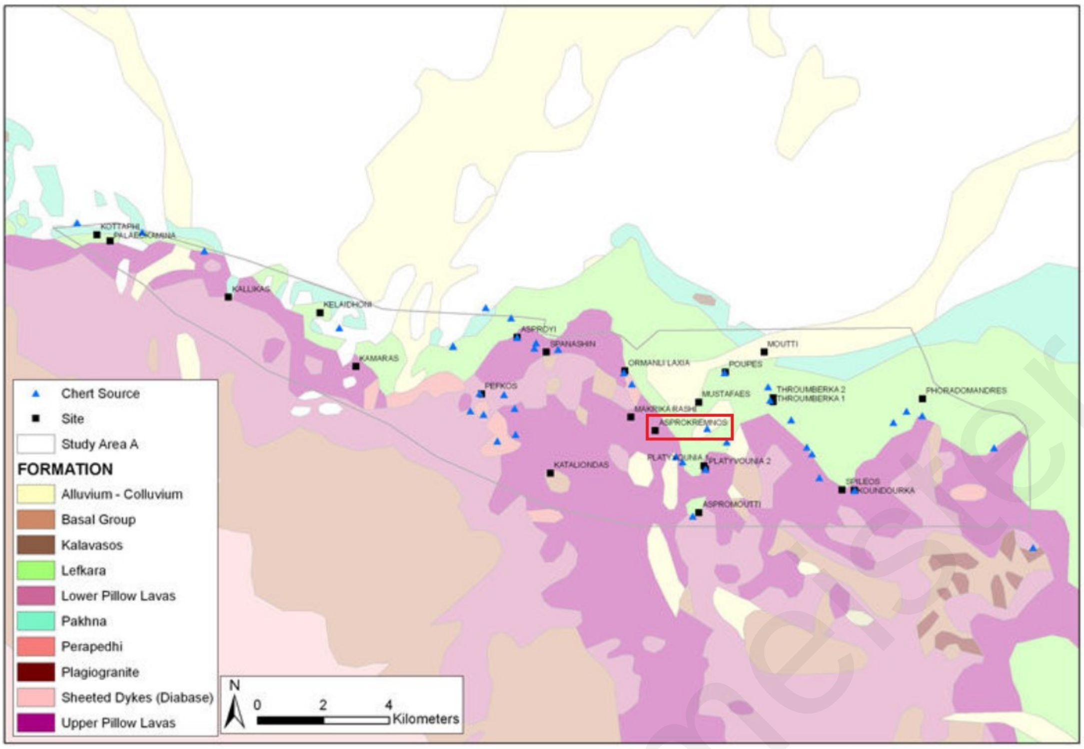


FIGURE 8: Geological map of the Ayia Varvara-Asprokremnos area. After Rosendahl 2010, 14; modified by the author.

This is particularly relevant to archaeological studies in this area, as these different units provide a variety of different stone resources for lithic production. In particular, ultramafic volcanic rocks such as diabase and gabbro are particularly desirable for the production of quern stones and other ground-stone tools due to their density and large crystal sizes. At Ayia Varvara-Asprokremnos, these materials can be collected from sources in the Troodos, but are also present as river cobbles in the nearby Gialias River. Meanwhile, flints and cherts are particularly desirable for the production of chipped stone tools. Some of the chert material from Ayia Varvara-Asprokremnos has been studied previously, and a provenance study has been made, however, it had only limited success in identifying the geological sources for this material.

Three surveys have been conducted in the area thus far: the *Elaborating Early Neolithic Cyprus* project, the *Tremithos Neolithic Survey*, and the *Idalion Survey Project* (Figure 9). Data from all three of these surveys were used to locate potential chert sources in the landscape, as well as identifying isolated chert artefacts.

Most chert sources in southern Cyprus are found on the edges of the Lefkara formation, along the boundary between the igneous and sedimentary zones (Stewart et al. 2020). This material can also be recovered from secondary deposits in stream beds and fields around the area. Chert material varies widely in colour, including browns, tans, and reds through to pinks, buffs, blues, greens, and mottled variations as well as in texture, ranging from translucent to opaque. Some colours and textures are more desirable for knapping purposes than others, with the very fine-grained translucent varieties proving particularly suited for this purpose (Suga et al. 2023).

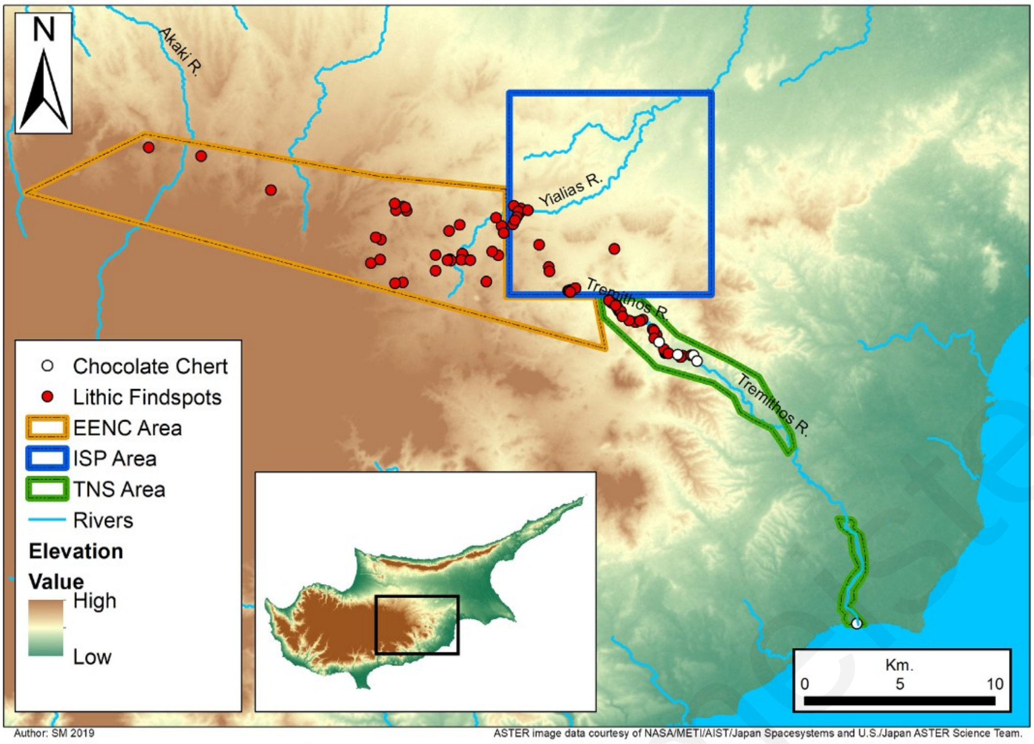


FIGURE 9: Map showing survey locations around the area of Ayia Varvara-Asprokremnos. Map from: Stewart et al. 2020, 2.

The chert sourcing study performed in this area utilised Instrumental Neutron Activation Analysis (INAA) in order to identify sixteen trace elements within 182 samples (Stewart et al. 2020). Eight of these samples were removed after visual or chemical identification proved they were not made of chert, leaving a total of 174 samples. Two different methods of visual sorting were applied to the dataset, in an attempt to identify potential groupings. However, most of the material was too homogenous for this to be effective. The one exception was a subset of material referred to as "chocolate chert", which is likely a silicified umber (dark earth taking its colour from iron and manganese) rather than a true chert material. This material is less common in the landscape and only outcrops in a few places within the study area, most notably in the upper Tremithos river valley east of Alambra (Stewart et al. 2020).

As the visual sorting was unable to distinguish between most of the samples, multiple statistical analyses were performed on the INAA results in an attempt to cluster the samples into potential origins. Only five of the sixteen elements studied – Barium (Ba), Calcium (Ca), Chlorine (Cl), Manganese (Mn), and Vanadium (V) – were found to be useful for diagnostic purposes, as the rest were either too low in concentration to be reliably assessed, or too homogenous across the entire dataset. Three cluster analyses were performed on this dataset. The first analysed all five of the elements listed above. The second prioritised Ba and Mn, as these appeared to be the most critical for distinguishing between sample clusters (Figure 10). Both of these methods separate the aforementioned "chocolate chert" from the rest of the dataset without issue, but the rest of the material appeared too homogenous for sources to be identified. Thus, a third cluster analysis was performed, comparing only the chocolate chert samples with the source material.

FIGURE 10: Cluster dendrogram based only on Ba and Mn elements, showing some of the results of the INAA chert sourcing study. The "chocolate chert" samples are shown in red. Note the high level of homogeneity between all of the other samples. Fig. from: Stewart et al. 2020, 8.

Overall, the chert sourcing study had only limited success. It appears that all of the chert material analysed here originated from the Lefkara formation chalks, and this geological unit appears to be too homogenous for individual outcrop locations to be identified (Stewart et al. 2020). However, this study contained silicified umber material as well. This material was both visually identifiable and chemically distinct from the Lefkara cherts, and was associated with Jurassic-era silicified umbers, most probably exploited from sources in the Tremithos river valley.

There was one other point of interest in this study. The researchers argued that, in addition to the geographical distinctions between the "chocolate cherts" and the Lefkara material, there should be a temporal pattern to its exploitation as well. First landfall sites, they argue, will be characterised by the exploitation of local material alongside imported, non-local material (Rockman 2009). Following this, a phase of exploration with the use of very diverse sources should be observed; before a final return to favoured sources once the resources of the area had been properly explored (Stewart et al. 2020). Under this theory, the chocolate chert- collected from coastal areas in the Tremithos valley, and likely associated with a landfall site- would have been used from the earliest occupation phases. If it proved to be a useful material, it may have been returned to in later periods, but there should have been an exploration of other sources soon after arrival.

It is somewhat unclear if this hypothesis is supported by the excavation data from Ayia Varvara-Asprokremnos. The early phases of this site show a high percentage of blue-grey Lefkara translucent chert, along with some red-brown translucent chert. The red-brown material dominates the later phases of the assemblage, despite the fact that the blue-grey Lefkara material is more readily available (McCartney et al. 2008). If the red-brown translucent chert in McCartney et al.'s paper and the chocolate chert in Stewart et al.'s study refer to the same material, then the theory about the coastal-sourced chocolate chert being a preferred resource is a well-supported hypothesis. However, neither of these papers provided detailed descriptions, or photographs, of the material in question, so it is difficult to draw conclusions.

3. Ochre in archaeological contexts

3.1 What is ochre?

The term “ochre” refers broadly to naturally-occurring, brightly coloured soils, which gain their colour from iron oxides. Ochre is a sedimentary rock, formed by the weathering of other materials. The exact chemical composition varies depending on the underlying geology of the region, but ochres can form in any sedimentary, igneous or metamorphic environment assuming the iron content is high enough. Some ferric compounds are particularly common in ochres, including hematite (Fe_2O_3) which produces colours ranging from red to brown and occasionally purple; and goethite ($FeO(OH)$), which varies from brown to orange and yellow (Dayet 2021).

Ochre has been used for a wide number of purposes throughout history. However, its use as pigment is one of the best documented, and artists continue to use it for this purpose to this day (E. Heying pers. comm. 16th April 2024). This function has received the most attention from archaeologists worldwide, to the extent that some archaeologists have sought to classify ochre sources by their archaeological use rather than by their chemistry or geology. Occasionally, non-ferric mineral compounds will be referred to as “ochres” due to their use as pigments, even if they are not, chemically speaking, true ochres (Stuart & Thomas 2017). In particular, aluminium and silica rich materials such as kaolinite ($Al_2Si_2O_5(OH)_4$), and some calcium carbonate compounds, produce distinctive white colours (Dayet 2021). Even if these compounds are not, geologically speaking, true ochres, they are often recovered from similar archaeological contexts and are part of the same broad patterns of use. Thus, archaeologists often study them alongside ochre material. Likewise, modern artists who use earth pigments will occasionally use the terms “ochre” and “earth pigments” interchangeably, prioritising the origin of a material over its chemistry (E. Heying pers. comm. 16th April 2024).

As “ochre” does not have one specific chemical formula, archaeologists often define this material based at least partially on its use. One such definition, which was developed specifically for a study in British Columbia, Canada, reads as follows:

> “*Deposits* [of iron oxides] *found within the archaeological record that are suitable for use as pigment based on criteria such as colour richness, texture, friability and presence and type of mineral inclusions*” (MacDonald et al. 2011, 3621).

While this definition is a good starting point, it is not ideal for the purposes of this study. Ochre might appear in the archaeological record most commonly as a pigment, but this is not its only use. Excluding other applications from the definition may result in some samples being overlooked as they are not considered “suitable” as pigments. This is a particular issue in areas where ochre is common within the landscape, and it may be difficult to distinguish between ochre nodules which are artefacts and those which are ecofacts. MacDonald et al.’s definition also specifies ochre material occurring within the archaeological record, which obliquely raises a known issue in sourcing studies: there is a degree of bias within the literature in favour of quarry sites which are known ethnographically, potentially at the exclusion of smaller outcrops or alternate sources which have fallen out of use (e.g. Stafford et al. 2002; Smith & Fankhauser 2009). Restricting the definition of archaeological ochre to the material and sites which are already known to researchers may serve to restrict future research in ways which lead to an incomplete understanding of past human interaction with the landscape as a whole.

Thus, due to these issues, a broader definition for ochre- one put forward by Popelka-Filcoff & Zipkin in a 2022 review paper- will be used here:

> *“Ochre* sensu lato *encompasses natural materials with an iron mineral chromophore that are culturally significant in symbolic and applied roles”* (Popelka-Filcoff & Zipkin 2022, 2).

3.2 How has ochre been used in the past?

The use of ochres as pigments predates the emergence of Homo sapiens, and has long been regarded as one of the major behavioural patterns characterising the hominin lineage (Velliky et al. 2019). The chronology for this behaviour is incredibly long and constantly under revision. At present, some of the earliest known dates for ochre in an archaeological context are associated with art: pieces of engraved ochre from Blombos Cave, South Africa, have been found dating to 100 000 years ago (Balter 2009), with another from Klasies River Cave 1 dating between 100 000 and 85 ka (d’Errico et al. 2012). Ochre as pigment in rock art is challenging to date with accuracy, as there are very few absolute dating techniques which can be applied to the material. More studies have found success with dating the tools used to produce art than dating the art itself: a ground ochre “crayon” was recovered from the 60-50 ka layers at the Madjedbebe Rock Shelter in Northern Australia (Clarkson et al. 2017), although the exact function of these sorts of tools has been called into question, and it is possible that this nodule was shaped as such for another purpose entirely (Wadley 2005). Ochre was also used as decoration in a funerary context at Lake Mungo in Australia around 42-38 000 years ago (Olley et al. 2006).

Proof for the widespread, systematic exploitation of this material only comes later on. The earliest known ochre mine in Europe is on Thassos Island, in Greece, and dates to around 20 000 years ago (Nerantzis & Papadopoulos 2013). The vast majority of ochre mines and quarries are known from ethnographic contexts, not archaeological ones: this is not to say that archaeological quarries did not exist, as they almost certainly did, only that the traces left behind in the archaeological record are very scarce and difficult for researchers to detect.

Art, and ochre use in it, is one of the best-studied aspects of prehistoric archaeology due largely to its preservation. Ochre is an inorganic compound, and one that preserves well over time as long as the material is not weathered. Rock art left undisturbed in cave contexts often survives thousands of years. Ochre which is buried at prehistoric sites will be preserved, often far past the point at which organic material has been lost (Bednarik 2015).

There are a large number of other uses for ochre recorded ethnographically, yet many of these are not well attested in the archaeological record. It is reasonable to assume that at least some other uses were common with some cultures throughout history. However, preservation conditions are not as ideal for many of these methods, so archaeological evidence remains scarce.

Ochre being used for tanning leather has been a reasonably common theory in archaeological circles since at least the 1960s, if not earlier (Rifkin 2011). The preservative effects of iron oxides are well known, and it was theorised that ochre would serve as an effective tawing agent for this purpose. However, the poor preservation of leather in the archaeological record means that very few artefacts have been found, anywhere in the world. So far, there is no real archaeological evidence for leather tanning with ochre, and ethnographic data to support this hypothesis is almost non-existent- only a handful of references are known, mostly from South Africa (Bleek 1928; Schapera & Goodwin 1953). In both of these cases, other, non-ochre tanning methods were also in use by the populations in question, and ochre was not considered to be an essential part of the process.

That said, a number of experimental studies have been performed to test the feasibility of this idea (Rifkin 2012), and it does appear to have some utility. Tanning with minerals is a common process, and while other mineral salts are more common- chromium sulphate appears to be "industry standard"- ferric oxide can be used for this process. First, the hide is removed from the animal and excess fat and hair is scraped away. Then, it is hydrated and covered in a mineral salt, then left for a period of time- usually a day or two- for the desired chemical reactions to occur. The minerals applied to the hide form chemical bonds with collagen in the remaining animal fat. This prevents collagenase- an enzyme which breaks down collagen- from acting on the hide, meaning it does not deteriorate (Rifkin 2011).

Currently, there is no definitive archaeological evidence for this process occurring – no preserved leather which was indisputably tanned with ochre. However, there is some indirect evidence that this may have occurred. In particular, Hilachon Tachtit Cave in Israel is a Natufian burial site with an extensive lithics assemblage (Dubreuil & Grosman 2009). The researchers have interpreted some of the chipped stone tools from this site as scrapers, associated with the removal of animal fat from hides. They also recovered ground stone tools with ochre residues (Dubreuil & Grosman 2013). The excavators interpreted these tools to correspond to the same *chaine operatoire* for the tanning of hides. While more direct evidence of hide tanning with ochre would be desirable, the poor long-term preservation of leather means that such evidence is unlikely to be found.

Other uses of ochre which have been reported ethnographically include sunscreen (Rifkin et al. 2014), mosquito repellent (Rifkin 2015), as an ingredient in tool hafting adhesives i.e. glue (Lombard 2007), red pottery slip (Eiselt et al. 2011), and medicinal purposes such as antiseptics (Velo 1984). It is also used for ritual purposes around the world to this day, and given the amount of ochre found in artistic, funerary, and ritual contexts in archaeological sites around the world, it must have played a major role in this area in the past as well. However, without access to ethnographic information, reconstructing these behaviours is very difficult.

It is important to note that determining the archaeological use of ochre for any of these methods is a challenging task. These will not leave traces in the record- ochre spread on an individual's skin as sunscreen, or used for medicinal purposes, will not be found in association with their remains. At most, archaeologists may recover ground ochre as a residue or powder, or traces of it on lithics- but "*because ochre powder could have been put to diverse uses, processed ochres do not necessarily represent the direct outcome of specific functional or symbolic behaviours"* (Rifkin 2011, 133).

3.3 Ochre use in the early Cypriot Neolithic

Ochre is not known from the Cypriot Epipalaeolithic. However, excavations at both of the known Pre-Pottery Neolithic A sites- Ayios Tychonas-Klimonas and Ayia Varvara-Asprokremnos- recovered ochre and pigments.

Excavations at Ayios Tychonas-Klimonas recovered 143 samples of "colouring materials" in red, yellow, black and green (Puaud & Lebon 2023, 393). Thirty of these samples were analysed with both X-Ray Diffraction (XRD) and X-Ray Flourescence (XRF) Spectrometry, which was able to correlate the green materials with a picrolite source in the Kouros Valley. The reds, yellows and blacks were tentatively linked to the southern margins of the Troodos. The potential uses of this material were not discussed in detail.

The excavations at Ayia Varvara-Asprokremnos, meanwhile, recovered a very large amount (>20kg) of ochre, in a range of colours including reds, greens, yellows, blacks, and purples. In addition, ground stone tools with ochre residues were found at Ayia Varvara-Asprokremnos. The excavators performed use-wear analysis on eleven of these tools (McCartney & Sorrentino 2019), as well as a portion of the chipped stone tool assemblage, and came to similar conclusions as the team excavating the Natufian Hilachon Tachtit Cave site described above: that is, the lithics assemblage may be indicative of the use of ochre in tanning leather. The presence of arrowheads and some of the faunal remains from Asprokremnos both suggest that hunting was occurring. As such, all the required resources for leather tanning- animal hide, stone scrapers, and ferric ochres- were present at the site. However, the absence of preserved leather throws some doubts onto its likelihood.

That said, evidence for any kind of leather production- irrespective of the method- is sparse until later periods, largely due to preservation issues. Ceramic imitations of leather objects are known from the 3rd Millenium BC (Rizopoulou-Egoumenidou 2009, 6), but none of the objects they are imitating have been found. Clay and limestone pot bellows dating to the Late Bronze Age would have needed leather components to operate (Kassianidou 2011), yet these were not preserved. Direct evidence for leather production, outside of the lithics assemblages described above, is not known until the Late Roman period- a potential tanning or dyeing workshop was discovered at Amathous (Rizopoulou-Egoumenidou 2009, 12). Even then, leather remains incredibly rare in the archaeological record. As such, it is unsurprising that leather artefacts from the Neolithic have not been preserved. A lack of recovered artefacts does not preclude their production.

Thus, while the evidence for leather tanning with ochre is limited, this hypothesis cannot be discounted. Hilachon Tachtit- the Natufian site in Israel with the strongest lines of evidence for this practice- predates Asprokremnos by around 200 years. The origins of the Epipalaeolithic/PPNA migrations into Cyprus remains a contested topic, yet the Levant is a likely source. While there is no evidence that these sites are associated with each other in any way, the possibility of cultural or behavioural links between these locations is an intriguing possibility.

Ochre has been recovered from Ceramic Neolithic and Chalcolithic sites on the island, often with more straightforward associations and uses than those seen in earlier periods. Red-painted pottery which utilises red ochres as pigment first appear in the early Ceramic Neolithic at Choirokoitia. These vessels are found at multiple sites on the island from the Ceramic Neolithic through to the Middle Chalcolithic (Bolger & Shiels 2003). Likewise, the application of red ochres to lime plaster floors and walls can be characteristic of Chalcolithic-era houses (Dalton 2019, 96), but its earliest appearance is at Choirokitia during the PPNC (Papadopoulous 2021). However, no PPNA or PPNB site on the island has produced evidence for ochre being used in either of these ways. Ochre in the early phases of the Cypriot Neolithic appears to leave a far less tangible record, and its intended uses can only be theorised.

4. Cypriot Archaeology

4.1 Epipalaeolithic Archaeology of Cyprus

Relatively few sites dating to the Epipalaeolithic and early Neolithic have been excavated in Cyprus so far: only three Epipalaeolithic sites have been published so far (Figure 11), alongside two PPNA sites. There is then a substantial increase in evidence, with many more PPNB and PPNC occupation sequences reported in the literature.

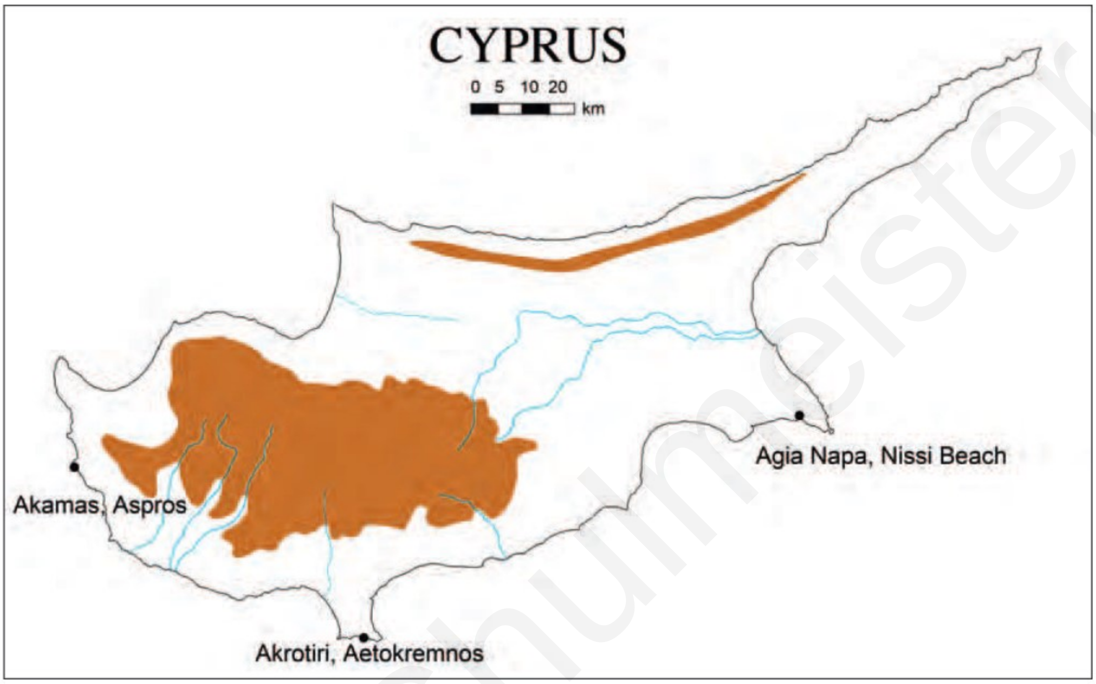


FIGURE 11: Locations of the three (potential) Epipalaeolithic sites currently known in Cyprus. Fig. from Ammerman et al. 2011, 264.

The earliest known occupation site on Cyprus is, at present, the Epipalaeolithic rock shelter at Akrotiri-Aetokremnos, dated to around 12 000 BP (Simmons 2014). The site is known for its lithics assemblage and also, importantly, for a wide variety of faunal remains found within the shelter, including large numbers of pygmy hippopotami. This site was excavated in the late 1980s and generated a great deal of controversy in the field- prior to this point, evidence for human occupation of any Mediterranean island prior to the Pre-Pottery Neolithic B was scant at best, and arguments for paleolithic-era seafaring were often challenged if not dismissed outright (Cherry 1990; Broodbank 2006). The well-supported radiocarbon chronology of this site forced this narrative to be reconsidered. In addition, the excavators of Akrotiri-Aetokremnos associated human activity at this site with the extinction of pygmy hippopotami (Simmons 1988), an event which had previously been linked to climatic changes alone. However, this suggestion was not without controversy- other researchers have since suggested that the faunal remains at Aetokremnos are not directly associated with human activity at all. It is argued that the drought conditions of the Younger Dryas may have led to the species' extinction (Zazzo et al. 2015), with the faunal assemblage of the site simply reflecting centuries-worth of animal deaths within a cave that was later occupied by humans. However, the association between the hippopotamus remains and the occupation layers is a strong one, and the stratigraphy of the site does not appear to have been substantially disturbed. The faunal assemblage also shows more in common with modern ecological studies of animal culls than of natural die-offs, in terms of demographics, thus suggesting that there was at least some degree of human involvement in the event (Simmons & Mandel 2016). A group of hunter-gatherers could easily have landed the final blow on a small remnant population of hippopotami already suffering from climatic stressors.

It is interesting to note that Aetokremnos appears to represent an “occupation” event rather than a “colonisation” one, as it was in use for a relatively short period of time, and does not appear to have direct continuity with any of the PPNA or PPNB settlements which followed (Simmons 2007). It has been argued that a two-stage migration process- that is, an initial wave of “scouts” followed later by permanent settlers- is a common pattern observed in many migrating groups throughout history (Fiedel & Anthony 2003, 153). However, in the case of Cyprus, the precise links between these Epipalaeolithic campsites and the later permanent settlements remains unclear, and the time scales involved may well be too large for a direct link to be established.

The occupation at Aetokremnos has been tentatively associated with groups of seafaring fisher-foragers from the nearby Levantine coast (Knapp 2020), perhaps venturing to the island for the first time due to climatic changes at the end of the Younger Dryas impacting their subsistence base. Interestingly enough, one of the other PPNA sites- Aspros Dive Site C, discussed below- has been linked, instead, with a population migrating from the shoreline of Southern Turkey (Ammerman 2020). Thus, it is possible that there were several contemporary migration events to the island, perhaps all driven- to some degree- by climatic stressors. The end of the Younger Dryas would have brought with it a warmer and wetter climate, which may well have made Cyprus more hospitable to human occupation by both farmers and foragers, from around the early PPNA onwards (Manning 2014).

Aside from Akrotiri-Aetokremnos, only two other (potential) PPNA sites are known on Cyprus although the dating is still contested for these. In the early 2000s, Albert Ammerman and colleagues investigated a number of fossilised aeolian dune fields around the coast of Cyprus. Two locations produced finds assemblages- Akamas-Aspros, and its satellite site of Alimann, both on the west coast, and Ayia Napa-Nissi Beach, in the southeast. While these locations are on the coast today- and part of the Aspros assemblage was recovered underwater – a significant marine transgression occurred during the Holocene, and the coastline in this area has therefore shifted dramatically. Today, the Mediterranean Sea is about 70m higher than it was 12 000 years ago (Simmons 2014b, 162). Given the relatively shallow slope of the coastal seabed in this area, such a change easily translates to hundreds of metres’ difference in the topography of the coastline. These sites, therefore, would not have been “coastal” occupations in the sense of being located on the beach as they are today, and were instead located some distance inland and with some degree of elevation (Figure 12).

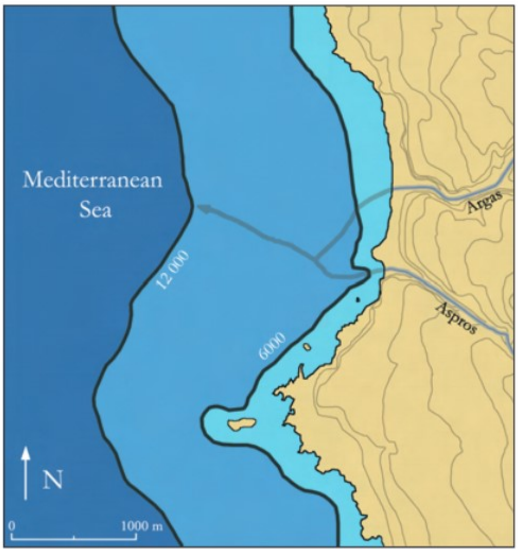


FIGURE 12: Coastline change at the Akamas-Aspros site over the Holocene. The black lines on this map indicate the location of the shoreline at 6000 and 12 000 cal years BP, while the grey indicates the paleochannel of the Argas and Aspros rivers. Fig. from: Ammerman et al. 2011, 264.

Despite the changes in landscape, these locations would have been desirable campsites at the time of their use. Aspros Dive Site C, for example, is located near the old channel of the Aspros River, meaning the site would have likely had access to fresh water. The aeolianite rock of this area has a variable pattern of erosion, and is generally less lithified with depth. As such, lower sections of vertical cliffs will generally erode faster, leading to the creation of overhanging outcrops, which could be used as shelter. Aspros Dive Site C features one such location, with the cliff on the north bank of the Aspros River proving particularly resistant to erosion from the marine transgression (Ammerman et al. 2011). The nearby beaches would have served as natural harbours for boats, at least during the summer months. While there were relatively few terrestrial resources available, there would have been an abundance of both marine resources and avian wildlife. Lithics represent the majority of material recovered from these sites, however, there is also shell material in the assemblage- both ornamental and food waste- and some avian bones (Knapp 2013, 60). Arguably, shellfish and avifauna were the primary resources that this population were utilising here (Zeman-Wiśniewska 2018).

Given the evidence for the exploitation of marine resources, Ammerman et al. interpret these sites to be representative of coastal foraging behaviour. They also claim that the occupations are epipalaeolithic in age, based primarily on the styles of lithic reduction technologies found at these sites. In particular, the underwater survey performed at Aspros Dive Site C recovered 38 pieces of chipped stone from the surface of the seabed (Ammerman et al. 2011). This material showed a striking similarity to that observed in the Ökuzini Cave in Turkey, an epipalaeolithic site, which may suggest links between Cyprus and Anatolia during this period. The researchers argue, therefore, that there was a pattern of coastal foraging behaviour occurring in early Neolithic Cyprus, with groups from the mainland –perhaps both Anatolia and the Levant – establishing camps on the island for the first time (Simmons 2014b, 161). Thus far, there does not seem to be any real continuity between these seasonal foraging camps and the more permanent settlements seen in the PPNA and PPNB.

However, there are some issues with this interpretation. Firstly, neither Nissi Beach nor Aspros have been fully excavated. At present, the exact scale of their occupation, both spatially and temporally, is unknown. There are also some questions about the context of the artefacts recovered, and the possibility that the stratigraphy is disturbed. In particular, Aspros Dive Site C- while an interesting proof of concept for underwater survey work- is particularly difficult to establish continuity for. Although 38 pieces of chipped stone were recovered from the seabed (Ammerman et al. 2011), but even the surveyors admit that searching for small fragments of lithic material, in a sandy seabed, underwater, is a challenge even for experienced maritime archaeologists. It is likely that some artefacts were missed by the surveyors due to the working conditions. In addition, this material is not in situ. At present, it is impossible to establish with any degree of certainty if this cluster of finds is: a) an archaeological site in and of itself, b) an extension of the larger (and largely unpublished) assemblages found on land, or c) simply a location where ocean currents have deposited material from a number of other sites in the region. There is also a complete lack of chronometric dates for this site, and the PPNA chronology is based entirely on the style of the lithic reduction technology.

Findings at Nissi Beach were somewhat more extensive, however, many questions remain unanswered. Material was collected from both surface surveys and test excavations at this site, with the finds – primarily lithics, alongside shellfish and avian faunal remains – recovered primarily from a B horizon soil that reaches around 30-40cm depth, although almost all artefacts were recovered from the top 25cm (Knapp 2013, 60). Two marine shells recovered from these layers were dated with radiocarbon to 7592-7551 cal BC and 7586-7547 cal BC respectively. Thus, this encampment appears to date to the Cypriot PPNB, not to the epipalaeolithic as the finds assemblage might suggest (Howitt-Marshall 2021, 241).

Clearly, further study is necessary at both of these aeolian dune sites. While the existence of the Aspros and Nissi Beach assemblages raises the possibility of additional, very early sites on the island, and highlights the importance of considering sea level changes when surveying, neither of these are conclusive evidence for epipalaeolithic occupation. There likely was a period of coastal foraging and exploration in Cyprus during the Epipalaeolithic, yet thus far, the archaeological evidence for this is incredibly limited. Current understanding of the earliest phases of human occupation is still entirely reliant on the excavations at Akrotiri-Aetokremnos.

4.2 The Cypriot PPNA

There are so far only two PPNA sites known from Cyprus. Both have been excavated, and one of the two published in full.

The settlement at Ayios Tychonas-Klimonas has been known since 1989, when a survey of the hinterland of the city-kingdom of Amathous identified two clusters of Neolithic activity in the area- one at Parekklisia-Shillourokambos, a PPNB site, and one at Klimonas (Vigne et al. 2023a, 25). However, it was not until 2009 that Klimonas was excavated, with the French School at Athens running several seasons between 2009 and 2016 (Vigne et al. 2023b).

The excavations revealed a PPNA village, notable for both its size and its similarity to equivalent PPNA settlements in the Levant. There is a large communal building in the centre of the site- a round structure with a diameter of around 10m (Figure 13). Surrounding it are a large number of smaller structures, most with diameters between 3m and 6.4m (Vigne et al. 2023a, 555). These are also round or oval-shaped constructions, made of earth with timber supports. They are either notched or partially dug into the slope of the hill, and generally feature non-structural hearths and east-facing entrances. Some of the larger structures contain earthen benches, features such as threshold stones and access ramps are found in some of the buildings. The structures were probably covered with flat, slightly sloping, roofs.

FIGURE 13: The large communal building St10 at Ayios Tychonas-Klimonas. Fig. from: Mylona, Wattez & Vigne 2023, Fig. 2.

The settlement probably covers somewhere between 5500m^2 and 9000m^2, although it was not excavated in full and only about half a hectare is preserved (Vigne et al. 2023a). Between the size of the site and the existence of the large communal building, Klimonas shares a number of similarities with PPNA villages in the Levant (Finlayson & Makarewicz 2017; Clarke & Wasse 2019), which is generally assumed to be the origin of this wave of settlement. This is further supported by the presence of wild emmer, which does not grow endemically on Cyprus and must have been introduced from the mainland; as well as the chipped stone industry, which shows marked similarities to material from Levantine sites such as Mureybet and Sheikh Hassan (Vigne et al. 2012).

Ayios Tychonas-Klimonas was dated to around 8800 cal BC (Vigne et al. 2017a), with a relatively short period of occupation- perhaps less than a hundred years. There does not appear to be direct continuity between the settlement at Klimonas and any of the PPNB sites on the island. That said, Parekklisia-Shillourokambos is located nearby and does exploit several of the same resources as Klimonas, including hunting of the endemic species of wild boar (Cucchi et al. 2021) and a lithics industry based on the high-quality flint resources in the Athiaki Valley (Vigne et al. 2017b, 23). Thus, the possibility of links between these should not be entirely disregarded.

Aside from Ayios Tychonas-Klimonas, only one other PPNA site has been excavated. A full description of Ayia Varvara-Asprokremnos is provided in a later section. In brief, this site was more likely to be a seasonal campsite than a permanent settlement like Klimonas. Only three structures existed at Ayia Varvara-Asprokremnos, each of which appears to have been used sequentially, meaning the site likely featured only one extant building at any given time during its occupation. Artefacts recovered from within these structures led the excavators to interpret these as workshops rather than residences (McCartney & Sorrentino 2019). Where Klimonas is notable for its structures and the scale of the village, Asprokremnos is almost entirely dominated by its lithics assemblage, which exceeds 3000kg in weight (McCartney 2017) and contains both chipped and ground-stone tools. Given its location in a geologically complex area, the scale of the lithics industry at the site, and the apparent lack of evidence for urban activity or any form of agriculture, Ayia Varvara-Asprokremnos has been hypothesised as a temporary encampment, specifically used by the Neolithic population of Cyprus for accessing mineral resources in the area.

Ayia Varvara-Asprokremnos was occupied between 8900-8600 BC (Manning et al. 2009). This places it as contemporary to the settlement at Ayios Tychonas-Klimonas. At present, there is no direct evidence- archaeological, genetic, or otherwise- that these two sites were occupied by the same population. However, their chronological overlap and geographical proximity mean that a relationship of some sort existing between the two is quite likely, and a shared origin is definitely possible. Further analysis of these site assemblages, preferably in tandem, would allow for more conclusions to be made here.

4.3 The Cypriot PPNB

A substantially larger number of sites are known from the Cypriot Pre-Pottery Neolithic B, and are located all over the island. Both Parekklisia-Shillourokambos and the recently discovered site of Pakhtomena-Armenokhori are in the vicinity of Ayios Tychonas-Klimonas, in the Limassol area (Briois et al. 2023). Kalavasos-Tenta is further inland, closer to Nicosia, while Kissonerga-Mylouthkia and Ais Giorkis are in the west (Figure 14). There is a small rural sanctuary, Kataliondas-Kourvellos, located near Ayia Varvara-Asprokremnos itself, which was also occupied during this PPNB (Birchler Emery et al. 2017), and it is likely that a number of other sites are not yet known to archaeologists.

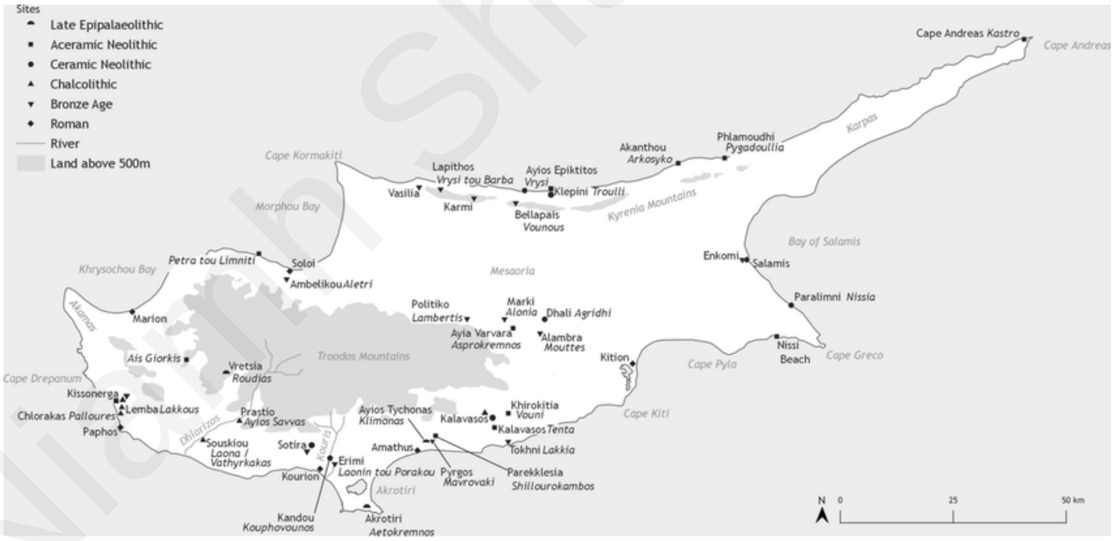


FIGURE 14: Locations of many of the important archaeological sites of Cyprus, dating from the Epipalaeolithic to the Roman period. Fig. from: Knapp 2020, 423.

The beginning of the Cypriot PPNB may potentially represent a secondary wave of migration to the island. This phase does not follow the same general trends as the PPNA-PPNB transition on the mainland. Instead, PPNB traditions and technology were adopted differently (if at all) than in the Levant, resulting in a Neolithic tradition which was regarded as unusual for the region in this period (Simmons 2009). Cattle were introduced to the island for the first time, although these would later go extinct and be introduced a second time in the Middle Bronze Age (Spyrou et al. 2024). It is possible that there was a secondary wave of migration from southwest Asia during this period, bringing animals, plants, a distinctive chipped stone industry, and burial practices (Peltenburg et al. 2000). However, many PPNA practices continued past the establishment of agriculture in Cyprus, despite being abandoned on the mainland (Clarke & Wasse 2019). The Cypriot PPNB was in many ways an “archaic” tradition for this period, and it has been argued that this was a deliberate choice by its inhabitants, perhaps as a population from Upper Mesopotamia sought to avoid the rapid changes and intensification of the mainland PPNB.

Thus, there is limited continuity between the PPNA and PPNB sites known in Cyprus. Both Ayios Tychonas-Klimonas and Ayia Varvara-Asprokremnos were abandoned prior to the PPNB, and there is no direct evidence at present that the populations of these sites were the same populations who established settlements such as Parekklisia-Shillourokambos. There are a number of outstanding archaeological questions in regards to the transition between these two periods, and more work in this area would be welcome.

5. Excavations at Ayia Varvara-Asprokremnos

5.1 Introduction and excavation history

Ayia Varvara-Asprokremnos is the only other PPNA site which has been excavated in Cyprus. The site is located inland, near the modern town of Ayia-Varvara, and close to the Gialias River (Figure 15). The area was first surveyed in 1995 (McCartney n.d.), with additional surveys performed in 2003, and then 2005, in preparation for the *Elaborating Early Neolithic Cyprus* (EENC) project (McCartney & Sorrentino 2019). The EENC project then ran seven seasons of excavations at the site between 2006 and 2013. All of the archaeological data collected from Ayia Varvara-Asprokremnos was done under the aegis of the EENC project. However, *the Idalion Survey Project* and the *Tremithos Neolithic Survey* also occurred in this area, and have provided important context for the chert sources in this region (Stewart et al. 2020).

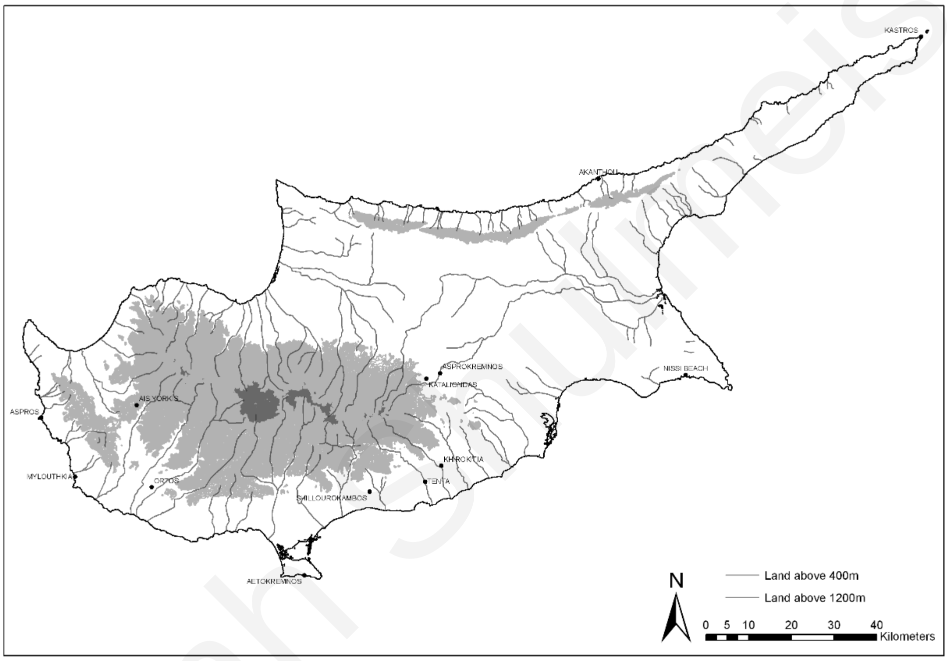


FIGURE 15: Location of early Neolithic sites, including Ayia Varvara-Asprokremnos, with waterways marked. The Gialias river, originating in the Troodos and flowing east into Famagusta Bay, passes close to the Asprokremnos site. © C. McCartney: Ayia Varvara-Asprokremnos Excavation Archive.

Excavations at Ayia Varvara-Asprokremnos revealed a site which most likely served as a temporary camp, rather than a permanently occupied village like Klimonas, although the two are contemporary to each other. Six radiocarbon dates from securely-stratified charcoal have dated the site to between 9141 cal. BC and 8569 cal. BC at 95.4% probability (Manning et al. 2009). Within this range, the site was likely occupied for around three hundred years, with three main phases of use, each associated with one primary structure that was only in use for that particular phase (McCartney & Sorrentino 2019). Each successive structure was erected south of the previous one, shifting around the edges of a large depression or pit, described below (Figure 16).

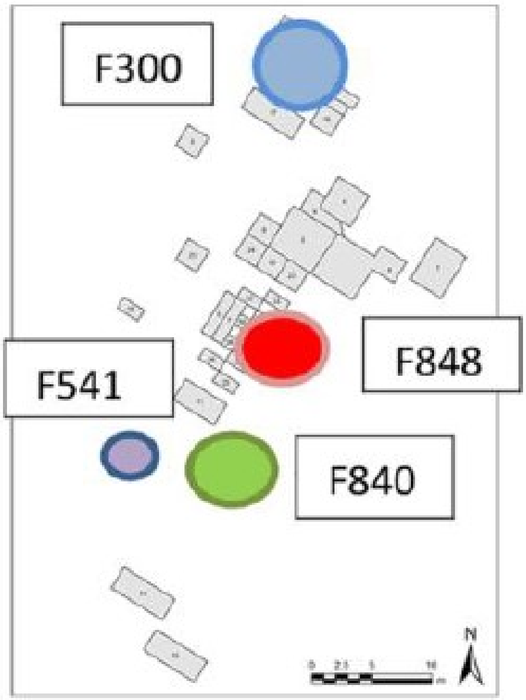


FIGURE 16: Site plan of Ayia Varvara-Asprokremnos, showing the locations of the three structures and the dump feature- F541 is a pit within dump feature F539. Figure from Rousou 2022, fig. 15.

5.2 Ayia Varvara-Asprokremnos: Structures and major features

The structures are subterranean round buildings, substantially smaller than the central structure at Klimonas: the earliest has a diameter of only 5m (Figure 17), and the latter two are both 4.5m wide (McCartney 2017; Figure 17). However, their construction methods do appear similar, with the structures cut into the havara/sediment and some postholes preserving evidence of timber supports. Thus far, there is no direct evidence linking the population at Ayios Tychonas-Klimonas with that of Ayia Varvara-Asprokremnos, however, the technologies used at both sites are markedly similar, and suggesting that there was some degree of connectivity between the two is not an unreasonable assumption.

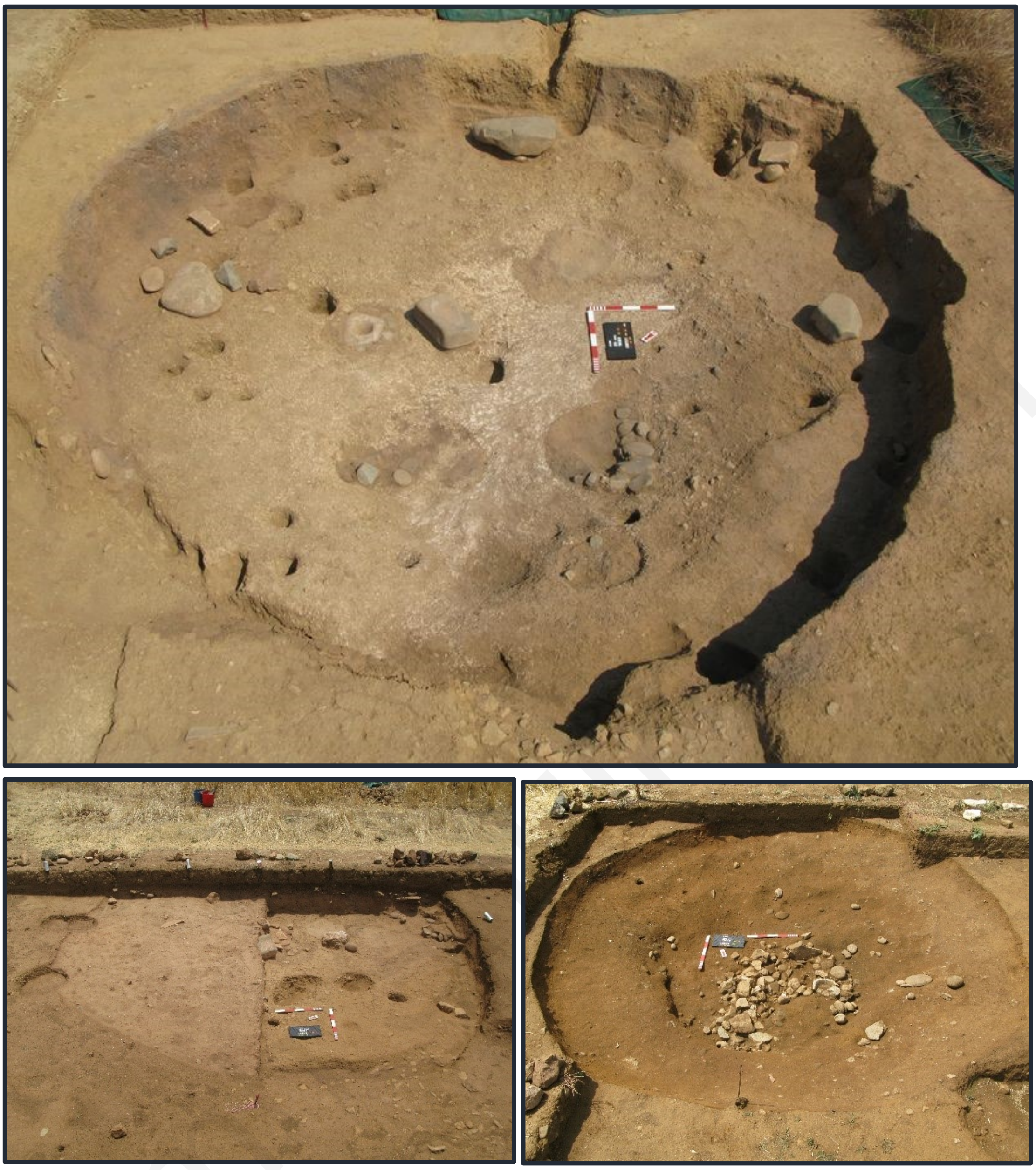


FIGURE 17: The three structures at Ayia Varvara-Asprokremnos: F300 (top) is the earliest in date, followed by F848 (bottom left) and then F840 (bottom right). © C. McCartney: Ayia Varvara-Asprokremnos Excavation Archive.

These three structures were in use sequentially: the uppermost layers of the earliest structure F300 are ashy layers with large amounts of debitage, and were interpreted by the excavators to be associated with activity in F848, the following building. This structure is, in turn, sealed by a hearth feature, which is itself associated with activity around F840, the final structure at this site.

In addition to these structures, there is a large, natural depression located in the centre of the site that was used as a dump for lithics material and debitage (McCartney et al. 2008). Most of the lithics material from the site was recovered from this feature, although a substantial number of artefacts were found within the structures as well. This includes a limestone bowl, recovered from the earliest of the three buildings, which had been deposited with ochre nodules in the base and deliberately buried prior to the building's abandonment (Figure 18).

FIGURE 18: Vessel G389; a limestone bowl with ochre nodules filling a hole in the base, at various stages of excavation and cleaning. © C. McCartney: Ayia Varvara-Asprokremnos Excavation Archive.

5.3 Ayia Varvara-Asprokremnos: The lithics assemblage

The lithics assemblage of Ayia Varvara-Asprokremnos is a very large one. Circa 3000kg of chipped stone was recovered during the excavations, along with more than 1300 ground stone objects (McCartney 2017). All stages of lithics production were found, from blanks to completed objects: of the 2333 chipped stone artefacts recovered from the dump feature in the centre of the site, 894 were classified as "tools". The rest were debitage or other byproducts of the manufacture process, indicating that this was an important production site (McCartney & Sorrentino 2019). Due to the amount of lithic material recovered, only a small percentage of the assemblage has been studied in detail thus far. The results found are summarised below.

5.3.1 Ayia Varvara-Asprokremnos: Ground stone tools

Most of the ground stone tool assemblage remains unstudied. Use-wear analysis was performed on only eleven ground-stone tools associated with ochre processing, nine recovered from a "workshop" context in building F840- that is, the structure corresponding to the third and final phase of the site (McCartney & Sorrentino 2019). All of these tools had traces of pigments on them and can, therefore, be associated specifically with ochre processing with a degree of confidence. Of the eleven tools, four were identified as pounders, three as grinders, and four as either grinding slabs or quern stones (McCartney & Torrentino 2019).

Some of these tools were made from chalk, although most were from volcanic material presumably sourced either from the Troodos directly, or from cobbles taken from the nearby Gialias River. Chalk appears to be used only for grinding slabs, not pounders or grinders, which may be due to the size of these artefacts. Chalk was locally available at large scales, while the easiest local sources for igneous stones would be river cobbles- and these may not have been large enough to produce the more sizeable artefacts. Creating a quern stone from diabase or gabbro may have required a trip into the Troodos mountains themselves, so the inhabitants of the site may have used the locally available chalk rather than venturing further afield. On the other hand, all of the pounders were formed of volcanic materials such as diabase. River cobbles are the most likely source of the material for these tools, as they were readily available.

5.3.2 Chipped stone tools

2333 chipped stone artefacts were recovered from one dump feature (F539), of which 894 were classified as “tools” (McCartney & Sorrentino 2019). This discrepancy in numbers between “artefacts” and “tools” emphasises the degree to which Ayia Varvara-Asprokremnos was a production site, as all stages of manufacture have been identified in the assemblage. Interestingly, however, this was not just a manufacturing location, as many of the tools recovered show evidence of use as well (Ktori 2010).

There does not appear to be any substantial shift in core technology over the occupation history of the site (McCartney n.d.). This is unsurprising: the site was likely only occupied for three hundred years or so at most (McCartney 2010), and on a seasonal basis at that. While some aspects of production evolved over that period, something as fundamental as a shift in core shaping may well require both a longer time period and a more permanent industry than what is observed at Ayia Varvara-Asprokremnos.

FIGURE 19: Some chert cores from the 2008 season at Ayia Varvara-Asprokremnos. © C. McCartney: Ayia Varvara-Asprokremnos Excavation Archive.

Multiple different methods for core shaping are present from the earliest phases of the site. 142 cores were studied in detail (McCartney n.d.), of which roughly 86.72% are associated with blade or bladelet production. Of these, 90.24% are uni-directional (Figure 19), 6.5% are bi-directional, and about 3.25% are associated with burin-type cores. Discoidal and change-of-direction flake cores, while present, constitute a nearly negligible part of the sample.

Clearly, blade production was the most common sub-industry of chipped stone tools at this site, and the vast majority of these were made through uni-directional flaking. That said, most cores utilising this method- roughly 59.46% of all uni-directional cores - rely on a secondary distal platform in order to further shape the blade, perhaps indicative of a gradual convergence towards bi-directional core methodologies.

Many of the cores also show evidence for reshaping during the production process, to allow for the continued manufacture of bladelets.

5.3.2.1 Arrowheads

Over 100 arrowheads recovered from the Asprokremnos excavations (Figure 20). These represent c. 4.1% of the chipped lithics assemblage (McCartney n.d.) and appear to show two different methods of production: some are formed on a narrow blade or bladelet and have a short, lozenge-shaped tang, while others have a tang formed through convex basal truncation. Many, from both styles, have retouch along the edges. Interestingly, not all of the arrowheads show evidence of use.

FIGURE 20: Some of the arrowheads found at Asprokremnos. © C. McCartney: Ayia Varvara-Asprokremnos Excavation Archive.

While arrowheads have been found at other early Cypriot sites (e.g. Vigne et al. 2012), they are generally not associated with later phases of the Cypriot Neolithic, and disappear entirely by the time of the Khirokitia Culture (Le Brun 2005). Thus, their presence at Ayia Varvara-Asprokremnos raises questions about trade links and contact between Cyprus and the Levant at different points in its history. These arrowheads are evidence that Asprokremnos, like Klimonas, probably had some contact with the Levant during its occupation. However, these links do not appear to continue into the PPNB. The apparent abandonment of this technology is one of several lines of evidence used to argue for a secondary wave of migration onto the island in this period, with a different cultural group responsible for the construction of sites such as Shillourokambos and Mylouthkia.

5.3.2.2 Other tools

A number of other lithic tools are found in the assemblage of Ayia Varvara-Asprokremnos. Details for some of these are shown in the table below.

% Assemblage	Type	Notes
22.5%	Burin-edge tools	Multiple methods of manufacture are known, including the reuse of other types of tools
5.6%	Scrapers	-
4.9%	Perforators	Some perforators appear to be made from reused arrowheads. Some also show evidence for is retouch.
11.5%	Notches	These tools have been theorised as being associated with stone bowl production due to their contexts.
5.1%	Truncations	These are often used as hafting devices, and appear to have been frequently retouched.
1.3%	Glossed tools	Primarily made on short blades and bladelets

FIGURE 21: Additional types of chipped stone tools recovered in the Asprokremnos excavations. © N. Shulmeister, After McCartney & Sorrentino 2019.

Overall, bladed tools dominate the chipped stone assemblage by a substantial margin. However, there were a number of other tools produced, with a wide variety of purposes, although further use-wear analysis would be beneficial for interpreting the assemblage. A minimum of 27.4% of the tools recovered from the site show some evidence of use, although the tools were assessed at a low magnification and further study may show that this percentage is actually far higher (McCartney n.d.).

5.4 Ayia Varvara-Asprokremnos: Ochre

As stated above, eleven ground stone tools with ochre residues were analysed as part of an investigation into the potential uses of ochre, particularly in relation to the possibilities of hide tanning. However, the ochre material itself has not been studied prior to this thesis.

About 20kg of ochre was recovered across all excavation seasons. McCartney considered this amount to be particularly notable, commenting that this *"could not have been processed for use only on-site or even on the island of Cyprus. Rather, it seems more likely that pigments, along with arrowheads made of superior quality cherts, were produced at Asprokremnos as commodities for export to the mainland"* (McCartney & Sorrentino 2019, 75). The feasibility of this argument is considered in the discussions section of this thesis. However, it is important to note that at present, no geochemical sourcing study has been performed that covers both Cypriot and Anatolian/Levantine sites. Long-distance pigment transport in the Neolithic does not appear to be a well-documented concept in the Near East, although the possibility should not be entirely discounted. While the context is incredibly different, the Indigenous population of Australia sometimes travelled huge distances to collect pigments, even when local sources were available- one ochre mine at Wilgie Mia in Western Australia was known to be part of trade routes stretching across the state, and potentially as far as Queensland (Mulvaney & Kamminga 1999, 28-30), a distance of at least 2000km. Dieri people from the Cooper Creek region travelled up to 500km annually to collect ochre from the Bookartoo (Parachilna) quarry in the Flinders Ranges (Mulvaney & Kammminga 1999, 31), with upwards of 70 men returning with 30kg loads of ochre each time. While moving ochre from Cyprus to the Levant would require a sea journey, the distance itself is much shorter than these cases. If the Asprokremnos assemblage is, truly, too large to be explained through local industry, then exports to the mainland were certainly possible.

5.5 Ayia Varvara-Asprokremnos: Other finds

The faunal assemblage consists almost entirely of suid (pig) remains, with isolated finds of avian bones. Given that there is no evidence for animal pens at the site, the excavators assumed that these were wild animals, and the population were hunters, rather than farmers raising a domesticated species. The exploitation of wild boar on Cyprus first appears at Akrotiri-Aetokremnos – that is, the earliest site currently known on the island – and it is likely that these animals were introduced to Cyprus by humans specifically to serve as a food source (Vigne et al. 2009). Suid remains are a common appearance at Cypriot sites through the PPNB, with Shillourokambos in particular being known for its faunal assemblage as well.

The botanical assemblage has not been studied yet, but appears to be minimal, with a small amount of carbonised material recovered from flotation but few, if any, seeds or pollen samples recovered.

While Asprokremnos is located about 25km from the coast, some marine shells were also found at the site. Several – particularly from the *Spondylus* genus – were worked into ornaments, and often pierced. They appear to have been used primarily as decoration rather than a food source, although a dual use cannot be entirely discounted. Stone picrolite beads were also found, primarily composed of picrolite, although the shell ornaments were far more numerous (Figure 22).

FIGURE 22: Some of the ornaments found during the excavations- mollusc (left, M 270), picrolite (middle, O24), and shell (right, M 271). © C. McCartney: Ayia Varvara-Asprokremnos Excavation Archive.

5.6 Ayia Varvara-Asprokremnos: Summary

Overall, the excavations at Ayia Varvara-Asprokremnos uncovered a very large assemblage of lithics- both chipped and ground stone tools- in various stages of production and use. The excavators also recovered a notable amount of ochre. However, very few structures were found- only three buildings were identified, and these appear to have been used sequentially rather than simultaneously. Botanical data from this site was minimal. While it has not been analysed in detail yet, the assemblage does not appear particularly notable, with a small amount of carbonized material emerging in flotation but no real evidence for agricultural activity present. Faunal remains are almost entirely suid, and probably associated with hunting rather than animal husbandry. Personal ornaments were found, although these were dispersed across the site, not associated with remains as grave goods or otherwise deposited in an apparently intentional manner.

The relative sparsity of any archaeological material other than ochre, stone tools, and the debitage associated with their production has led researchers to suggest that occupation may have only occurred seasonally at Ayia Varvara-Asprokremnos (McCartney n.d.). It is likely that this site served as a semi-permanent camp, associated with the collection and processing of mineral resources. The three structures most likely served as workshop spaces rather than residences. While there is no direct link between the sites, Ayia Varvara-Asprokremnos is best interpreted as a satellite for a larger settlement such as Ayios Tychonas-Klimonas rather than its own unique cultural unit.

6. Methodology

6.1 Sample collection and selection

Ochre material studied in this project was obtained from a variety of sources.

Most of the material analysed here was found during the excavations at Ayia Varvara-Asprokremnos, performed under the aegis of the *Elaborating Early Neolithic Cyprus* (EENC) project between 2005 and 2013. Both stone tools and ochre were recorded as finds in the project database, with all objects of these types recorded in detail during the course of the excavations. Since Dr Carole McCartney passed away in 2021, this material has been held in the storage of the Department of Antiquities at the Cyprus Museum, who granted a permit for this material to be studied for this thesis.

All ground stone tools held by the Department of Antiquities were checked visually for macroscopic traces of ochre. In total, 45 artefacts with potential residue traces were identified, and all of these were photographed, then analysed in more detail according to the methodology described below. However, it is important to note that this dataset is definitely incomplete. There is one stone bowl with ochre traces currently on display in the Cyprus Museum, and it was not possible for this artefact to be removed for analysis. In addition, McCartney and Sorrentino (2019) published some use-wear analysis of ground stone tools with ochre traces from this site. In their study, they identified eleven artefacts with ochre residues preserved. However, these artefacts are currently stored at the depot of the Lemba Archaeological Project, not the Cyprus Museum, and could not be re-assessed for this project.

There were several thousand individual pieces of ochre recovered from the Ayia Varvara-Asprokremnos excavations. The excavators estimated that 20kg of ochre had been found across the project's entire history (McCartney 2017). Most of this material was recovered as small, <1cm pieces, weighing only a few grams each.

Thus, due to time constraints and also limitations from the analytical methods, not all ochre pieces were studied. Instead, all samples that did not have at least one piece of ochre greater than approximately 1.5cm in diameter were removed from the dataset. This measurement was chosen for ease of handling the material, and also due to the size of the p-XRF: while the X-ray beam is only about 3mm (Olympus n.d.), it is difficult to position the p-XRF to allow for an accurate reading of a sample that is substantially smaller than the window of the device itself. Removing the smallest samples left a total of 301 pieces of ochre in the dataset. All of these were photographed and entered into the catalogue (Appendix 1).

Reference material for sourcing studies was collected from the surrounding landscape. In 2023, thirty reference samples were collected from seven mine sites around the study area. Mine sites were chosen for this purpose due to their proximity to Ayia Varvara-Asprokremnos, the easily identifiable ochre outcrops at these locations, and the ease of access. 30 samples allowed for multiple colours of pigment to be collected from each mine site, dependent on what was available in the landscape.

6.2 Sample analysis

All material – stone tools, ochre artefacts, and reference material – was photographed according to standard archaeological methods. Munsell colours were identified for the ochre material. Then, all samples were analysed via portable X-Ray Flourescence (p-XRF). This method was chosen as p-XRF was the only analytical method which could be performed within the Archaeological Research Unit of the University of Cyprus itself. In addition, it is a non-destructive analytical method which produces very fast results, and was therefore ideal for analysing a large dataset such as the ochre material from Ayia Varvara-Asprokremnos. The device used was an Olympus Vanta handheld XRF scanner equipped with the Olympus, (Tokyo, Japan) "Geochem" Suite. Analysis of the elemental composition was performed using an X-ray source with the voltage set to 8–40 kV, which enabled measurements of major and minor elements (Mg; Al; Si; P; S; K; Rb; Ca; Sr; Ti; V; Cr; Mn; Fe; Co; Ni; Cu; Zn; As; Se; Y; Zr; Nb; Mo; Ag; Cd; Sn; Sb; W; Au; Hg; Pb; Bi; Th and U).

Statistical analysis was performed on the results using the computing program R (R Development Core Team, 2008). Principal Component Analysis (PCA) were performed on the XRF data using the *prcomp* function. Dendrograms were created with the *hclust* hierarchical clustering formula, with the *dendextend* package providing additional support. The centroid method of clustering was used to generate all tree diagrams, with Euclidean distance.

6.3 GIS and mapping

ArcGIS was used to make maps of the site area. The location of Asprokremnos itself was determined based on a combination of satellite images and cadastral maps. The reference sources for the ochre were all taken from known mine sites, and as such, their coordinates were already known. Likewise, the inclusion of stream channels for analytical purposes used pre-existing data from the area.

7. Results

7.1 Intra-site distribution of ochre

The site of Ayia Varvara-Asprokremnos is constituted primarily of three structures alongside a large depression or pit (Figure 16)**.** Most of the ground stone tools and ochre was recovered from these locations.

Forty-five stone tools with ochre residues were identified amongst the material held in the Cyprus Museum's Storerooms. These are in addition to the eleven artefacts previously analysed by McCartney and Sorrentino (2019), which are stored elsewhere. As such, a total of fifty-six tools with ochre residues were found at Ayia Varvara-Asprokremnos. Most of these (39/56, 69.6%) were found inside the three structures, with the latest, F840, yielding the largest number of ground stone tools with ochre residues. Feature F539, the large depression in the centre of the site, also contained a number of these artefacts, with about 80% of the assemblage accounted for within the three features described above (Figure 23).

Feature	# tools	% tools with residue
Structure F300 (earliest)	12	21.4%
Structure F848 (middle)	7	12.5%
Structure F840 (latest)	20	35.7%
"working hollow" F539	6	10.7%
Other locations	11	19.6%

FIGURE 23: Intra-site distribution of ground stone tools with ochre residue.

Ochre material was also recovered from this site in large quantities. The 301 ochre samples studied here came from a total of 167 contexts across the site. Just under half of these samples were found in one of the three structures (Figure 24). Of particular note were contexts 651 and 714, both surfaces/fills within the lower levels of feature F848. Excavation of these two contexts returned over 12% of the ochre finds from the entire site, apparently representing "caches" of this material. While a handful of contexts featured large, individual pieces of ochre, 651 and 714 were the only contexts where very large amounts of smaller, (worked?) pieces were found.

Feature	# ochre finds	% ochre finds
Structure F300 (earliest)	57	18.9%
Structure F848 (middle)	49	16.3%
Structure F840 (latest)	39	13%
"working hollow" F539	22	7.3%
Other locations	134	44.5%

FIGURE 24: Intra-site distribution of ochre. Note that these are minimum numbers of ochre finds: Harris matrices for the site are incomplete. Not all contexts could be easily positioned within the site stratigraphy, and it is possible that some contexts in the "other locations" section are actually associated with the identified features.

Only one ground-stone vessel, G389, was found with a piece of ochre *in situ* within the vessel itself. However, there were thirteen contexts from which both stone tools and ochre were recovered (Figure 25).

Context #	Location	Description
426	F300	Stony fill layer in the upper part of F300
464	F300	Contained G389, a limestone bowl with ochre (see Figure 19)
568	F539	Purple clayey fill located within central pit F539
583	-	Ploughsoil
614	F539	Second layer of fill in F541, a cut within central pit F539
633	F539	Third layer of fill in F541, a cut within central pit F539
700	F539	Stone setting within central pit F539
853	F848	Spit of F848 itself; the layer below topsoil
911	F840	Upper part of lower midden fill in F840
958	F840	Lower part of lower midden fill in F840
1017	F840	Silt base of F840 below central stone pile
1021	F840	Stone concentration/grinder horde on base of F840
1024	F840	Base of F840/lower part of stone concentration

FIGURE 25: Contexts containing both ground stone tools with ochre residues, and ochre material itself.

7.2 Geochemical sourcing

In order to estimate potential sources for a geological material such as ochre, it is first necessary to collect reference material from the surrounding landscape to compare it with. Thirty ochre samples from seven mine sites were collected in 2023 (Figure 26).

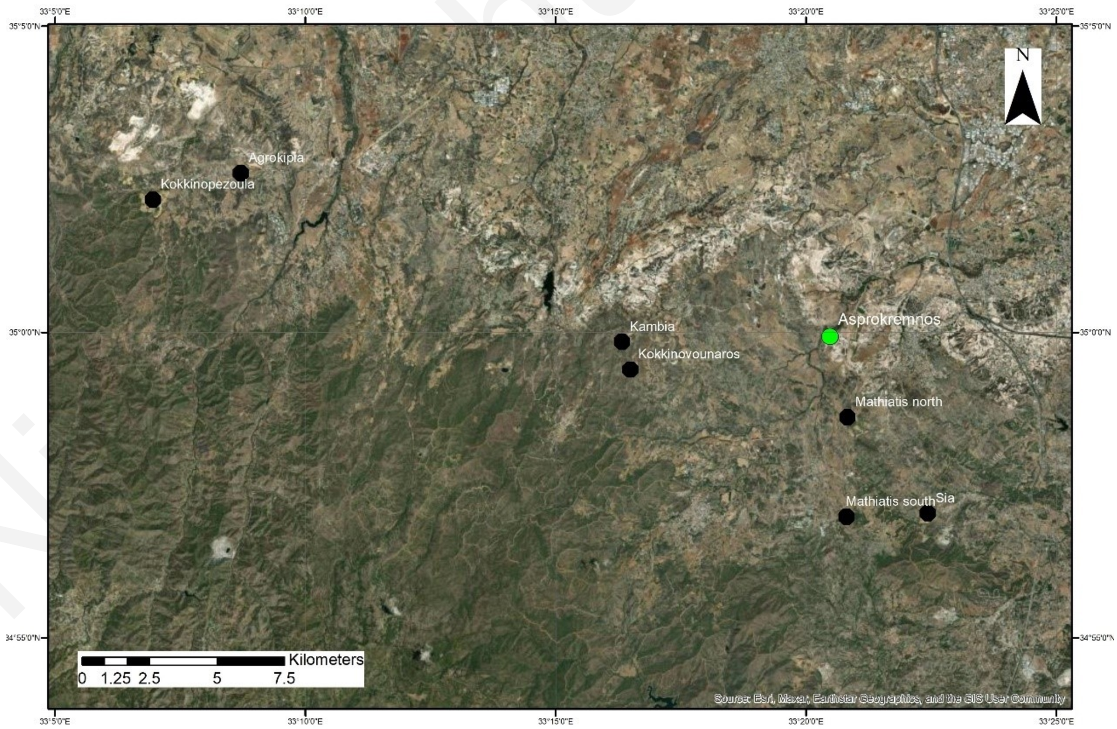


FIGURE 26: Map of the area around Ayia Varvara-Asprokremnos, showing the site and reference locations. Figure made in ArcGIS with assistance from Dr M. Polidorou.

First, to establish the potential value of a sourcing study, a Principal Component Analysis (PCA) was performed on these 30 reference samples. Ideally, each of the sources will cluster separately, with distinct chemical signatures for different locations.

The initial attempt at this was not particularly successful (Figure 27). While there did appear to be some degree of clustering, an outlying sample (#1, far right) meant that the other samples were all clustered together, irrespective of their source. However, this was to be expected: sample 1, collected from the Mathiatis N mine, was an umber, not an ochre. As such, it is unsurprising that it has a noticeably distinct chemical composition to the other samples.

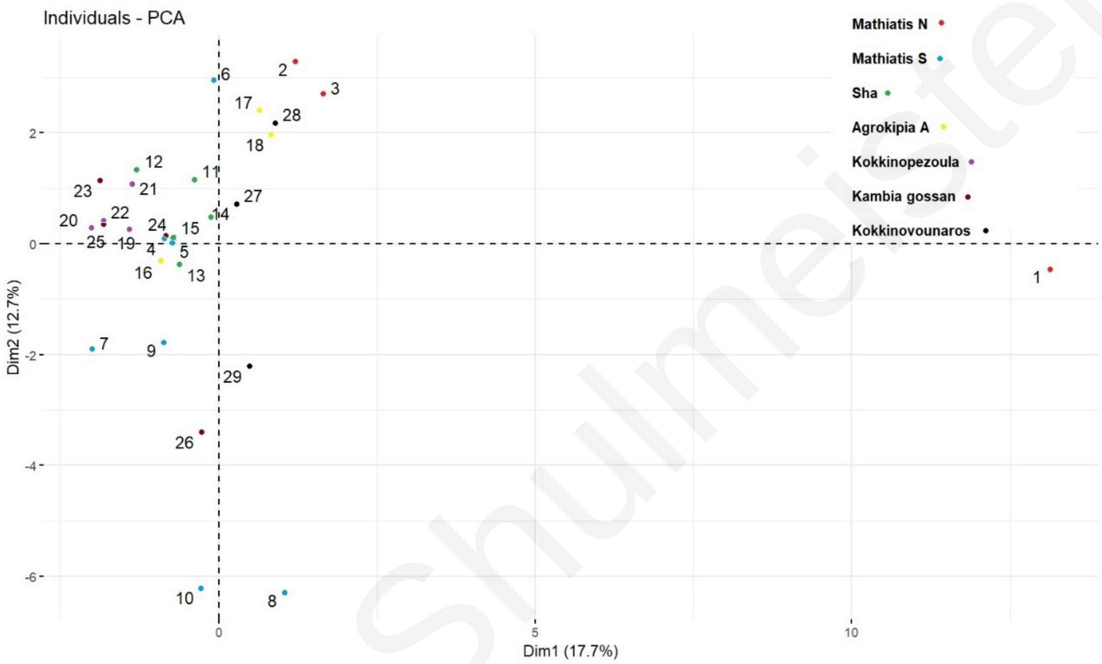


FIGURE 27: Initial PCA for reference material.

The PCA was rerun without this sample in order to test the efficacy of XRF for an ochre-specific sourcing study. This produced a very different model. While the different mine sites do share some overlap, there is an identifiable pattern of clustering: in particular, materials from Kambia gossan and Kokkinopezoula appear together in the top right of the graph; Sha samples are generally centered around the origin; and Mathiatis S material dispersed across the lower axes (Figure 28).

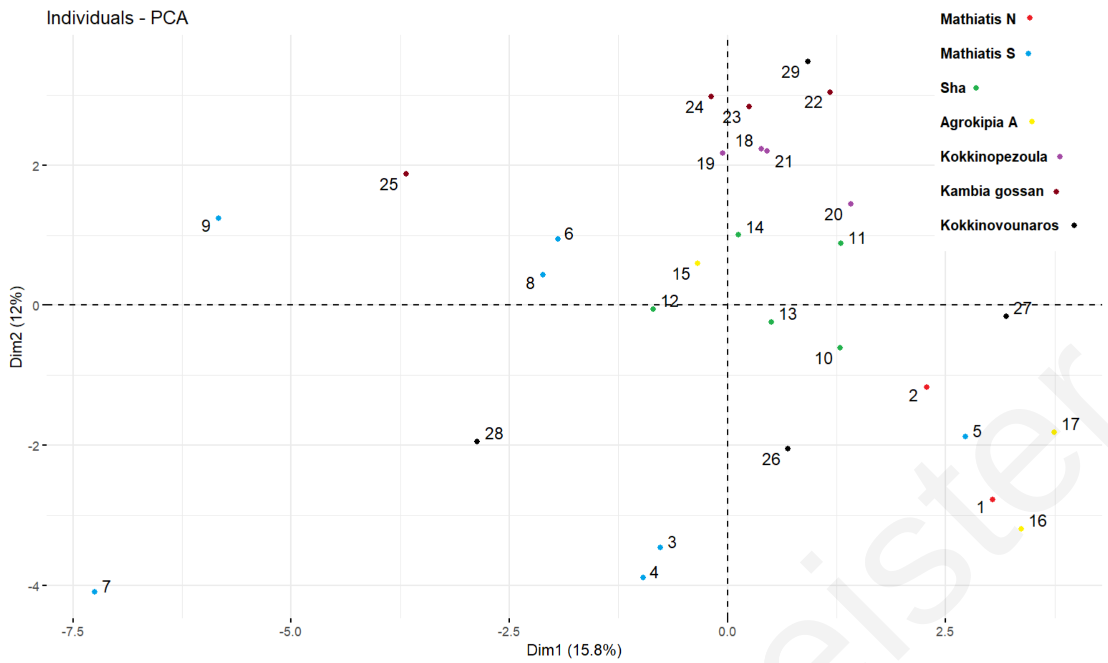


FIGURE 28: PCA of reference material without the umber MN1.

This is actually a very good result for an XRF-based analysis of ochres. p-XRF has been applied to a number of sourcing studies in the past, however, it frequently struggles to distinguish between potential sources: often, the trace elements which would allow these to be identified are below the detection limits for the device. Also, while the eigen values for this analysis are quite low- the two dimensions are accounting for 15.8% and 12% of the variance in the dataset, respectively- this is to be expected given the large number of elements analysed here. 42 elements were above the detection limits of the XRF- this is a large number of variables which the analysis has to account for (Figure 29).

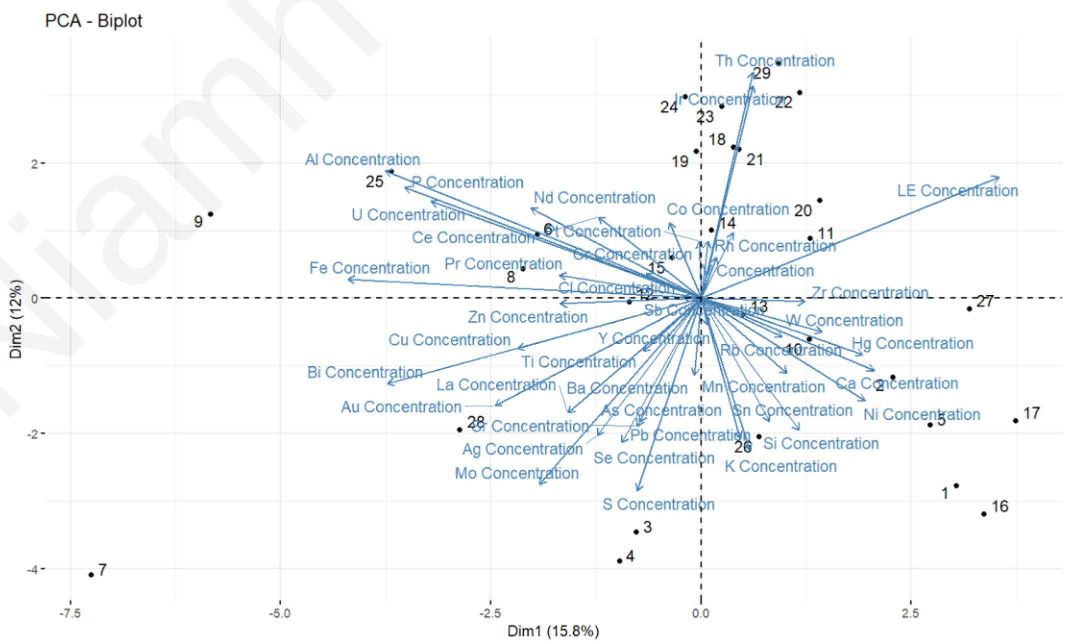


FIGURE 29: elemental distribution for the reference material; excluding umber MN1.

As there is some degree of clustering within the dataset, and therefore the potential for a sourcing study to provide viable results, the archaeological material was then added to the dataset.

First, the reference material was compared to the XRF data from stone tool residues. In these models, the reference materials cluster slightly differently. Hierarchical clustering in the dendrograms was performed with the centroid method, wherein each sample was considered individually, and grouped with the sample it was most similar to. The centre/centroid of each of these groups was then found, and in the next layer of the agglomerate clustering, each of these groups was combined with the group it was closest to. This process continued until all samples had been combined into one supergroup. PCAs, meanwhile, work off the covariance matrix of the dataset. That is, rather than considering each sample individually and finding the other samples it is closest to, this method looks at the range of variance in each element, then determines how the variance in each element relates to the other elements.

In the PCAs, the samples are placed in data space based on alignment to the key discriminating elements. This is different to the hierarchical clumping undertaken by the cluster analyses. Therefore, these two analytical methods do generate different results, even when working off the same set of data.

The first dendrogram produces was for the reference material only, to ensure that the dendrogram also produced a viable result. Residue material was then added to the dataset. However, it rapidly became clear that there was an issue with this method: most of the residue samples were more similar to each other than to the reference material, with four layers of agglomerative clustering needed to link the vast majority of the residue samples with the references.

There was one group of residues which grouped seperately from the rest (Figure 30). In an attempt to explain this, the residue samples from chalk slabs were identified separately from those on volcanic material. As predicted, most of the isolated residues were from chalk samples. Therefore, it appears likely that the XRF results for these are detecting the material of the stone tool in addition to the ochre residue. These results are therefore not included in any further analysis of the ochre from the site.

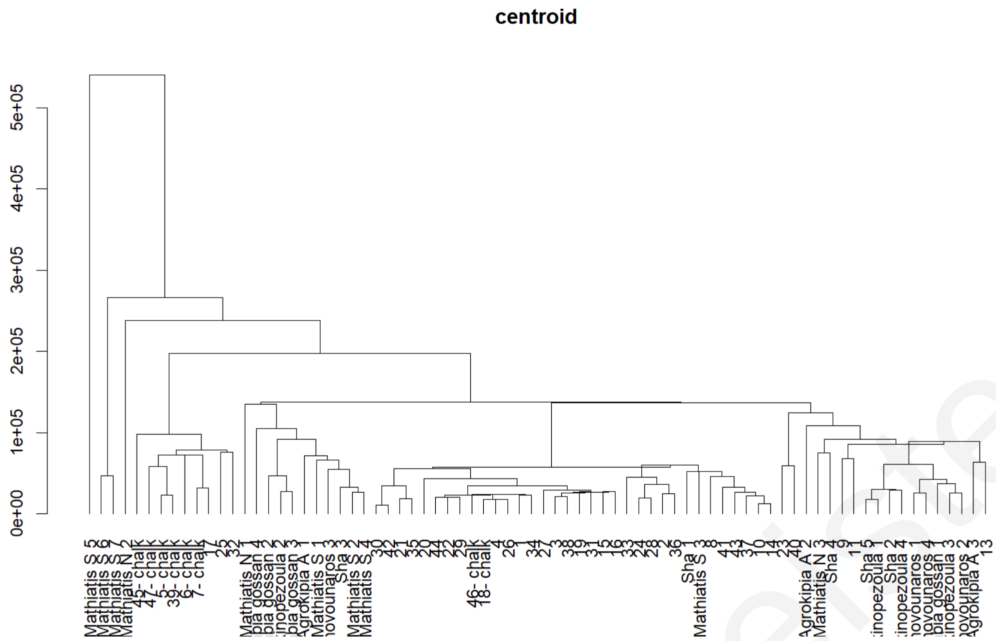


FIGURE 30: Dendrogram showing the relationship between reference material and the ochre residues. Samples from chalk slabs are identified. Note that most are grouped together on the far left of the graph.

Then, the ochre samples from Ayia Varvara-Asprokremnos were plotted against the reference material. The full dataset of 301 ochre samples was too large to be graphed in a readable manner: the only identifiable samples on a PCA of this dataset were the outliers. The dendrogram was able to determine that *most* of the ochre samples from Ayia Varvara-Asprokremnos were more similar to each other than to the reference material, but detailed interpretation was impossible. Therefore, samples of particular archaeological importance were isolated from the dataset. To start with, only those samples that were found within the structures were analysed (Appendices 4-5). However, this dataset was still too large for effective use. Thus, the sample was further restricted to those from contexts containing both ochre and stone tools, as these contexts have the best association with ochre use at the site (Figure 31).

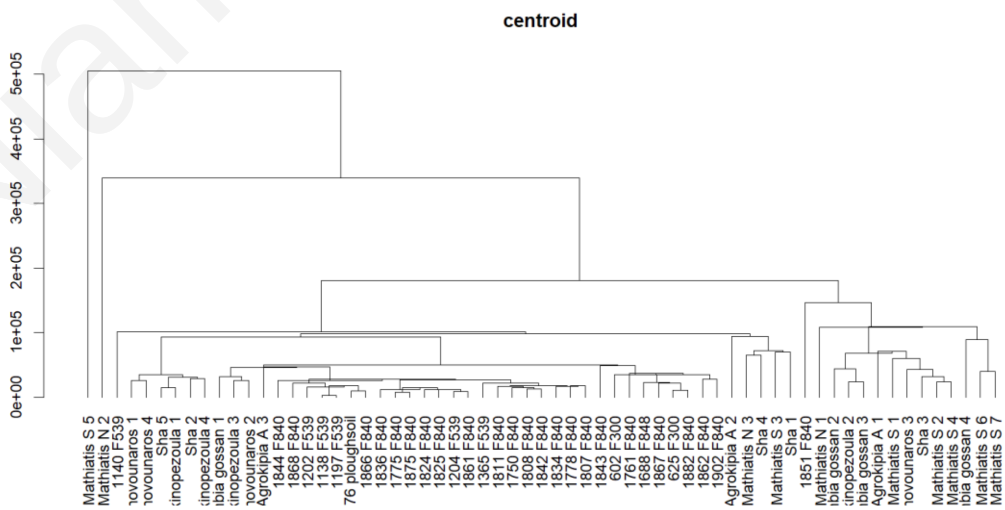


FIGURE 31: Samples from contexts containing both ochre and stone tools, compared with reference material.

Samples from the two contexts with ochre "caches" were also examined. This material was relatively homogenous, with no clear-cut distinction between the two contexts. Most of these samples were more similar to each other than to the reference material, although there were four samples which, while similar to each other, formed a distinct cluster from the rest of the Ayia Varvara-Asprokremnos material (Figure 32).

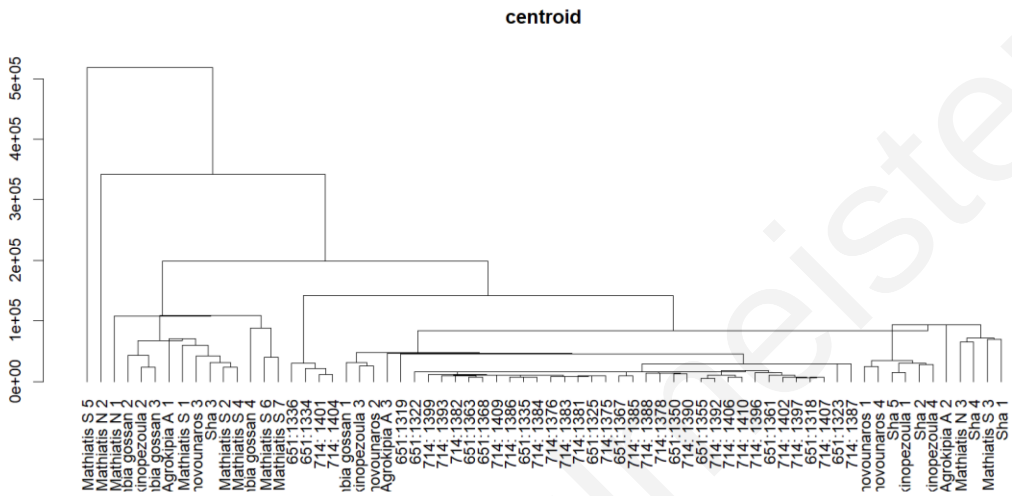


FIGURE 32: Ochre samples from contexts 651 and 714, both located within structure F848, compared to reference material.

8. Discussion

8.1 Ochre distribution and use within Ayia Varvara-Asprokremnos

A majority of the ochre recovered from Ayia Varvara-Asprokremnos came from the three structures that were found during the excavations. The material was found primarily in small pieces: nodules with a diameter of <1cm were the most common ochre find at the site, and even the larger samples were only rarely more than 3cm in diameter. Ochre outcrops in the surrounding area are large – reference material was collected in chunks ranging from about 500g to 1kg, and larger pieces could have been easily collected if they were necessary. Collecting and transporting ochre samples from the landscape which are the same size as the archaeological material would have been more difficult than removing large pieces, and reducing them at the archaeological site. Thus, it is likely that the ochre pieces collected at Ayia Varvara-Asprokremnos are remnants of the industrial processes performed there. They probably represent ochre "debitage", if the term can be applied to materials other than stone, and, as such, are likely evidence of ochre processing in and of themselves.

There were shifts in the patterns of ochre distribution across the history of the site (Figure 33). Stone tools associated with ochre processing were most common in the earliest and latest phases of the site, with fewer in the intermediate stages. Ochre samples, on the other hand, generally decreased in number over time. This would suggest that there were several waves of ochre collection. If the site was occupied seasonally, or only intermittently across its history, then every new occupation phase may have been accompanied by a new expedition to collect ochre. However, if this was happening, the ochre was probably being sourced from the same approximate area each time: the XRF study, described in detail below, sees no real change in ochre provenance across the samples from the three structures.

Feature	# tools	# ochre samples	Both tools and ochre present?
F300 (earliest)	12 stone tools	57	Twice
F848 (middle)	7	49	Once
F840 (latest)	20	39	5 contexts

FIGURE 33: Ochre and stone tool distribution patterns across the site's history.

Based solely on the quantities of ochre, there appears to be a general decrease in use over time. However, the degree of association between ochre and the stone tools shows a different trend. Ground stone tools were found in all three structures, but the last, F840, contained the most, and was also where most contexts containing both ochre and ground stone tools were located. G. Sorrentino referred to structure F840 as a likely ochre "workshop", based on the preliminary analysis of stone tools he performed (McCartney & Sorrentino 2019). Analysis of the rest of the ground stone assemblage does not disagree with this. The ground stone tools from this site contain traces of ochre. There is no evidence thus far for any other material (e.g. cereals) being processed. F840 contains a large number of tools with ochre residues preserved, and while it may have contained less ochre than the other structures, it did still have a substantial amount of material. The association between the mineral resources and the stone tools is clear: the final building at this site (and, most likely, the earlier structures as well) served as a workshop area for processing ochre.

The question then arises of exactly what the ochre was being used for. Documented uses for this material in the ethnographic record are numerous and varied, however, it is frequently difficult to ascertain its purpose archaeologically. Very few of the known uses for ochre preserve in the archaeological record: ochre pigments in rock art are common worldwide, but do not appear to be present in the Cypriot PPNA: the earliest ochre drawing known on the island is a schematic human figurine on the wall of building 11, dating to the PPNC occupation of Kalavasos-Tenta (Todd 1982, 47). Likewise, one of the PPNC structures at Tenta features a floor which had been coloured red with ochre. Again, this practice has not yet been recorded in the PPNA or PPNB. Even the use of ochre in burials – widely attested to elsewhere in the world, including in association with other hominin species – does not appear in the earliest phases of the Cypriot Pre-Pottery Neolithic. Ochre use in the earliest Cypriot Neolithic appears to have been largely constrained to activities which do not leave clear traces in the archaeological record.

There are a number of practices for which the archaeological evidence is generally nonspecific. Ochre used for medicinal purposes will not be preserved in the archaeological record except, perhaps, for evidence of its processing. Similarly, ochre as body paint is a relatively common phenomenon worldwide, yet finding evidence of this in the archaeological record is near impossible. Ochre in hide tanning also requires the material to be ground before use, and given the rarity of preserved leather artefacts in the record, it is grinding stones, and, perhaps, chipped stone tools such as scrapers associated with hide processing, which are used to infer this process indirectly.

Ground ochre, or the tools used for grinding it, generally represent the best evidence archaeologists can find for processes such as these. Ochre "industries", therefore, can be found, but distinguishing between specific processes is nearly impossible without ethnographic data from a related modern-day culture. No group is able to claim this association with the Cypriot Neolithic.

Ayia Varvara-Asprokremnos shows evidence for the grinding of ochre, which is a necessary step in almost all of the ochre production chains described above. It does not appear as if the ochre was burnt or roasted at any stage, which is curious, given that heating ochre to produce different colours is a not uncommon process (Helwig 1997). This may suggest that ochre was not primarily being used for artistic purposes by the population of Ayia Varvara-Asprokremnos, or at least that specific colouring was a secondary concern. Then again, the geological landscape of Cyprus provides a very wide range of pigments, so it may not have been necessary to roast the ochre material to generate new colours. Elisabeth Heying, a modern artist working with earth pigments, was able to generate at least twenty different colours from material collected from the Cypriot landscape (Figure 34).

Heying's processing method was simple and consisted only of grinding the material, filtering it with water in order to further refine the material into a smoother powder, and adding a binding agent so that it would function as paint- no burning or roasting was necessary (E. Heying pers. comm., 16th April 2024).

FIGURE 34: Earth pigments created in Cyprus by artist Elisabeth Heying, 2023-24 Fulbright Artist. Image taken by author, at the Cyprus American Archaeological Research Institute (CAARI), 16th April 2024.

Given the diversity of Cypriot earth pigments, it is not particularly surprising that material was not roasted to generate more colours. However, the lack of rock art, or evidence for painting on structures, still suggests that the ochre may have had another, non-artistic purpose at Ayia Varvara-Asprokremnos. Grinding processes alone still allow for multiple potential uses including ritual, medicinal, and hide tanning.

It is this latter process which is of particular interest here. Previous efforts to argue for hide tanning with ochre have emphasised the presence of chipped stone tools such as scrapers associated with the removal of fat from animal hides, evidence for hunting or the presence of animals from which these hides *could* be removed, and ground stone tools/ochre residues indicative of ochre present in such quantities to serve as a tanning agent. The Natufian site of Hilazon Tachtit cave, in Israel, is the site with the clearest lines of evidence for this in the published literature (Dubreuil & Grosman 2009).

Ayia Varvara-Asprokremnos fits all three of the criteria described above. Around 5% of the chipped stone tool assemblage is in the form of scrapers: given the sheer number of lithics recovered from this site, this is a substantial amount of material. Specialised analysis of the stone tools has not been performed yet, and as such no one has examined the scrapers in detail. Their morphology has not been fully described, and analytical techniques such as Gas Chromatography and Mass Spectrometry, capable of identifying lipids from animal fats, have not been performed. More work in this area would be beneficial. However, there is nothing in the preliminary analysis to suggest that these scrapers were *not* used on animal hides.

Likewise, the faunal assemblage has not been studied in detail, but appears to be dominated by suids – that is, pigs – which are indisputably a good source for hides. It is possible to identify butchery marks associated specifically with skinning on archaeological bone samples (e.g. Saliari & Felgenhauer-Schmiedt 2017). Performing these investigations on the Asprokremnos assemblage would permit the association between the pig remains and hide tanning to be drawn with even more confidence.

Finally, there is the question about the amount of ochre required. Rifkin's experimental work determined that between 4 and 6mm of ochre needs to be applied over the entirety of a hide for the tanning process to work (Rifkin 2012). His studies were based in South Africa, and as such focused on the local animals of that environment, but he determined that a larger animal – there, a wildebeest or kudu antelope – would require around 4.4kg of ochre. Admittedly, Rifkin's "ochres" were relatively low quality, and this estimate was assuming that grinding his "ochres" would produce a substantial amount of waste material and only a small amount of usable iron oxide. The material at Ayia Varvara-Asprokremnos appears to be better-suited for this purpose than Rifkin's experimental material, so the amount required is probably lower. In addition, pig hides would likely be somewhat smaller than Rifkin's estimates for wildebeest. Modern wildebeest hides for sale are around 170cm x 150cm, while pigs are highly variable dependent on weight but are generally larger than $1m^2$. As such, 2-3kg of ochre per hide, minimum, would not be an unreasonable amount to be required for the tanning process.

Therefore, the >20kg of ochre recovered from Ayia Varvara-Asprokremnos is not actually an unreasonable amount of material, if leather tanning was indeed occurring at this site. If tanning each individual hide requires several kilograms of ochre, it is likely that the inhabitants of Ayia Varvara-Asprokremnos would have gone to an ochre source to collect a new set of material each time a new hide was tanned (or each time a new set of hides were collected, if the animals were slaughtered in groups). The ochre would then need to be ground before it could be applied to the hides. As a result, the ochre samples recovered in the excavations – almost all small nodules of material – may well represent the ochre left over once a pigskin-worth of material had been ground into powder. The pieces would have been too small for tanning another hide, so the leftover material would have been ignored, and more, larger pieces collected from the surrounding landscape for the next tanning event.

In these sorts of circumstances, 20kg of waste material across ~300 years of human activity, even if it was periodic or seasonal, is relatively unsurprising. Given that only 38.3% of the stone artefacts recovered from hollow F539 are actually "tools", and the rest is debitage (McCartney & Sorrentino 2019), the inhabitants of Ayia Varvara-Asprokremnos were clearly not too concerned about the use and re-use of mineral resources. The geology of the surrounding landscape was abundant enough that stone material could be discarded if it was not an ideal fit for whichever tool they were creating. Likewise, ochre is incredibly abundant in the landscape. There is no reason why the inhabitants of Ayia Varvara-Asprokremnos would have needed to use every tiny fragment of this material, when they could simply collect a larger, more easily worked piece from the surrounding countryside.

Thus, McCartney's claim that the ochre assemblage of Ayia Varvara-Asprokremnos "*could not have been processed for use only on-site or even on the island of Cyprus"* (McCartney & Sorrentino 20, 75) appears quite unlikely. If hide tanning with ochre was occurring at this site- and there is no evidence to suggest it was not – then 20kg of waste material could easily be generated by the hide tanning process alone. The scale of leather tanning at this site cannot be directly inferred from the amount of ochre left behind – and the faunal remains have not been analysed yet, so a minimum number of individuals cannot be estimated from there, either – but it would not need to be a huge industry in order to generate this amount of material, particularly stretched across the site's entire occupation history. Of course, the actual evidence for ochre processing is only in the form of ground-stone tools, and therefore nonspecific. It is entirely possible that ochre had other uses that have not been preserved in the record, ranging from ritual to medicinal to artistic. However, it is unlikely that any one of these processes would have required the same scale of industry as leather tanning. If McCartney's interpretation of hide tanning activity at this site is correct

– and, given the current available data, there is no reason why it should not be –then her additional claim about the ochre assemblage being too large for intra-site use only is probably incorrect. It would be interesting to compare the archaeological material from Asprokremnos with other sources, either at Klimonas or in the Levant, but the site does not need long-distance trade in order to explain the abundance of mineral resources found here.

Overall, Ayia Varvara-Asprokremnos featured three structures across its history. At a minimum, the latest of these structures, F840, was a workshop area where ochre processing occurred, although it is likely that some degree of ochre grinding was also practiced in earlier phases as well. The most likely purpose for this activity was in association with hide tanning through ochre, although the lines of evidence for this are non-specific enough that other potential uses cannot be entirely discounted.

8.2 XRF sourcing

The term "sourcing" is a somewhat misleading one to use in the context of archaeological provenance studies. As explained by M. Steven Shackley:

> "*One of the most misused terms in archaeometry is the word 'sourcing'… it implies that whatever is submitted to the archaeometrist will return with a bona fide and certified source provenance that is not probabilistic at all, but confidently determined… nothing is ever really 'sourced'. The best we can do is provide a chemical characterisation and a probable fit to known source data."* (Shackley 2008, 196).

"Sourcing" studies do not operate with any degree of certainty. At best – assuming the sampling and analysis methodologies are performed correctly, and the potential sources are sufficiently discrete – then a likely origin point may be established. However, doing so is assuming three main factors. Firstly, the methodology used must be able to provide accurate and precise enough data for the investigation to be performed. Secondly, the chemical compositions of the potential sources in the landscape need to be discrete enough to be classified separately; and thirdly, the geology of the region must be well documented enough that potential sources are unlikely to be missed.

Here, portable X-Ray Fluorescence was used to analyse over 300 archaeological samples, alongside 30 reference samples from the surrounding landscape. Thus, in order for this methodology to be useful, the XRF must provide useful data, the seven reference sites must be chemically distinct, and the geology of the region must be covered adequately across these sites.

Portable XRF is an analytical method that provides information on the elemental composition of an object. As it is both non-destructive and very efficient- the settings utilised for this study were able to analyse forty-two elements, and only required seventy-five seconds per sample- this method is a very common one for sourcing studies to utilise. However, its efficiency is undercut by the fact that it is a relatively inprecise and inaccurate method. Results from one particular p-XRF machine will generally be internally consistent, but the method becomes quite imprecise when comparing across different machines. For this study, this was not an issue- all samples and reference materials were run through the same device- but it is a factor to consider if and when comparing data across sites or projects. In addition, the speed of analysis means that the detection limits for this machine are higher than in other analytical methods. Often, p-XRF struggles to identify trace elements in a sample. This is problematic, as trace elements are crucial for differentiating between sources in a provenance study.

Despite these issues, the p-XRF analysis was at least partially successful in this case. The first PCA generated from the reference material (Figure 27) immediately isolated the umber sample (Mathiatis North 1) from the ochres, demonstrating that the statistical analysis method was functioning. Removing this sample meant that patterns began to emerge.

There was some overlap between the different sites, and some sample locations clustered better than others. Samples from Mathiatis S, for instance, had a very wide spread across the PCA (Figure 28, shown in blue), while Kokkinopezoula (purple) and Kambia gossan (red) clustered closer together. Ideally, the seven reference sites would form seven discrete clusters with overlap. This is not the case here. This is unsurprising, given the aforementioned issues with XRF analysis and the relative similarity in the geology of all of this material. Quite frankly, the degree of clustering observed here is *incredibly* good for a study based only on p-XRF data: ochre sourcing work performed elsewhere in the world has rarely obtained actionable results based only off p-XRF data. Most studies utilise X-Ray Diffraction and/or other methods such as ICP-MS, INAA, PIXE-PIGE and raman spectroscopy as well. Frequently, p-XRF is performed as an initial step to identify samples of interest for further analysis. This was the initial plan for this project as well, however funding and time constraints meant that XRD analysis was impossible. Fortunately, the p-XRF performed better than expected and good results were obtained with this method alone. While there is some overlap between the seven reference sites studies here, the clustering patterns are still distinct enough for some initial interpretations to be made.

It is important to note that geological source plays a larger role for the multivariate analysis than Munsell colours. Umbers and other non-ochre materials are located in completely separate areas of the graph to the ochre. However, for the multivariate analysis performed, it is the trace elements – that is, the ones varying between sites – which control the positioning of the rest of the reference material. Reference samples were plotted based on their colours as well (Appendix 6) but, in general, a red and a yellow ochre from one site will be more similar to each other than two red ochres from different sites.

Once it was established that the reference samples were forming (somewhat) distinct clusters, analysis began on the archaeological material. The first materials plotted were the ochre residues from the stone tools. It quickly became apparent that there were two distinct groups within the archaeological dataset, with most of the samples appearing relatively homogenous, and a small handful grouped separately. Further investigation showed that most of the secondary group were those samples taken from chalk slabs (Figure 30). It is likely, in this case, that the p-XRF was reading both the ochre residue and the underlying geology of the stone tool. As such, these results are of very limited value for ochre sourcing. This particular issue was noticeable when the analysis was being performed: even though the only samples studied here were the ones which had been specifically identified by the excavators as having ochre residues, in many cases, the "residue" in question was not visible to the naked eye. As p-XRF can penetrate several millimetres, depending on the material, it is not particularly surprising that the geology of the stone tools is interfering with the results here. It would be difficult to correct for this issue: the "residues", where they exist, are thin enough that they would be difficult to remove and subsample for any destructive analytical method. PIXE-PIGE analysis is a non-destructive method that may be able to account for these samples, but even so, there is a fairly high chance that the stone tool's composition will also be captured with this method. As such, it may not be worthwhile performing further analysis on the stone tool residues.

The archaeological ochre samples, when plotted against the reference material, did produce viable results. Almost all of the archaeological samples fit within the range of the reference material – while the dendrogram produced for all 301 reference samples is too crowded to be properly readable, (Appendices 2-3). However, almost all the archaeological material shares one characteristic: that is, in almost all cases, any given piece of archaeological ochre is more similar to any other piece of archaeological ochre than it is to *any* of the reference samples studied here.

The simplest explanation for this phenomenon is that the actual source or sources of the archaeological ochre were not studied here. Given the positioning of the reference material on the dendrograms – it splits, mostly, into two groups, one on the far left and one on the far right, with a small number of samples scattered in between (Figure 32) – it is likely that the *actual* source is located in an intermediate area between the reference samples that were collected. Given the locations of the reference sites, and assuming that there is not a completely distinct geological unit in the area – no such unit appears on any geological map – the missing source is probably close to Ayia Varvara-Asprokremnos itself.

As stated previously, most of the reference samples cluster to the far left and far right of the dendrograms produced. However, a handful of samples are exceptions to this rule, and cluster within the range of the archaeological material: Kambia Gossan 1 (a yellow), Kokkinopezoula 3 (dusky red), and Kokkinovounaros 2 (yellow) are particularly similar to each other and group with the archaeological material within only 2-3 steps of agglomeration, and with relatively short mean vectors between the reference cluster and the archaeological cluster (Figure 32). In addition, sample Agrokipia A 3 (weak red) is more similar to the archaeological material than it is to any of the other reference samples, although it is still somewhat isolated from the archaeological ochre (Figure 31).

While these four reference sites are distinct from each other, what they all have in common is that they are located to the west of Ayia Varvara-Asprokremnos (Figure 35). This is particularly interesting, as the sites to the south – Sha and Mathiatis – are actually closer to Ayia-Varvara in terms of straight-line distance. If the occupants of Asprokremnos were simply using the closest material to hand, then the Mathiatis material should have been closely associated with the archaeological material. Instead, a variety of sites from further afield show the highest degree of similarity.

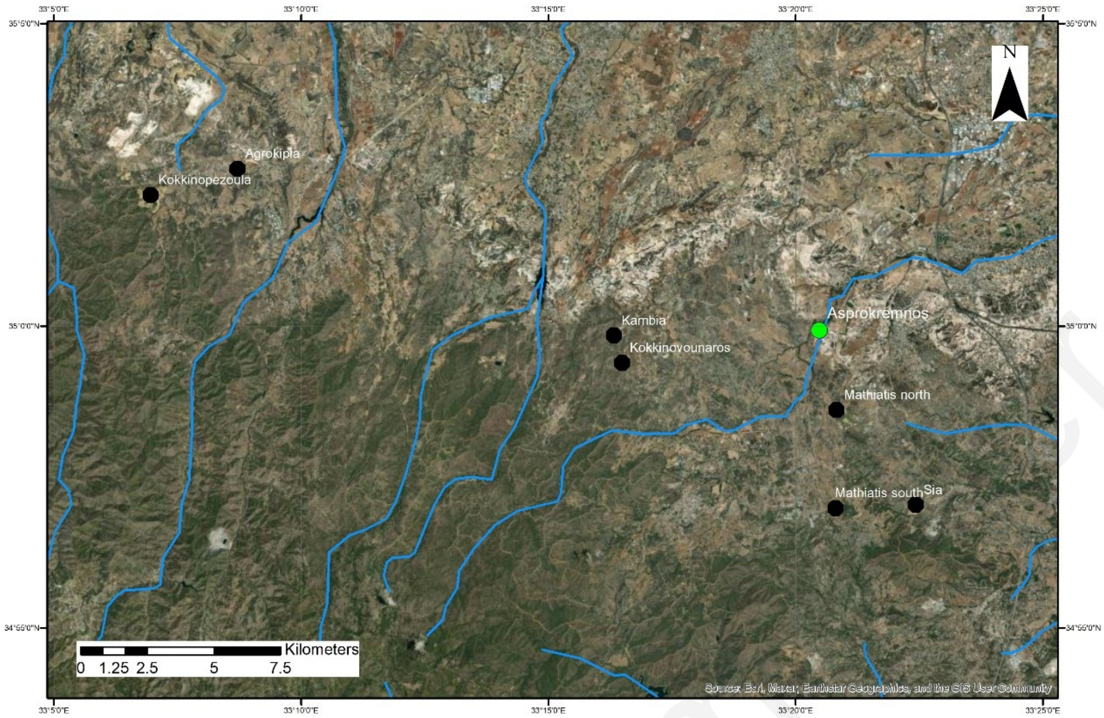


FIGURE 35: Map showing the locations of Ayia Varvara-Asprokremnos, the reference sites for ochre, and the channels of the major rivers in the area. Figure made in ArcGIS with assistance from Dr M. Polidorou.

One potential explanation is that the missing source is somewhere along the banks of the Gialias River (Figure 35). This river flows in a roughly easterly direction, meaning that it could easily carry materials from more westerly source locations and deposit them closer to the site. It has already been established that many of the ground stone tools at Asprokremnos were formed from volcanic cobbles, most likely collected from this river, so it is clear that the inhabitants were utilising the mineral resources of this area. Ochre along the riverbank would have been: a) accessible without requiring excavation or mining, and b) quite visible in outcrops, which would have made for a desirable source. This material probably has a similar geochemistry to the material upstream, which, in this case, is located to the west, closer but not identical to reference sources such as Agrokipia A, thus explaining why these sources appear to be a better match.

This is further supported by the work of artist Elisabeth Heying, who has been making paints out of earth pigments in Cyprus as a Fulbright Artist. Her collection includes multiple pigments from sites studied here, including Mathiatis and Sha, as well as two different pigments made from material in the Ayia Varvara-Asprokremnos area itself, one yellow/brown she termed “Asprokremmos toffee” and a reddish brown “Asprokremmos bourbon cherry” (E. Heying pers. comm., 16th April 2024). Heying passed the archaeological site of Asprokremnos while looking for coloured earths, and mentioned that both of the “Asprokremmos” pigments were made from materials collected at/near the river. Clearly, there are ochre outcrops in this area which could have been exploited by past populations. Given the current dataset, outcrops along the banks of the Gialias River appear to be the most likely source of ochres for the site of Ayia Varvara-Asprokremnos, although geochemical analysis on this material would be necessary in order to prove this hypothesis.

Overall, the sourcing study proved surprisingly effective given the limitations of portable XRF. While the individual reference sources considered in this study do not form completely discrete groups, and none match the archaeological material exactly, it is hypothesised that the banks of the Gialias River are the most probable source for ochre material. There are, however, a number of outstanding questions which could benefit from further analysis. In particular, geochemical investigations into these Gialias River outcrops would be particularly beneficial. It would also be interesting to perform further geochemical studies on the ochre material with other methods such as XRD, in order to compensate for the somewhat imprecise nature of p-XRF measurements. Finally, comparative analysis between this dataset and the ochre assemblage of Ayios Tychonas-Klimonas would be particularly interesting: McCartney has previously suggested that the ochre assemblage at Asprokremnos may have been traded elsewhere, potentially even away from Cyprus. While overseas trade seems somewhat implausible, it would be interesting to see if the other PPNA site on the island was utilising local ochre from the Amathous area, or if the Asprokremnos assemblage was transported at least that far.

9. Conclusions

Ayia Varvara-Asprokremnos is a PPNA site located in central Cyprus, at the foothills of the Troodos and near the Gialias River. It likely served as a temporary or seasonal encampment, specifically established for the purpose of exploiting the diverse geological resources of its surroundings. While the structural archaeology of this site is minimal – only three buildings were found during excavations, and these were likely occupied sequentially rather than simultaneously – the lithics and ochre assemblages are both substantial. The site was a centre for stone tool production and likely featured at least some degree of hunting, primarily of wild pigs.

Ochre from Ayia Varvara-Asprokremnos was processed in the “workshop” structures, as evidenced by ground-stone tools with ochre residues still present. This activity was most prevalent in the latest stages of the site’s occupation, although it probably did occur during all periods. The exact use of this material is unclear, as the only evidence for its processing is in the grinding stones themselves, and there are multiple applications for ochre which require its grinding prior to use. Given the scale of activity at this site, it is likely that hide tanning with ochres was performed here. However, other uses- be they artistic, ritual, or medicinal- cannot be entirely discounted at present.

Portable-XRF sourcing of this material was not conclusive. However, uniformity amongst the archaeological ochre samples suggests that almost all samples were collected from the same source, and their relation to the reference material suggests that this was local to the area. In particular, the association between the archaeological data and some reference points to the west of the site may suggest that ochre was being collected from outcrops along the nearby Gialias River, which flows from west to east. Alluvial deposits probably have similar geochemistry to sources in the west, while also being close to the site and both visible and accessible. However, further geochemical work would be needed to prove this analysis.

In future, the application of other analytical methods would be of particular interest and may allow for a more detailed investigation of mineral provenance at this site. As well as additional methods, it could benefit from a broadening of the study area, including both material from the Gialias River and, potentially, the archaeological assemblage at Ayios Tychonas-Klimonas, in order to understand mineral exploitation across Pre-Pottery Neolithic Cyprus more broadly. In addition, the uses of ochre at this site have not been fully explored. Further investigation into the lithic assemblage, particularly the scrapers, alongside a detailed study of the faunal remains, may go some way towards proving questions about leather-working and hide tanning which have thus remained unanswered.

Ayia Varvara-Asprokremnos is an interesting site given both its uniqueness – a temporary camp associated specifically with mineral resources – and its similarities to other PPNA sites in both Cyprus and the Levant. The earliest phases of the Cypriot Pre-Pottery Neolithic have only gained real attention within the last decade, and as such, the site of Ayia Varvara-Asprokremnos is a major contributor to archaeological understanding of this period.

10. Bibliography

Ammerman, A.J., 2020. Cyprus: The Submerged Final Palaeolithic of Aspros Dive Site C. In G. Bailey., N. Galanidou., H. Peeters., H. Jöns, & M. Mennenga (eds), *The Archaeology of Europe's Drowned Landscapes*. Coastal Research Library, vol 35. Springer. 429-442.

Ammerman, A.J., Howitt-Marshall, D., Benjamin, J., & Turnbull, T. 2011. Underwater Investigations at the Early Sites of Aspros and Nissi Beach on Cyprus. In J. Benjamin, C. Bonsall, C. Pickard, & A. Fischer (eds), *Submerged Prehistory*. Oxbow books. 263-271.

Astolfi, M., 2023. Stone quarry sites at Kourion in Cyprus: new archaeological and geological data. Association for the Study of Marble and Other Stone In Antiquity (ASMOSIA XII). İzmir, Türkiye, 8th-14th October 2023.

Bailey, W.R., Holdsworth, R.E., & Swarbrick, R.E., 2000. Kinematic history of a reactivated oceanic suture: the Mamonia Complex Suture Zone, SW Cyprus. *Journal of the Geological Society* 157:6, 1107-1126.

Balter, M., 2009. Early Start for Human Art? Ochre May Revise Timeline. *Science* 323:5914, 569.

Bednarik, R.G., 2015. A taphonomy of palaeoart. *Antiquity* 68:258, 68-74.

Birchler Emery, P., Beck, J., Agapiou, A., Constantin, D., Lysandrou, V., Merminod, B., & Themistocleous, K., 2017. Linking a rural sanctuary with ancient metallurgy at Kataliondas Kourvellos (Cyprus). *BAF-Online: Proceedings of the Berner Altorientalisches Forum* 1.

Bleek, D.F. 1928. Bushmen of central Angola. *Bantu Studies* 3, 105-125.

Bolger, D., Crewe, L., Croft, P., Dalton, M., Dixon, J., Dobosz, A., Goring, E., Kinnaird, T., Lorentz, K., McCartney, C., Palamakumbura, R., Paraskeva, C., Peltenburg, E., & Ridout-Sharpe, J., 2019. *Souskiou-Laona Excavation Project*. Accessed 3rd May 2024, https://doi.org/10.5284/1057535.

Bolger, D., & Shiels, J., 2003. The Chalcolithic Settlements: The Pottery. In E. Peltenburg (ed), *The Colonisation and Settlement of Cyprus: Investigations at Kissonerga-Mylouthkia, 1976-1996.* Lemba Archaeological Project, Cyprus, III.1. 133-168.

Bragin, N.Y., 2023. The Most Important Events of Geological Evolution of Cyprus in the Late Cretaceous. *Stratigraphy and Geological Correlation* 30, 78-95.

Bragina, L.G., 2012. Radiolarian biostratigraphy of the Perapedhi Formation (Cyprus): implications for the geological evolution of the Troodos Ophiolite. *Bulletin de la Société Géologique de France* 183:4, 343-348.

Briois, F., Bigne, J.D., Hadad, R., Mazzucco, N., Mylona, P., Rousou, M., Tombret, O., & Zazzo, A., 2023. Le site épipaléolithique de Pakhtomena (Armenokhori*). Bulletin archéologique des Écoles françaises à l'étranger* [En ligne], Chypre, mis en ligne le 02 juin 2023, consulté le 28 juin 2023.

Broodbank, C., 2006. The Origins and Early Development of Mediterranean Maritime Activity. *Journal of Mediterranean Archaeology* 19:2, 199-230.

Calon, T.J., Aksu, A.E., & Hall, J., 2005. The Oligocene-Recent evolution of the Mesaoria Basin (Cyprus) and its western marine extension, Eastern Mediterranean. *Marine Geology* 221: 1-4, 95-120.

Chen, G., & Robertson, A.H.F., 2021. Evidence from Late Cretaceous-Paleogene volcanic rocks of the Kyrenia Range, northern Cyprus for the northern, active continental margin of the Southern Neotethys. *Lithos* 380-381, 105835.

Cherry, J.F., 1990. The First Colonization of the Mediterranean Islands: A Review of Recent Research. *Journal of Mediterranean Archaeology* 3:2, 145-222.

Clarke, J., & Wasse, A., 2019. Time out of joint: A re-assessment of the Cypriot Aceramic Neolithic site of Kalavasos-Tenta and its regional implications. *Levant* 51:1, 26-53.

Clarkson, C., Jacobs, Z., Marwick, B., Fullagar, R., Wallis, L., Smith, M., Roberts, R.G., Hayes, E., Lowe, K., Carah, X., Florin, S.A., McNeill, J., Cox, D., Arnold, L.J., Hua, Q., Huntley, J., Brand, H.E.A., Manne, T., Fairbairn, A., Shulmeister, J., Lyle, L., Salinas, M., Page, M., Connell, K., Park, G., Norman, K., Murphy, T., & Pardoe, C., 2017. Human occupation of northern Australia by 65,000 years ago. *Nature* 547, 306–310.

Cucchi, T., Domont, A., Harbers, H., Evin, A., Alcàntara Fors, R., Saña, M., Leduc, C., Guidez, A., Bridault, A., Hongo, H., Price, M., Peters, J., Briois, F., Guilaine, J., & Vigne, J.D. 2021. Bones geometric morphometrics illustrate 10th millennium cal. BP domestication of autochthonous Cypriot wild boar (Sus scrofa circeus nov. ssp). *Scientific Reports* 11. 11435.

Dalton, M., 2019. Geoarchaeological analyses of domestic space and building technologies. In E. Peltenburg, D. Bolger, & L. Crewe (eds), *Figurine Makers of Prehistoric Cyprus: Settlement and Cemeteries at Souskiou*. Oxbow Books, UK. 91-96.

Dayet, L., 2021. Invasive and Non-Invasive Analyses of Ochre and Iron-Based Pigment Raw Materials: A Methodological Perspective. *Minerals* 11, 210-244.

d'Errico, F., Moreno, R.G., & Rifkin, R.F., 2012. Technological, elemental and colorimetric analysis of an engraved ochre fragment from the Middle Stone Age levels of Klasies River Cave 1, South Africa. *Journal of Archaeological Science* 39:4, 942-952.

Dubreuil, L., & Grosman, L., 2009. Ochre and hide-working at a Natufian burial place. *Antiquity* 83, 935-954.

Dubreuil, L., & Grosman, L., 2013. The Life History of Macrolithic Tools at Hilazon Tachtit Cave. In O. Bar-Yosef & F.R. Valla (eds), *Natufian Foragers in the Levant: Terminal Pleistocene Social Changes in Western Asia.* International Monographs in Prehistory. 527-543.

Eiselt, B.S., Popelka-Filcoff, R.S., Darling, J.A. & Glascock, M.D., 2011. Hematite sources and archaeological ochres from Hohokam and O'odham sites in central Arizona: an experiment in type identification and characterization. *Journal of Archaeological Science* 38:11, 3019-3028.

Fiedel, S.J., & Anthony, D.W., 2003. Deerslayers, Pathfinders, and Icemen: Origins of the European Neolithic as seen from the frontier. In M. Rockman & J. Steele (eds), *The Colonization of Unfamiliar Landscapes: The Archaeology of Adaptation*. Routledge, London. 144-168.

Finlayson, B., & Makarewicz, C., 2017. The Construction of Community in the Early Neolithic of Southern Jordan. In M. Benz, H.G.K. Gebel, & T. Watkins (eds), *Neolithic Corporate*

Identities Studies in Early Near Eastern Production, Subsistence, and Environment 20. Berlin. 91-106.

Galili, E., Şevketoğlu, M., Salamon, A., Zviely, D., Mienis, H.K., Rosen, B., & Moshkovitz, S., 2016. Late Quaternary beach deposits and archaeological relicts on the coasts of Cyprus, and the possible implications of sea-level changes and tectonics on the early populations. *Geology and Archaeology: Submerged Landscapes on the Continental Shelf*. Geological Society, London, Special Publications.

Geological Survey Department, 1995. Geological Map of Cyprus. Geological Survey Department, Ministry of Agriculture, Natural Resources, and Environment. https://www.moa.gov.cy/moa/gsd/gsd.nsf/page32_en/page32_en?OpenDocument&Start=1&Count=1000&Expand=1. Accessed 15th March 2024.

Geological Survey Department, 2017. *Troodos Ophiolite.* Cyprus Geological Survey Department, Ministry of Agriculture, Rural Development, and Environment. https://www.moa.gov.cy/moa/gsd/gsd.nsf/page47_en/page47_en?OpenDocument. Accessed 28th February 2024.

Geological Survey Department, 2017. *Keryneia Terrane*. Cyprus Geological Survey Department, Ministry of Agriculture, Rural Development, and Environment. https://www.moa.gov.cy/moa/gsd/gsd.nsf/page49_en/page49_en?OpenDocument. Accessed 28th February 2024.

Guilaine, J. 2023. Klimonas and the continental PPNA. In J.D. Vigne, F. Briois & J. Guilaine (eds), *Klimonas: An Early Pre-Pottery Neolithic Village in Cyprus*. Paris: CNRS. 17-22.

Helwig, K., 1997. A note on burnt yellow earth pigments: documentary sources and scientific analysis. *Studies in Conservation* 42:3, 181-188.

Howitt-Marshall, D., 2021. Mariners, Maritime Interaction, and the 'Ritual' of Sea Travel in Early Neolithic Cyprus. In S. Demesticha., L. Blue., & K. Baika (eds*), Under the Mediterranean I. Studies in Maritime Archaeology*. Leiden: Sidestone Press. 239-266.

Kähler, G., & Stow, D.A.V., 1998. Turbidites and contourites of the Palaeogene Lefkara Formation, southern Cyprus. *Sedimentary Geology* 115, 215-231.

Kassianidou, V., 2011. Blowing the Wind of Change: The Introduction of Bellows in Late Bronze Age Cyprus. In P.P. Betancourt & S.C. Ferrance (eds), *Metallurgy: Understanding How, Learning Why*. *Studies in Honor of James D. Muhly*. Prehistory Monographs 29. INSTAP Academic Press, 41-48.

Kenyon, K.M., 1954. Excavations at Jericho. *The Journal of the Royal Anthropological Institute of Great Britain and Ireland* 84:1-2, 103-110.

Kinnaird, T.C., Robertson, A.H.F., & Morris, A., 2011. Timing of uplift of the Troodos Massif (Cyprus) constrained by sedimentary and magnetic polarity evidence. *Journal of the Geological Society* 168, 457-470.

Knapp, A.B., 2013. *The Archaeology of Cyprus: From Earliest Prehistory Through the Bronze Age*. Cambridge University Press, Cambridge.

Knapp, A.B., 2020. Maritime Narratives of Prehistoric Cyprus: Seafaring as Everyday Practice. *Journal of Maritime Archeology* 15, 415-450.

Ktori, M., 2010. *Polished Artifacts. Issues of Tool Function from the PPN Ayia Varvara Asprokremnos Assemblage: A Use-wear Approach.* Unpublished MA thesis, University of Cyprus, Nicosia.

Le Brun, A., 2005. Like a bull in a chine shop: identity and ideology in Neolithic Cyprus. In J. Clarke (ed.), *Archaeological Perspectives on the Transmission and Transformation of Culture in the Eastern Mediterranean*, Council for British Research in the Levant, pp. 113-117.

Lombard, M., 2007. The gripping nature of ochre: The association of ochre with Howiesons Poort adhesives and Later Stone Age mastics from South Africa. *Journal of Human Evolution* 53:4, 406-419.

MacDonald, B.L., Hancock, R.G.V., Cannon, A., & Pidruczny, A., 2011. Geochemical characterization of ochre from central coastal British Columbia, Canada. *Journal of Archaeological Science* 38, 3620-3630.

Manning, S.W., 2014. Temporal placement and context of Cypro-PPNA activity on Cyprus. *European Prehistory* 11:1-2, 9-28.

Manning, S.W., McCartney, C., Kromer, B., & Stewart, S.T., 2009. The earlier Neolithic in Cyprus: recognition and dating of a Pre-Pottery Neolithic A occupation. *Antiquity* 84, 693-706.

McCartney, C., nd, in press. The lithic assemblage of Ayia Varvara-Asprokremnos: a new perspective on the Early Neolithic of Cyprus. In E. Hildebrand (ed.) *Studies in Technology, Environment, Production and Society*. Berlin, ex Oriente.

McCartney, C., 2017. Agia Varvara Asprokremmos. A late PPNA specialized site on Cyprus. In J.D., Vigne, F. Briois, & M. Tengberg (eds), *Actes de la séance de la Société préhistorique française* Paris, 18-19 mars 2015. 47-58.

McCartney, C., Manning, S.W., Rosendahl, S., & Stewart, S.T., 2008. Elaborating Early Neolithic Cyprus (EENC) Preliminary Report on the 2007 Field Season: Excavations and Regional Field Survey at Agia Varvara-Asprokremmos. *RDAC.* 67-86.

McCartney, C., & Torrentino, G., 2019. Ayia Varvara-Asprokremnos- a preliminary analysis of stone tools used in pigment processing and tanning with ochre. In L. Astruc, C. McCartney, F. Briois & V. Kassianidou (eds.), *Near Eastern lithic technologies on the move. Interactions and contexts in Neolithic traditions*, 8th International Conference on PPN Chipped and Ground Stone Industries of the Near East; Nicosia, November 23rd-27th, 2016.

Moutsiou, T., Ioannides, D., Charalambous, A., Schöder, S., Webb, S.M., Thoury, M., Kassianidou, V., Zomeni, Z., & Reepmeyer, C., 2022. X-ray Fluorescence Spectroscopy of Picrolite Raw Material on Cyprus. *Heritage* 5:2, 664-676.

Mulvaney, J., & Kamminga, J., 1999. *A Prehistory of Australia*. Smithsonian Institute Press.

Mylona, P., Wattez, J., & Vigne, J.D., 2023. The earthen architecture as a mirror of the Neolithic cultural organization: the case of the PPNA site of Klimonas in Cyprus. *Palethnologie* 11.

Nerantzis, N., & Papadopoulos, S., 2013. Reassessment and new data on the diachronic relationship of Thassos Island with its indigenous metal resources: a review. *Archaeological and Anthropological Sciences* 5, 183-196.

Olley, J.M., Roberts, R.G., Yoshida, H., & Bowler, J.M., 2006. Single-grain optical dating of grave-infill associated with human burials at Lake Mungo, Australia. *Quaternary Science Reviews* 25:19-20, 2469-2474.

Olympus, n.d. *XRF Analyzers- Vanta Max and Vanta Core: Vanta Specifications*. Evident Scientific. https://www.olympus-ims.com/en/xrf-analyzers/handheld/vanta/#!cms[focus]=cmsContent14332. Accessed 28th March 2024.

Papadopoulous, A., 2021. Prehistoric Cyprus: fieldwork and research, 2003–2020. *Archaeological Reports* 67, 81-108.

Peltenburg, E., Colledge, S., Croft, P., Jackson, A., McCartney, C., & Murray, M.A., 2000. Agro-pastoralist colonization of Cyprus in the 10th millennium BP: initial assessments. *Antiquity* 74, 844-853.

Polidorou, M., & Evilpidou, N., 2017. Coastal Palaeogeography of Akrotiri Peninsula, Cyprus. In: *New Technologies, Hazards and Geoarchaeology - Paolo Pirazzoli in memoriam*. Athens, Greece.

Popelka-Filcoff, R.S., & Zipkin, A.M., 2022. The archaeometry of ochre *sensu lato*: A review. *Journal of Archaeological Science* 137, 105530.

Puaud, S., & Lebon, M., 2023. Les matières colorants rouges et noires et les matières minerales dures de couleur verte. In J.D. Vigne, F. Briois, & J. Guilaine, 2023. *Klimonas, an early Pre-Pottery Neolithic village in Cyprus - Klimonas, un village néolithique précéramique ancien à Chypre*, Paris, CNRS Editions (Gallia Préhistoire, International supplement 1). 393-397.

R Development Core Team (2008) *R: A Language and Environment For Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. URL http://www.R-project.org.

Rifkin, R.F., 2011. Assessing the Efficacy of Red Ochre as a Prehistoric Hide Tanning Ingredient. *Journal of African Archaeology* 9:2, 131-158.

Rifkin, R.F., 2012. Processing ochre in the Middle Stone Age: Testing the inference of prehistoric behaviours from actualistically derived experimental data. *Journal of Anthropological Archaeology* 31:2, 174-195.

Rifkin, R.F., 2015. Ethnographic and experimental perspectives on the efficacy of ochre as a mosquito repellent. *The South African Archaeological Bulletin* 70:201, 64-75.

Rifkin, R.F., d'Errico, F., Dayet-Boulliot, L., & Summers, B., 2014. Assessing the photoprotective effects of red ochre on human skin by in vitro laboratory experiments. *South African Journal of Science* 111:3/4.

Rizopoulou-Egoumenidou, E., 2009. *Tanning in Cyprus from the 16th to the 20th Century. From the traditional tanneries to modern industries*. Nicosia: Publications of the Cyprus Research Center.

Robertson, A., 1977. Tertiary uplift history of the Troodos massif, Cyprus. *GSA Bulletin* 88:12, 1763-1772.

Robertson, A., & Xenophontos, C., 1993. Development of concepts concerning the Troodos ophiolite and adjacent units in Cyprus. *Geological Society, London, Special Publications* 76. 85-119.

Robitaille, J. 2023. Macrolithic tools. In J.D. Vigne, F. Briois, & J. Guilaine, 2023. *Klimonas, an early Pre-Pottery Neolithic village in Cyprus - Klimonas, un village néolithique précéramique ancien à Chypre*, Paris, CNRS Editions (Gallia Préhistoire, International supplement 1). 285-309.

Rockman, M., 2009. Landscape Learning in Relation to Evolutionary Theory. In A. Prentiss., I. Kuijt., & J. Chatters (eds). *Macroevolution in Human Prehistory.* Springer, New York, NY.

Rollefson, G., 2003. The Neolithic Period. In S. Richard (ed.), *Near Eastern Archaeology: A Reader*, 244-253. Penn State University Press.

Rousou, Maria 2022. *Exploitation des ressources végétales et impact environnemental des premiers peuplementshumains à Chypre: approches anthracologique et carpologique*, Muséum National d'Histoire Naturelle Paris - University of Cyprus (unpubl. PhD Thesis).

Saliari, K., & Felgenhauer-Schmiedt, S., 2017. Skin, leather, and fur may have disappeared, but bones remain… The case study of the 10 th century AD fortified settlement Sand in Lower Austria. *Ann. Naturhist. Mus. Wien, Serie A* 119, 95-114.

Schapera, I. & Goodwin, A. J.H. 1953. Work and wealth. In: Schapera, I. (ed.), *The Bantu-speaking Tribes of South Africa. An Ethnographical Survey*. Routledge, London. 131-171.

Schuiling, R.D., 2011. Troodos: A Giant Serpentinite Diapir. *International Journal of Geosciences* 2, 98-101.

Shackley, M.S., 2008. Archaeological petrology and the archaeometry of lithic materials. *Archaeometry* 50:2, 194-215.

Simmons, A.H., 1988. Extinct pygmy hippopotamus and early man in Cyprus. *Nature* 333:6173, 554-557.

Simmons, A.H., 2007. The Earliest Cypriots. *Archaeologia Cypria* V, Association of Cypriot Archaeologists, 13-27.

Simmons, A.H., 2009. Until the cows come home: cattle and Early Neolithic Cyprus. *Hunter Gatherer Research* 1, 1-10.

Simmons, A.H., 2014. Akrotiri-*Aetokremnos* (Cyprus) 20 years later: an assessment of its significance. *Eurasian Prehistory* 10:1-2, 139-156.

Simmons, A.H., 2014. *Stone Age Sailors: Paleolithic Seafaring in the Mediterranean*. Taylor & Francis Group.

Simmons, A., & Mandel, D.R., 2016. Site Formation Processes at Akrotiri-Aetokremnos, Cyprus: Why is the site so controversial? In M. Ghilardi (ed.), *Géoarchéologie des îles de la Méditerranée*. Paris: CNRS Éditions, 57-72.

Smith, M., & Fankhauser, B., 2009. Geochemistry and identification of Australian red ochre deposits. *PalaeoWorks Technical Report* 9, Canberra.

Spyrou, A., Roberts, P., Bleasdale, M., Lucas, M., Crewe, L., Simmons, A., & Webb, J., 2024. Human-cattle interactions in PPNB and Early- Middle Bronze Age Cyprus: Integrating zooarchaeological and stable isotope data. *Archaeological and Anthropological Sciences* 16:64.

Stafford, M.D., Frison, G.C., Stanford, D., & Zeimans, G., 2003. Digging for the Color of Life: Paleoindian Red Ochre Mining at the Powars II Site, Platte County, Wyoming, U.S.A. *Geoarchaeology* 18:1. 71-90.

Stewart, S.T., Murphy, S., Bikoulis, P., McCartney, C., Manning, S.W., & Hancock, R.G.V., 2020. Early Neolithic chert variability in central Cyprus: Geo-chemical and spatial analyses. *Journal of Archaeological Science: Reports* 29. 102088.

Stuart, B.H., & Thomas, P.S., 2017. Pigment characterisation in Australian rock art: a review of modern instrumental methods of analysis. *Heritage Science* 5:10.

Suga, E., Tsukada,K., Tarawneh, O., Massadeh, S., & Kadowaki, S., 2023. Explaining the Increase in "High-quality Chert" in the Early Upper Paleolithic Artifacts in Southern Jordan: Quantitative Examination of Chert Mechanical Properties and Fracture Predictability. *Journal of Palaeolithic Archaeology* 6:35.

Todd, I.A., 1982. Vasilikos Valley Project: Fourth Preliminary Report, 1979-1980. *Journal of Field Archaeology* 9:1, 35-77.

Velliky, E.C., Barbieri, A., Porr, M., Conard, N.J., & Macdonald, B.L., 2019. A preliminary study on ochre sources in Southwestern Germany and its potential for ochre provenance during the Upper Paleolithic. *Journal of Archaeological Science: Reports* 27, 101977.

Velo, J., 1984. Ochre as Medicine: A Suggestion for the Interpretation of the Archaeological Record. *Current Anthropology* 25:5, 674.

Vigne, J.D., Zazzo, A., Saliège, J.F., Poplin, F., Guilaine, J., & Simmons, A., 2009. Pre-Neolithic wild boar management and introduction to Cyprus more than 11,400 years ago. *PNAS* 106:38, 16135-16138.

Vigne, J.D., Briois, F., Zazzo, A., Willcox, G., Carrère, I., Daujat, J., & Guilaine, J., 2011. A New Early Pre-Pottery Neolithic Site in Cyprus: Ayios Tychonas – Klimonas (ca. 8700 cal. BC). *Neo-Lithics* 1/11.

Vigne, J.D., Briois, F., Zazzo, A., Willcox, G., Cucchi, T., Thiébault, S., Carrère, I., Franel, Y., Touquet, R., Martin, C., Moreau, C., Comby, C., & Guilaine, J. 2012. First wave of cultivators spread to Cyprus at least 10,600 y ago. *Proc Natl Acad Sci* 109:22. 8445-8449.

Vigne, J.D., Briois, F., & Tengberg, M., 2017. Nouvelles données sur les débuts du Néolithique à Chypre/ New data on the beginnings of the Neolithic in Cyprus. In J.D., Vigne, F. Briois, & M. Tengberg (eds), *Actes de la séance de la Société préhistorique française* Paris, 18-19 mars 2015. 7-11.

Vigne, J.D., Briois, F., Cucchi, T., Franel, Y., Mylona, P., Tengberg, M., Touquet, R., Wattez, J., Willcox, G., Zazzo, A., & Guilaine, J., 2017. Klimonas, a late PPNA hunter-cultivator village in Cyprus: new results. In J.D., Vigne, F. Briois, & M. Tengberg (eds), *Actes de la séance de la Société préhistorique française* Paris, 18-19 mars 2015. 21-45.

Vigne, J.D., Briois, F., Guilaine, J. 2023. *Klimonas, an early Pre-Pottery Neolithic village in Cyprus - Klimonas, un village néolithique précéramique ancien à Chypre*, Paris, CNRS Editions (Gallia Préhistoire, International supplement 1).

Vigne, J.D., Cucchi, T., Rousou, M., Bailon, S., Carrère, I., Devillers, B., Douché, C., Gourichon, L., Hadjikoumis, A., Mylona, P., Papayianni, K., Parès, A., Tengberg, M., Zazzo, A., Guilaine, J.,

& Briois, F., 2023. Historical dynamics of the human-environment interactions in Cyprus during the 12th-10th millennia cal. BP: The last 30 years contributions of the Amathous area (Limassol district), *Journal of Archaeological Science: Reports* 50, 104049.

Wadley, L., 2005. Ochre crayons or waste products? Replications compared with MSA 'crayons' from Sibudu Cave, South Africa. *Before Farming* 3, 1-12.

Xenophontos, C., 1991. Picrolite, Its Nature, Provenance, and Possible Distribution Patterns in the Chalcolithic Period of Cyprus. *Bulletin of the American Schools of Oriental Research* 282/283, 127-138.

Zazzo, A., Lebon, M., Quiles, A., Reiche, I., & Vigne, J.D., 2015. Direct Dating and Physico-Chemical Analyses Cast Doubts on the Coexistence of Humans and Dwarf Hippos in Cyprus. *PLoS One* 10:8.

Zeman-Wiśniewska, K., 2018. The space above. Sacred sky in Prehistoric Cyprus. In L.D. Nebelsick., J. Wawrzeniuk., & K. Zeman-Wiśniewska (eds), *Sacred space: contributions to the archaeology of belief*. Archaeologica Hereditas 13, Monographs of the Institute of Archaeology of the Cardinal Stefan Wyszyński University in Warsaw. 29-32.