Sacred Spaces: The characterisation of space and practice at the Early Bronze Age cult centre of Dhaskalio-Kavos, Keros, Greece

By:

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Abstract

The ‘special deposits’ recovered during excavations in the 1980s and 2000s at Dhaskalio-Kavos on the island of Keros, Greece, give claim to the site as the world’s earliest maritime sanctuary. The concentration of fragments of EBA Cycladic marble figurines and vessels at Dhaskalio-Kavos are separate from, yet in close proximity to the headland settlement of Dhaskalio, which emphasises the significance of partitioning specific practices at the cult centre. Through the use of high-resolution geochemical survey by way of hand-held portable X-ray fluorescence (HHpXRF), this thesis has sought to understand the character and spatial organisation of activities associated with the EBA cult centre at Dhaskalio-Kavos whilst also aiming to better explore the role that geochemistry can play in archaeological research. A programme of routine analysis of contexts from excavations at Dhaskalio under the auspices of the Keros-Naxos Seaways Project allowed for the detailed chemical characterisation of occupation surfaces across the settlement. This revealed evidence for extensive metalworking of both copper and lead during Dhaskalio Phase A (EC IIA) and Phase B (EC IIB), with the suggestion that this practice continued on a smaller scale during the final phase of occupation (Phase C). The extent of metallurgical practice at Dhaskalio offers an understanding of how the site became a major social centre during the EC II period, and how the changing socioeconomic landscape of the late EC II may explain changes to the spatial distribution of these activities at the site. Furthermore, the intensive application of on-site, *in situ* soil chemistry within the contexts of excavation facilitated the real-time feedback of soil chemical results to excavators, specialists, and field directors, in order to form part of the ongoing decision-making process and overall interpretation of the site. This use of soil chemistry is not routinely undertaken in archaeological research. Therefore, it is hoped that this thesis may help to establish a methodological best practice for how HHpXRF can be used to better aid archaeological interpretation in the field.

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CHAPTER 1: Introduction

1.1 Introduction to Study

The today uninhabited island of Keros, located in the central Cyclades between the larger islands of Naxos and Amorgos, is home to one of the most important settlements and ritual sites in the EBA Cyclades. The 'special deposits' recovered during the remarkable excavations in the 1980s and 2000s at Dhaskalio-Kavos on Keros, Greece, give claim to the site as the world's earliest maritime sanctuary (Renfrew et al., 2012). Study of the 'special deposits' has indicated people from a wide region congregated at Kavos with the intent of depositing a rich array of material, itself from a wide geographic region, in practices which preceded the later emergence of coherently-organised religion. The marble sculptures, in the form of the iconic Cycladic figurines, were all intentionally broken elsewhere; not at the sanctuary, and not, it seems, anywhere else on Keros (Renfrew, 2013). A single fragment of each sculpture was selected for transport to Keros and deposition at the sanctuary. Analysis of other finds has shown that participants in these rituals came from far and wide in the Aegean (Gavalas, 2017; 2018). The concentration of fragments of EBA Cycladic marble figurines and vessels at Dhaskalio-Kavos are separate yet in close proximity to the headland settlement of Dhaskalio, and emphasise the significance of partitioning specific practices at the cult centre.

Dhaskalio lies c. 90m to the west of Kavos and was likely joined to mainland Keros by a thin spit of land during the EBA before rising sea levels disconnected the two landmasses (Lambeck, 1996). Excavations at the settlement, which took place between 2006 and 2008, revealed multiple phases of architecture and, significantly, evidence for metallurgical practice, which seems to have taken place on a small scale throughout the known settlement (Georgakopoulou, 2016). The close proximity of Dhaskalio to the special deposits on Kavos necessitates questions as to the role that Dhaskalio played in the ritual practices taking place on Kavos. In what ways might the settlement have assisted the enactment of such ritual practices? And, given the evidence for both primary and secondary production, what role did metallurgy play at the site? These important questions may be answered through exploring the nature of activities taking place at Dhaskalio, and how the space was organised in order to facilitate the activities taking place at the Special Deposits. The latest excavations of Dhaskalio (2016 to 2018) offered a unique opportunity to explore the relationship between the settlement at Dhaskalio and the Kavos coastline. Generating a detailed understanding of the spatial organisation of activities at Dhaskalio is critical for understanding the wider environment and infrastructure that supported the specific practices identified at Kavos itself. This project hopes to aid in answering these questions pertaining to spatial organisation at Dhaskalio-Kavos through the implementation of high-resolution geochemical survey.

Archaeology has long established that diverse human activities may significantly affect the formation and chemical composition of archaeological soils (Middleton & Price 1996; Entwistle et al. 2000; Oonk et al. 2009). This relation between human activity and soil chemistry has given rise to chemical prospection methods on archaeological sites (Aston et al. 1998), the study of specific land-based practices (Konrad et al. 1983; Muhs et al. 1985), and the characterisation and interpretation of archaeological soil features (Lillios, 1992). Despite these established and extensive applications, the use of soil chemistry remains rare in routine archaeological fieldwork. This is due to a number of factors, including time and cost, but the uncertainty as to why specific chemical elements are enhanced by particular practices has also inhibited the wider use of soil chemistry. The processes by which anthropogenic matter may become concentrated in archaeological soils are complex and remain, in many instances, poorly understood (Oonk et al. 2009: 38).

In light of the difficulties of identifying specific activities from chemical analyses, geochemical investigations have largely been used to simply highlight areas of increased human activity or simply the presence of 'archaeology' (e.g. Bintliff et al., 1992). However, there are important exceptions to this ambiguity in dealing with geochemistry. Craft activities, and especially non-ferrous metalworking, have been shown to result in clear heavy metal enhancement that is orders of magnitude greater than enhancements associated with generic 'domestic' activities (Oonk et al. 2009). This quantitative difference means that areas associated with metalworking can be broadly identified though elevated levels of heavy metals (Cu, Pb), and given enough sampling points, differential use of space may be identifiable. Most studies have been restricted to a limited number of samples that has in turn constrained the interpretive potential of geochemical data. Higher sample numbers can permit a finer understanding of the organisation of space and the spatial routines associated with past human action, rather than the broad characterisation of extensive contexts by a handful of samples (Frahm and Doonan, 2013).

Conventional geochemical analysis, utilising laboratory-based methods, operate with restricted sample numbers due to limitations of sampling time and costs of analysis (e.g. Maskall et al. 1995; Middleton & Price, 1996; Entwistle et al. 2000; Wilson et al. 2008; Wilson et al. 2009). As such, sampling strategies employed when utilising laboratory methods are often determined more by the logistics of shipping soil and the expense of analysis, and have rarely been employed to identify spatial patterning at a level of resolution commensurate with human practice, instead being used for broadly descriptive programs of soil characterisation (Frahm & Doonan, 2013). In light of the centrality of space in theories of 'agency' and practice, alongside the burgeoning importance given to context, the ability to characterise space through the analyses of soil matrices is significant. Developments in portable analytical instrumentation, such as hand-held portable X-ray fluorescence (HHpXRF), enables the ability to undertake rapid in situ analysis in a cost-effective manner, and permits high resolution analysis of spatial patterning as a way of defining signatures of practices manifest in extended regions of the soil matrix. Furthermore, real time production of geochemical results in the field allows this data to inform excavation strategy throughout the course of an excavation. Such an approach is simply impractical in conventional geochemistry due to the lengthy periods required for sample preparation and laboratory analysis.

Therefore, this thesis represents the coming together of both archaeological and methodological concerns. In situ, high-resolution geochemical survey will allow for a detailed analysis of

Dhaskalio-Kavos, which will offer insight into the spatial organisation of specific craft practices taking place at the EBA ritual centre, and the excavations at Dhaskalio, under the auspices of the Cambridge Keros-Naxos Seaways Project, offers a unique opportunity to better explore the role that geochemistry can play in archaeological research.

1.2 Aims and Objectives

1.2.1 Aims

The overall aim of this thesis is to understand the character and spatial organisation of activities associated with the EBA cult centre at Dhaskalio-Kavos. This spatial characterisation will largely be concerned with metallurgical practice, especially with regards to how these activities may be considered within an understanding of the ritual nature Dhaskalio-Kavos. In addition, the rich material culture present at Dhaskalio-Kavos, coupled with the extensive programme of excavation and analysis under the auspices of the Cambridge Keros-Naxos Seaways Project, offers a unique case study for the development of geochemical methodologies. Therefore, the secondary aim of this thesis is to better explore the role that geochemistry can play in archaeological research.

1.2.2 Objectives

The aim to characterise the spatial organisation of Kavos and settlement at Dhaskalio will be achieved through the following objectives:

- High resolution wide-area geochemical prospection surveys of Dhaskalio-Kavos and the settlement site at Dhaskalio.
- Targeted high-resolution surveys (0.25m-0.5m) of all archaeological floors, and anthropogenically significant fills and deposits within the Dhaskalio excavation.
- Use results from the multi-scalar geochemical surveys to characterise a range of activities across the Dhaskalio-Kavos Landscape with a special focus on metalworking and craft practice.

These objectives will allow for an analysis of how the organisation of specific practices establish Kavos as significant centre for social congregations and how this transformed through time.

The aim to better explore the role that geochemistry can play in archaeological research will be achieved through the following objectives:

- The intensive application of on-site soil chemistry techniques using HHpXRF for a campaign of rapid, in situ analysis within the contexts of excavation.
- Provide real-time feedback of soil chemical results to excavators, specialists, and field directors in order to form part of the ongoing decision-making process and overall interpretation of the site.

1.3 Importance of Study

The dense and extensive character of architecture at Dhaskalio prevents total excavation and the topography and vegetation do not permit geophysics. Geochemistry therefore is one of the few methods available that can characterise the entire site to both inform excavation planning and to define variability across the site. This element of prospection coupled with subsequent characterisation of archaeological contexts from within open excavations will permit an unprecedented geochemical record for an archaeological site. Furthermore, the rich material culture present at EBA Cycladic sites coupled with the extensive program of excavation under the auspices of the Keros-Naxos Seaways project offer great potential to better explore the role that geochemistry can play in archaeological research. Therefore, it is hoped that the interpretations and conclusions of this thesis will represent a significant piece of work in terms of method development, as well as the delineation of space at a significant EBA cult centre.

1.4 Thesis Outline

This thesis starts with two introductory chapters in order to offer historical and methodological context for the succeeding study. Chapter 2 will offer a broad understanding as to the historical context of this project, starting with summary of current understanding pertaining to EBA Cycladic communities, and the evidence which provided such interpretation. This will be followed by an overview of previous investigations at Dhaskalio-Kavos in order to offer site-specific context to the current study.

Chapter 3 then offers theoretical and methodological context to this study by detailing the historical use of geochemistry in archaeology, and considers the impact of the evolution of portable techniques on future applications of in situ methods of soil analysis in the field.

Chapter 4 presents the field and desk-based methods used for obtaining high-resolution geochemical data. This chapter includes information pertaining to in situ sampling strategies, instrumentation, analytical perdition, data handling, and statistical and spatial processing of geochemical data.

Key results obtained using these methods are then presented in Chapter 5. This chapter is broken into two main sections, the wide-area surveys of Kavos and Dhaskalio, which includes results of the principal component analysis, and the spatial analysis of occupation layers from trenches at the settlement of Dhaskalio. Results from this section are reported on a trench by trench basis, with information pertaining to chronological phasing given where available. All results are presented alongside interpretive commentary, offering insight into the implications of the spatial distribution of various chemical concentrations from an anthropogenic perspective.

Chapter 6 constitutes the main discussion of the thesis. This chapter is broken into two main sections. The first discussion aims to frame the geochemical data within the archaeological context of Dhaskalio-Kavos and the wider EBA Cyclades. Soil chemical results will be used in order to analyse how the spatial organisation of activities at Dhaskalio changed throughout its use as a significant centre, as well as how these changing activities may have been linked to the ritual practices taking place at Kavos.

The second theme of discussion will be focussed on methodological aspects of this research and how the use of in situ geochemical analysis within an excavation context offers great interpretive value for archaeological research.

The thesis then closes with Chapter 7 which presents the overall conclusions of the study.

CHAPTER 2: The Cyclades during the Early Bronze Age and the site of Dhaskalio-Kavos

2.1 Introduction

Decades of continuous archaeological investigation has cemented the Early Bronze Age (EBA) Cyclades as one of the most highly studied, yet enigmatic periods of Aegean prehistory. One of the most noteworthy discoveries has been that of the EBA sanctuary and allied settlement at Dhaskalio-Kavos on the island of Keros. Recent excavations (2016 to 2018) offered a unique opportunity for exploring the spatial organisation of this EBA Cycladic settlement and its link to a ritual centre. Whilst this thesis is largely concerned with aspects of this remarkable site, it is important to offer some context within which the results of this study should be considered. This chapter will offer a broad understanding as to the historical context of this study, though it should not be considered exhaustive. Information pertaining to Dhaskalio-Kavos alone spans multiple published volumes, and several explanatory syntheses for the Bronze Age Cyclades have been produced (e.g. Berg, 2019; Barber, 1987; Broodbank, 2000a; Renfrew, 1972; Shelmerdine, 2008). Therefore, the following section will provide a summary of our current understanding of EBA Cycladic communities, and the evidence which provided such interpretations. Subsequently, a brief explanation of the evidence from previous investigations on Dhaskalio-Kavos will be presented in order to offer site-specific context to the current study, as well as demonstrate how this site offered an arguably unparalleled opportunity for exploring methods of high-resolution geochemical analysis.

2.2 Archaeology of the Cycladic Early Bronze Age

The Cyclades have been the subject of archaeological scrutiny since at least the late 19th century. The excavations at Delos by the French School of Archaeology in 1877 saw the first major, systematic excavation in these islands. However, the excavators at Delos were solely interested in the attractiveness of the Classical, Hellenistic, and Roman past, classifying the "rough handmade earthenware" and "strange figurines" which made up the EBA Cycladic remains as merely "other prehistoric remains" (Oikonomides, 1965: xxi). It was the appearance of two publications by James Theodore Bent in 1884 and 1885 and Christos Tsountas in 1898/9 which marked the beginning of the EBA Cyclades as a special subject of archaeological research (Evans, 1979: 7; Renfrew, 2008: 1). Subsequently, the Cyclades witnessed an intensification of archaeological interest, particularly from the mid-twentieth century. This research includes excavations and extensive surface surveys of various Cycladic islands (e.g. Caskey, 1971; Doumas, 1977; Renfrew, 1972), and numerous studies centred around specific aspects of material culture (e.g. Carter, 1998; Gale and Stos-Gale, 1981; 1984; 2008; Georgakopoulou, 2005; Renfrew, 1967; Sherratt, 2000; Sotirakopoulou, 2016; Wilson, 1999). These studies have produced a large body of archaeological data, allowing for several broad syntheses of life in the EBA Cyclades (see for example Berg, 2019; Broodbank 2000 and references within).

The Aegean Bronze Age has traditionally been partitioned into three periods: Early, Middle, and Late (abbreviated to EBA, MBA, and LBA respectively). These broad chronologies are often further subdivided into smaller periods. For instance, the EBA, with which this thesis is concerned, has often been subdivided into EB I, EB II, and EB III (EC I, II, and III in some instances when referring to only the Cyclades). However, the classification of these chronological divisions has been the subject of much debate (Barber and MacGillivray, 1980; Rutter, 1984 - for a detailed debate pertaining to the existence of Rutter's EC III 'gap', see the 2013 'Minding the Gap' volume from *American Journal of Archaeology*). This is, in part, due to the relative lack of a continuous stratigraphic sequence which spans the entire EC period at any one Cycladic site. Indeed, traditional understanding of the Cycladic EBA chronology has largely depended on the long occupational sequence at the major settlement site of Phylakopi on

Melos (Barber, 1987: 22). Whilst it is unnecessary for the current study to delve extensively into the arguments pertaining to chronological nomenclature, a brief clarification of terms used specifically for the EBA Cyclades is needed for the following discussion.

Rather than use the more or less standard tripartite divisions of EC I, II, and III, which he saw as an inadequate analogy merely based on chronological sequences from Crete and the Greek Mainland (Renfrew, 1972: 135), Renfrew (1972) offered an alternative dating system for the EBA Cyclades. Dissatisfied with the confusing methods for understanding EBA Cycladic phasing employed by researchers during the previous decades (Renfrew, 1972: 136), Renfrew instead offered a chronological sequence based on the identification of distinct cultural groups. These 'cultures', defined by Childe as "constantly recurring assemblages of artefacts" (Renfrew, 1972: 135), are named after Early Cycladic cemeteries, settlements, or islands which produced assemblages of artefacts understood as being indicative of broad cultural identities in the Cycladic EBA (Barber, 1987: 24; Renfrew, 1972: 147). Through the systematic analysis of Early Cycladic grave site assemblages, and subsequent comparison with the stratigraphic sequence at Phylakopi (Renfrew, 1972: 138-47), Renfrew distinguished three cultures from the EBA Cyclades, naming them Grotta-Pelos (EC I) after the sites on Naxos and Melos, Keros-Syros (EC II) after the Cycladic islands of the same name, and Phylakopi I (EC III) in accordance with the original phasing at the settlement at Melos. This system was subsequently adopted by Doumas (1977), with the exception of the term "Grotta-Pelos", which he renamed "Pelos-Lakkoudes" (Lakkoudes after a cemetery site on Naxos) due to the observation that material from Grotta was more in common with those ascribed to the subsequent chronological period (Barber and MacGillivray, 1980: 156). In addition to these overarching cultures, a number of smaller cultural groups which fall either within or between the main groups, were proposed by Renfrew (1972) and Doumas (1977). Renfrew placed the Kampos group (after the EC cemetery on Paros) during the transition between Grotta-Pelos and Keros-Syros, whilst the Kastri (so called after the settlement site on Syros) and Amorgos (after the island of the same name) groups became subdivisions of the Keros-Syros and Phylakopi I cultures (Barber and MacGillivray, 1980: 143).

Conversely, whilst retaining Renfrew's Kampos, Kastri, and Amorgos groups, Doumas elected to include further subdivisions of Lakkoudes, Pelos, Plastiras, and Syros, which encompassed EC I and early EC II (Barber and MacGillivray, 1980: 143).

It is likely evident from the above explanation, that this "culture" terminology used for defining chronological periods for the Early Cycladic Culture is arguably overly complex and, as a result, needlessly esoteric. Indeed, Barber and MacGillivray (1980), echo this notion, stating that "the culture system has resulted in a good deal of confusion" (Barber and MacGillivray, 1980: 144). They argue that, whilst defining these cultural traditions is useful for the study of certain material evidence, particularly pottery and figurines, the "traditional and essentially chronological divisions" of the EBA Cyclades "better reflect the facts" (Barber and MacGillivray, 1980: 144). However, whilst essentially advocated a return to the traditional tripartite terminology, Barber and MacGillivray did offer one significant change. It was proposed that there should be a subdivision of EC III into two periods, EC IIIA and EC IIIB, with earlier EC IIIA being used to describe Renfrew's Kastri Group, and the later EC IIIB being used for Renfrew's Phylakopi I culture (**figure 2.1**) (equivalent to the old EC III, see Barber and MacGillivray, 1980). However, the final phase of the Early Bronze Age in the Cyclades represents a further period of contention amongst archaeologists (see below), and this return to traditional tripartite terminology, albeit modified, did not serve to satisfy burgeoning questions regarding a perceived lack of chronological continuity during the EC III period (Rutter, 1984).

At the end of the 3rd millennium BCE, there is seemingly an observable abandonment of many of the previously established EC settlements, often accompanied by evidence for the violent termination of occupation (Wiener, 2013). This evidence, alongside an observable change in material culture, led Rutter (1984) to propose the existence of an EC III 'gap' (Rutter, 1984). Rutter's main concern was to show that a major cultural hiatus separated the two periods labelled EC IIIA and EC IIIB by Barber and MacGillivray. It was argued that this hiatus included not only significant cultural discontinuity (already noted to some extent by Barber and MacGillivray, 1980), but also a significant gap of perhaps a century and a half in the Cycladic EBA culture sequence. Consequently, Rutter argued that "EC IIIA" (Renfrew’s Kastri Group) should be renamed "EC IIB" because it was contemporaneous with later EH II (Early Helladic II) on the Greek Mainland and, by extension, later EM II (Early Minoan II) on Crete, whereas Barber's and MacGillivray's "EC IIIB" (Renfrew’s Phylakopi I) should be seen instead as MC I (Middle Cycladic I) as it was generally agreed to be contemporaneous with early MH (Middle Helladic) on the Mainland and, by extension, early MM IA (Middle Minoan IA) on Crete (**figure 2.1**) (Rutter, 1984). This, in effect, removed EC III from the chronological sequence for the Cyclades.

Date (BCE)	**Numerical phase (tripartite- Barber & MacGillivray- Rutter)**	**Culture name**	**Dhaskalio phase**
3200-3000	ECI	Grotta-Pelos	
3000-2800	ECI/II	Kampos group	
2800-2500	ECII	Keros-Syros	A
2500-2200	ECII/III – ECIIIa – ECIIb	Kastri group	B/C
2200-ca.2000/1900	ECIII – ECIIIb – MCI	Phylakopi I	

Figure 2.1: Table showing the Cycladic Bronze Age chronological system.

Since Rutter formulated his ‘gap’ hypothesis in the 1980s, evidence for cultural continuity between the EC II Late period and the beginning of the Middle Bronze Age has continued to draw much debate. Recent evidence from Rivari on Melos has been used to date the cemetery to EC II-III (Sampson and Fotiadi, 2008; Televantou, 2008), and evidence from Akrotiri on Thera has also been used to suggest continuity in occupation between the end of EC II and the MC period (Sotirakopoulou, 1996; 2008). However, this suggestion of chronological continuity at Akrotiri is largely established by the dating of pottery on a purely stylistic basis, with little contextual evidence based on stratigraphic sequence. When total assemblage, stratigraphical approaches to the same assemblages have been undertaken, including some analytically based data on provenance and technology, evidence for an EC III phase of occupation at Akrotiri is lacking (Kariotis et al., in press), as it is at Ayia Irini-Kea and most of other major sites. Instead, it has been shown that the EC II Kastri Group material at Akrotiri is succeeded by an assemblage associated with the beginning of what is the Middle Bronze Age elsewhere in the

Aegean (Akrotiri Phase A), with clear changes to technological choice and imports (Day et al., 2019; in press). This evidence demonstrates a significant hiatus in the ceramic sequence at Akrotiri and supports the notion of discontinuity in habitation patterns during this period of the Cycladic EBA, which saw many of the dispersed EBA sites being permanently abandoned by the end of the third millennium. Sites which have been excavated since the debate over the "EC III" gap began, such as Skarkos on Ios and Markiani on Amorgos, have failed to provide a complete EC sequence (Angelopoulou, 2017: 145; Broodbank, 2000: 326-31), meaning that the complexities surrounding the EB II-III transition and the nature of a defined EB III culture in the Cyclades remain unresolved problems (for a detailed debate pertaining to the existence of Rutter's EC III 'gap', see the 2013 'Minding the Gap' volume from *American Journal of Archaeology*). However, the continuous stratigraphic progression and associated unbroken radiocarbon sequence at Dhaskalio-Kavos may indicate that the site was in use from the Keros-Syros culture to the Phylakopi I culture (Renfrew et al., 2012). Indeed, extensive excavations at Dhaskalio-Kavos revealed a stratigraphic sequence which has allowed for the distinction of three successive phases of occupation, spanning the Early Cycladic II and Early Cycladic III periods (Renfrew et al, 2012; Sotirakopoulou, 2015). These phases of occupation have been defined as Dhaskalio Phases A, B, and C (see **figure 2.1**). Dhaskalio Phase A represents the earliest period of human activity on Dhaskalio during the Early Bronze Age. Typological analysis of the pottery assemblage from these layers has been used to place Dhaskalio Phase A in the Keros-Syros culture (Early Cycladic II) (Sotirakopoulou, 2016), and radiocarbon dating from a number of samples acquired during the 2006 to 2008 excavations dates this phase to between c.2750 BCE and c.2550 BCE (Renfrew et al, 2012). Radiocarbon estimates place the transition between Phase A and Phase B at c.2550 BCE (Renfrew et al, 2012) and typological study of the Dhaskalio pottery places Phase B into the earlier phase of the 'Kastri group' (late Early Cycladic II) (Sotirakopoulou, 2016). Finally, Dhaskalio Phase C is known to be the final phase of occupation of Dhaskalio during the EBA (Renfrew et al, 2012), corresponding to the Early Cycladic III period. This is supported by a pottery assemblage associated with the later or main phase of the Kastri Group (Sotirakopoulou, 2016: 1) and radiocarbon estimates which date the beginning of Phase C to c.2400 BCE and ending in c.2300 BCE (Renfrew et al, 2012). This continuation of use throughout late EC II and EC III makes Dhaskalio-Kavos almost unique in the region. Possible reasons for this persistent use of the site throughout this contentious period will be discussed later in this chapter where a more detailed outline of how Dhaskalio-Kavos has come to be regarded as a 'maritime sanctuary' will be addressed. However, questions which necessarily arise as to the nature of any changes to the organisation of activities at the site throughout this period of use is an area which this thesis hopes to address through high-resolution geochemical survey which is discussed in chapter 6.

2.3 Life in the Cycladic Early Bronze Age

The Cyclades are a group of islands in the central Aegean (**figure 2.2**), represented by more than two hundred islands of varying sizes, with the largest being Naxos. Although the area of the Cycladic islands varies substantially, the average size is 75 sq. km and, for the most part, the islands are thinly covered in soil and largely lack an adequate source of fresh water. Consequently, they offer a less than ideal environment for the purpose of agriculture (Broodbank, 2008: 47). Yet it is these sparse, rocky islands which proved conducive to the development of one of the most successful small-scale island societies in the EBA Aegean. Reasons for the settlement of the Cyclades and subsequent development of a complex society is debatable. However, there are compelling natural factors, both geographical and geological, which may have enticed early settlers to inhabit the islands.

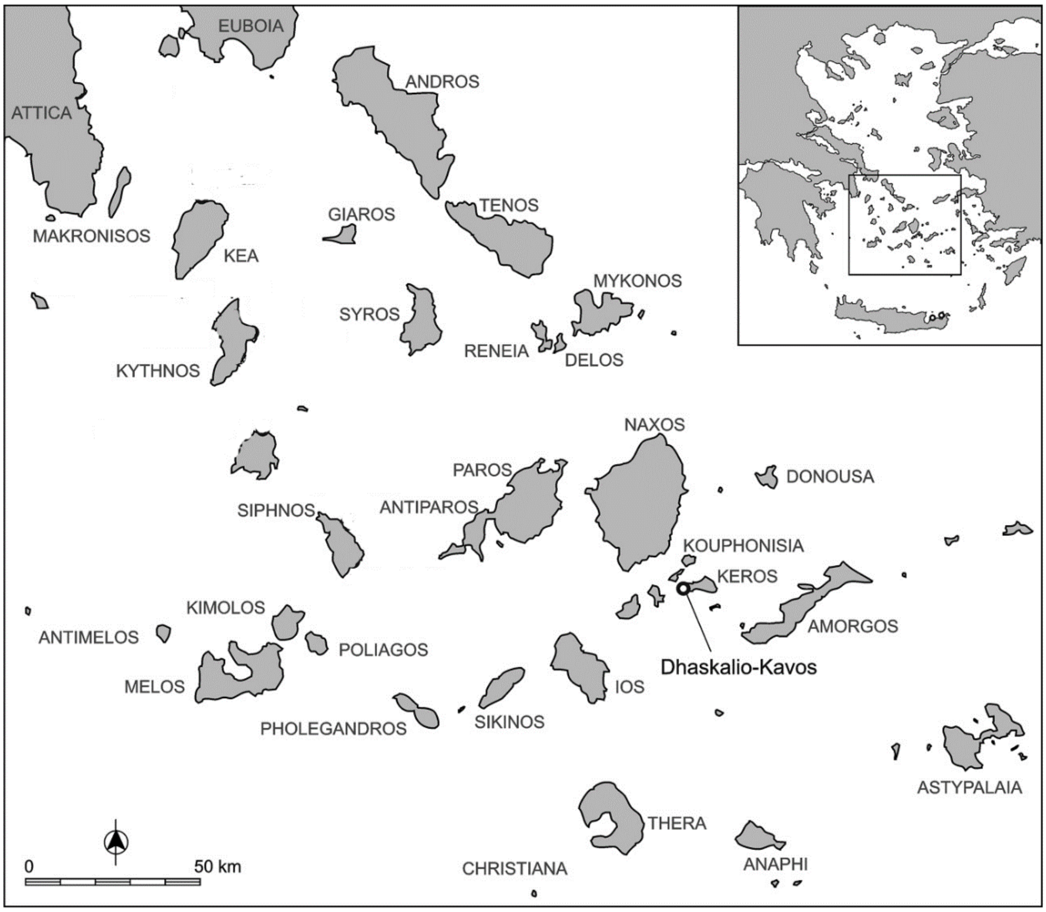

Figure 2.2: Map of the Cycladic islands and their location in the Aegean. The location of Dhaskalio-Kavos is also marked (image after Georgakopoulou, 2016).

The Cyclades are ideally located between the mainland of what is now Greece and Turkey, as well as being bordered to the South by Crete. The islands of Andros and Kea brush the coasts of Euboea to the northwest and Attica to the west, the easternmost islands of Amorgos and Anafi look out over the southeast Aegean and Anatolia, Melos lies midway between Crete and the Peloponnese, and Thera offers the last southernmost outpost before the open sea towards Crete. As a result, much interregional communication in the eastern Mediterranean necessarily passes through the islands of the Cyclades (Broodbank, 2008: 48). Of particular importance for the current study, is the geographical location of Dhaskalio-Kavos on the island of Keros which lies between the islands of Naxos and Amorgos in the central archipelago known as the *Μικρές Κυκλάδες* (small Cyclades) (see figure 2.2). The importance of the location of Dhaskalio-Kavos within the overall Cyclades will be discussed in greater detail later in the chapter. However, it is worth highlighting here how these geographic conditions may have proved beneficial in cementing the site as an important place during the EBA. Indeed, using Proximal Point Analysis, Broodbank (1993; 2000: 184) highlights the centrality of Keros within the Cyclades, suggesting that the island may have been home to a key maritime trading hub during the EBA. In addition to advantageous geographical factors, the Cyclades, due to their volcanic origin, are rich in mineral resources (Doumas, 2010: 101). For many prehistoric communities in the Aegean, obsidian, a naturally forming volcanic glass, was the primary raw material utilized for the manufacture flaked stone tools (Carter, 1998: 17). The Cyclades contains two of three sources of obsidian in the Aegean on Melos and Antiparos, with an additional source on the island of Giali in the Dodecanes (Carter, 1998: 17). However, the overwhelming majority of obsidian found on prehistoric Aegean sites comes from Melos (Carter & Kilikoglou, 2007; Frahm et al., 2014). The Cycladic islands of Siphnos, Seriphos, Kythnos, and Keos also offer abundant sources of metal-rich minerals, notably lead, silver, and copper (Broodbank 2008: 47). The importance of obsidian for manufacturing tools, and the value of metal sources in the EBA, inevitably reinforced the Cyclades as a place of economic importance, with Dhaskalio-Kavos situated within the central hub of connectivity (Broodbank, 1993).

2.3.1 Neolithic origin

Despite evidence for the use of Melian obsidian at Franchthi Cave in the Argolid from as early as the Upper Palaeolithic (Laskaris et al., 2011; Perlès, 2003: 81), which demonstrates the antiquity of Cycladic mineral exploitation, current evidence suggests that it is not until the Late Neolithic (LN)/Final Neolithic (FN) (roughly dated to 5,300 to 3,200 BCE) that the islands of the Cyclades were settled on a more sedentary basis (Berg, 2019: 91-7). This relatively late settlement of the Cyclades, at least as compared to the Greek mainland, was clearly not due to a lack of seafaring skills, as Melian obsidian from the Peloponnese demonstrates that communities from the mainland were capable of travelling across the water in order to access Cycladic mineral resources. Instead, it is likely that the thin soils and rather limited flora found in the Cyclades, particularly on coastal regions, which compare unfavourably to the Greek mainland, held little attraction for Neolithic farmers (Zachos, 1996a: 85). Indeed, even after the first Cycladic islands were permanently populated, space was not as intensively utilised as other regions of the mainland (Zachos, 1996a: 86). Despite this, it is estimated that 27 Cycladic islands were inhabited by the 5th millennium BCE, with a further 12 islands being occupied during the 4th millennium BCE (Broodbank, 2000). In terms of identifiable material assemblages, the LN is represented by the Saliagos culture, whilst the Attica-Kephala culture is the hallmark of the FN period (Berg, 2019: 91-117).

The Saliagos culture spread to most of the Cycladic islands (Zachos, 1996a: 85), with key sites including: Saliagos off Antiparos (for which the LN culture is named), Grotta and Zas cave on Naxos, Koukounaries on Paros, Akrotiri on Thera, Minoa on Amorgos, Ftelia on Mykonos, and Agrilla and Kouphi on Melos (Berg, 2019: 92). During this period, it appears that Cycladic settlements were villages of considerable size, with populations estimated to be above 100 occupants (Berg, 2019: 92). These relatively large villages appear to have been long-lived communities which were widely spaced around the island landscape during the LN period (Berg, 2019: 92). This is again true for the FN, although some differences, particularly in terms of subsistence strategies may be apparent during this period (Broodbank 2000a: 145-50). Characteristic finds of the Saliagos culture include pottery, stone and bone tools, ornaments, and figurines, the most famous of which is the 'Fat Lady of Saliagos' (**figure 2.3**) (Berg, 2019: 93-5; Zachos, 1996b: 156), but also schematic figurine forms in marble (Preziosi & Weinberg, 1970: 4; Sotirakopoulou, 2005: 49; Televantou, 2017). The characteristic (often open shaped) dark ground pottery of the Saliagos culture, with white linear motifs (Berg, 2019: 93), is encountered in the LN of mainland Greece, the Dodecanese, and Asia Minor, which offers a suggestion as to the origin of LN Cycladic settlers (Zachos, 1996a: 85-6).

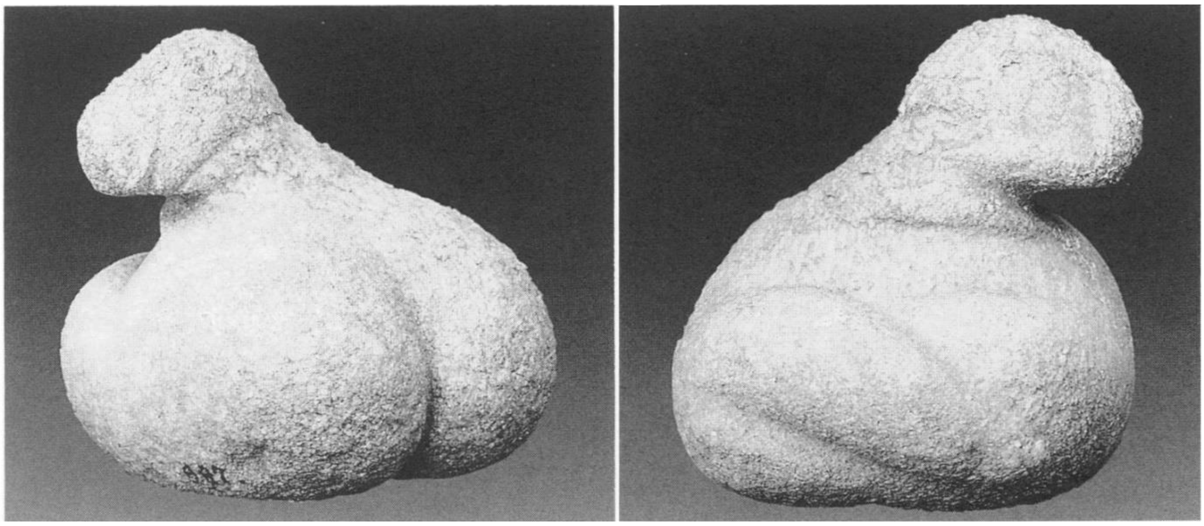

Figure 2.3: Image displaying the 'Fat Lady of Saliagos' (image Mertens, 1998: fig. 1).

During the FN, or 'Chalcolithic' period, pattern-burnished pottery and red-crusted ware are characteristics of the Attica-Kephala culture, which hints at cultural affinities between the peoples of the Cyclades and settlements in Attica, Euboea, and the Saronic Gulf (Berg, 2019: 95). The type-site of the Attica-Kephala culture is the settlement of Kephala on Kea which, until recently, represented the only known site in the Cyclades which displayed the hallmarks of its namesake culture. However, more recent discoveries, for instance Ayios Sostis on Siphnos, Zas Cave on Naxos, and Strofilas on Andros, indicate that the wider Cyclades may have been part of this wider tradition, playing an essential role in furthering maritime communication between different regions of the Aegean (Berg, 2019: 95; Zachos, 1996a, 86-7; Zachos, 1996c). This period also displays the first instances of settlements located near allied cemetery sites, a feature which became ubiquitous with EBA habitation sites (Barber, 1987: 76; Berg, 2019: 95). Crucially, the FN also represents the first period in Cycladic prehistory where metallurgical processes are first used for tools (Zachos, 1996d) and items of prestige and personal adornment (Zachos, 1996e). It is, then, the peoples of the Cycladic FN which first display characteristic cultural traits which can be recognised in communities of the Cycladic Early Bronze Age.

2.3.2 Early Cycladic I /Grotta-Pelos Culture (ca. 3100/3000-2650 B.C.)

The first phase of the Early Cycladic period (EC I/Grotta-Pelos/Pelos-Lakkoudes) marks the start of conspicuous transformations in Aegean societies. The archaeological record for the EBA Cyclades in general is largely dominated by excavations of cemeteries (Broodbank, 2008: 52). These excavations have often been driven by attempts to rescue the archaeological evidence from continuous looting which has plagued EBA Cycladic cemeteries since the early 19th century and, in many cases, has resulted in a loss of important contextual information (Marthari, 2001). This is particularly true for the EC I period (Angelopoulou, 2017: 134). Despite extensive looting at EC I sites, sufficient materials have been retrieved through systematic excavation to offer us an insight into the characteristic assemblage associated with the Grotta-Pelos culture. To that end, pottery is typically manufactured from coarse, gritty fabrics and finished with a dark burnished sheen, often with incised, rectilinear decoration (Barber, 1987: 89; Berg, 2019: 148; Renfrew, 1972: 153). The most common shapes within settlements are open bowls with thickened, 'rolled' rims and tubular lugs on the exterior of the vessel (**figure 2.4**), whilst a wider variety of shapes in finer fabrics are known from cemeteries (Barber, 1987: 89, Renfrew, 1972: 154-5). Stone vessels include the collard jar, or 'Kandili' (with or without pedestal foot), palette, and simple bowl (Barber, 1987: 97-8). Palettes and bowls have been known to include internal traces of blue or red colouring (Berg, 2019: 138). These residues may be associated with the processing of pigments, likely azurite (Hendrix, 2003) and cinnabar (Birtacha, 2017), or the mixing of paint, possibly for body modification (Broodbank, 2000: 248-249; Hoffman, 2002; Hendrix, 2003) or the painting of figurines (Broodbank, 2000: 247-275; Hekman, 2003 :133; Marthari, 2017). The figurines in question, typical of Grotta-Pelos culture, are schematic, violin-shaped varieties which emphasise particular humanistic qualities like the neck and limbs, as well as the more naturalistic Plastiras and Louros varieties (Sotirakopoulou, 2005; Carter, 2008; Renfrew, 2017). The apparent painting of these figurines is important, as it may point to more specific cultural traditions which continued into later periods of the EC period, and directly relates to ritual practices observed at Dhaskalio-Kavos. Indeed, it appears that the paintings were created at various times (Hoffman, 2002; Hendrix, 2003). It has been postulated that new paint was added periodically to these figurines in order to ready the objects for participation in ceremonial events conducted by the small Cycladic communities (Hoffman, 2002; Hendrix, 2003). It is further suggested that, when these figurines reached the end of their uselife, because of their significance to these ceremonial practices, they could not merely be disposed of, rather, they needed to be taken out of circulation (Renfrew, 2013b). Before the sanctuary on Keros was established during the Keros-Syros culture, this may have been achieved through burial practices (Hoffman, 2002; Hendrix, 2003; Renfrew, 2013b). These speculations as to the use and deposition of marble figurines highlights how the significance of these objects may have become tradition within EC culture before Dhaskalio-Kavos became established as a place of significance in the region.

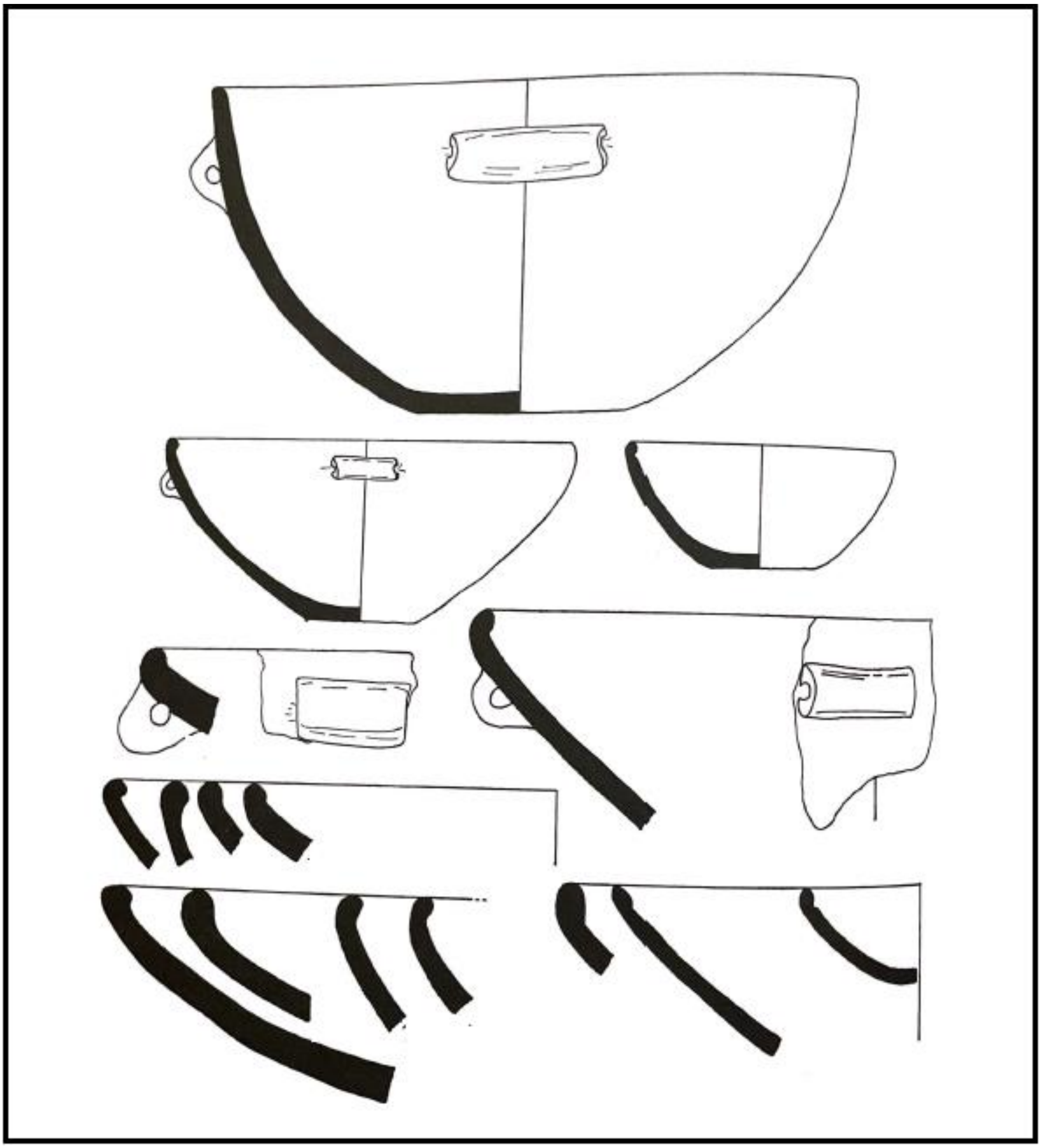

Figure 2.4: Illustration of bowls from the Grotta-Pelos culture (image after Renfrew, 1972: fig. 10.1).

Metals also played an important role in EC I life. Indeed, Renfrew (1972) assigns the invention of metallurgy as a major factor in the emergence of Aegean civilisation, creating new professions, generating wealth, and encouraging the expansion of trade contacts. In addition, the adoption of metal tools could have facilitated more efficient craft practice (such as carpentry or stonemasonry), farming, and even domestic chores (Barber, 1987: 99). Despite this, few significant metal objects are known from the EC I period (Barber, 1987: 100; Berg, 2019: 155; Georgakopoulou, 2005: 35). Indeed, the scarcity of metallurgical evidence from EC I at the time led Renfrew to propose that metallurgy only became widespread in the Cyclades in the Early Bronze Age II (Renfrew, 1967). However, this perception of a metal-poor EC I is now considered erroneous based on widespread evidence for Final Neolithic metal working, such as at Zas cave on Naxos (Zachos, 1996d), increasing sample size of EC I artefacts, and the continuities in artefact typologies from the Neolithic to EC II (Berg, 2019: 155). The relative scarcity in the archaeological record has since been attributed to social strategies adopted by EC I communities, such as the choice not to deposit metal objects in graves (Nakou, 1995) which only became common in succeeding periods of the Early Bronze Age when, presumably, metal items (at least within a funerary context) played a more pivotal role in expressing an individual's identity or status (Sherratt, 2007: 250). Metals are also inherently susceptible to corrosion and are readily recycled, both of which could also account for the relative lack of metallurgical remains from EC I, especially if the contemporary communities lacked depositional practices specific to metal objects. Consequently, the current consensus amongst scholars is that metal production and use was widespread in the EC I period with Cycladic communities exploiting regional mineral sources in order to manufacture objects from copper, lead, silver, and occasionally gold (Barber, 1987: 100-110; Berg, 2019: 155-60; Georgakopoulou, 2005; 2016; Renfrew, 1967).

As with our knowledge of "Grotto -Pelos" material culture, which comes largely from cemetery sites, our knowledge of EC I settlements is limited. Indeed, the number of excavated settlements for this early period of the Cycladic EBA is very small, with the majority of our knowledge of habitation sites coming from surface finds (Broodbank, 2000: 151). However, from this limited evidence, it appears that EC I settlements were smaller in size, more dispersed, and seemingly often shorter lived as compared to the previous Later Neolithic period (Angelopoulou,2017: 134). This suggests that the people inhabiting the Cyclades underwent a change in their way of living, where a greater reliance on animal husbandry allowed for their settlements to expand into more marginal areas and smaller islands, whilst short-lived, permanent agricultural installations continued to be situated on lowland coastal promontories (Broodbank, 2000: 150-51; Whitelaw, 2002). Evidence from EC I cemeteries, as well as the small amount of known settlement sites, suggests that population sizes within individual settlements was limited to around a few dozen people (Broodbank, 2000: 151; Renfrew, 1972: 157), and an apparent lack of variation in character within individual settlements suggests that these farming communities were essentially egalitarian and self-sufficient (Angelopoulou, 2017: 134). However, contrary to this assessment, some evidence suggests that EC I may represent the beginning of a more complex sociopolitical way of life for the Cycladic islanders, at least in terms of outside relationships. This notion is reflected by the fortified settlement at Markiani on Amorgos, which was first occupied during the EC I period, and continued to be an active settlement throughout EC II, with its last phase of occupation occurring during the period of the so called Kastri group (Angelopoulou, 2017: 134). Evidence suggests that Markiani was a defended settlement from the time it was first established (Marangou, 2006: 86). The horseshoe shaped defensive wall protected the settlement from the land to the north, whilst allowing open access to the sea (Marangou, 2006: 86; Renfrew, 2006: 248). Despite contradictions within the literature as to the level of social organisation within EC I communities, the fact that Markiani emerges as a defended community from the time of its inception may indicate the development of some level of internal organisation, at least at a level commensurate with such an achievement (Renfrew, 2006: 253). Certainly, the defensive nature of the Markiani marks the start of settlement patterns witnessed in later periods of the EBA Cyclades. Already, it appears that Cycladic communities were largely connected by the sea, a notion which is greatly expanded on by Broodbank (2000; 2008). Whilst long range travel was likely limited, material evidence suggests that cultural affinities existed between the people of EC I Cyclades and other parts of the wider Aegean, especially during the period associated with the Kampos group, which marks the transition between EC I and EC II.

The Kampos Group is so named after an assemblage of EC artefacts first recorded at the Kampos cemetery on Paros (Betancourt and Davaras, 2004: 231). The assemblage (***figure 2.5***) includes the so-called ‘frying pan’ with circular pan, straight sides, a rectangular handle, and incised rather than stamped decoration, as well as vessels including the incised bottle, the spherical and the conical pyxis, the chalice, and the deep bowl or jar (Alram-Stern, 2011: 11-13; Betancourt and Davaras, 2004: 231; Renfrew 1972, 527– 528; Wilson and Day, 2000: 55-6). The Kampos group assemblage also includes marble figurines of the Louros Type, and miniature collard jars (Alram-Stern, 2011: 13). In addition to the Kampos cemetery on Paros, assemblages typical to the Kampos Group have been recorded from Cycladic cemeteries at Louros on Naxos, Krasades on Antiparos, and saliently, Agrilia on Ano-Kouphonisi, located between the islands of Naxos and Keros (Alram-Stern, 2011: 11; Renfrew, 2010: 288). Despite their association with burial practices in the Cyclades, the diverse objects of the Kampos Group assemblage may have fulfilled a number of functions outside of this funerary context. For example, although their exact function is disputed (see Coleman, 1985), 'frying pans' are abundant in settlement sites across the Aegean, and container-like vessels, such as the pyxides and bottles, may well have been used for domestic storage and subsequently repurposed for burial rituals (Alram-Stern, 2011: 11-13). However, some objects from the Kampos Group are more overtly symbolic or ritualistic, such as the figurines and collard jars, which often contain blue pigment (Alram-Stern, 2011: 13). Yet, perhaps most interesting with regards to life in the EBA Cyclades, is what the distribution of Kampos Group assemblages can tell us about external connectivity during this period.

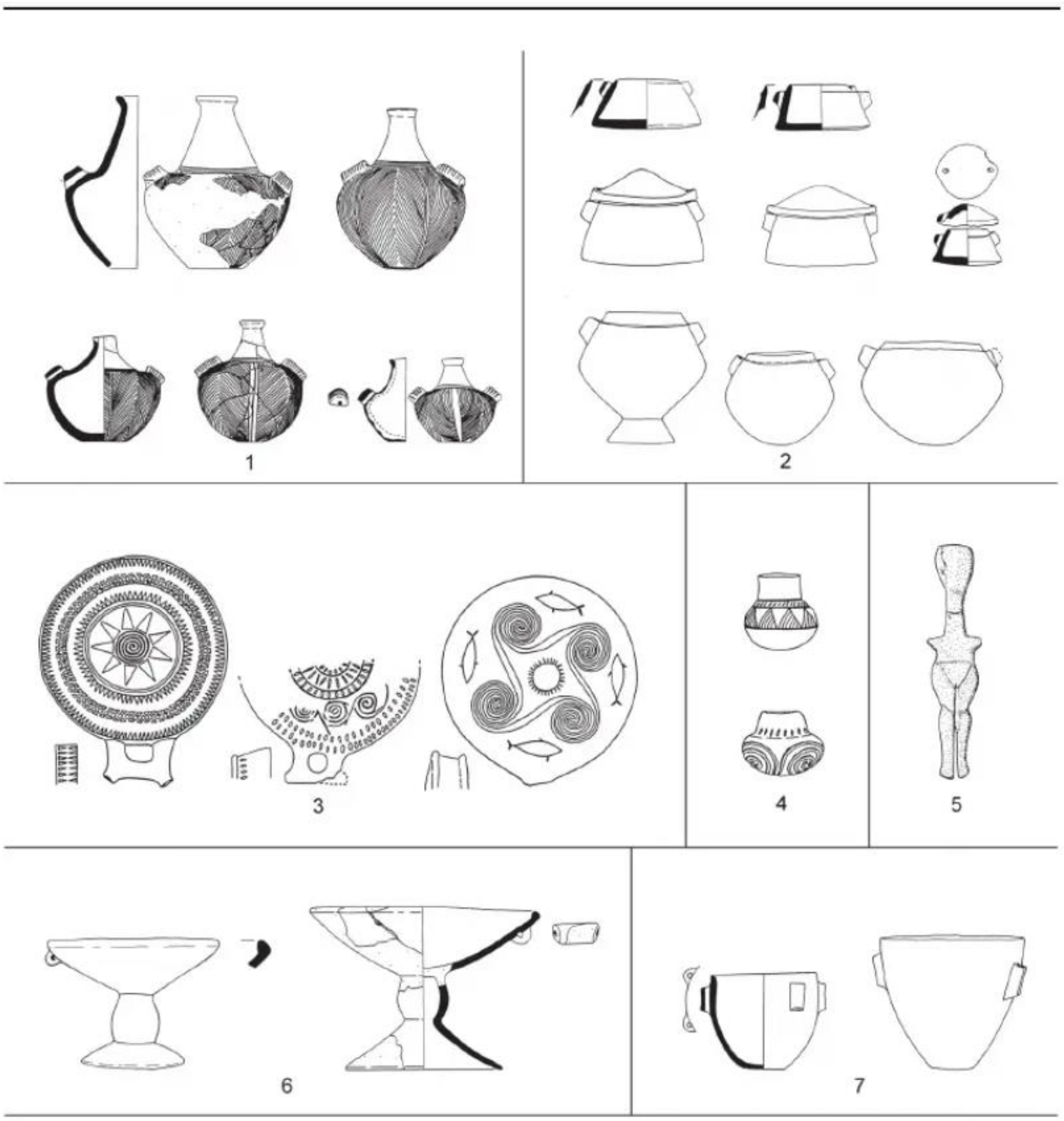

Figure 2.5: Characteristic artefacts from the Kampos Group assemblage. 1 – herringbone incised bottles, 2 - pyxides of conical and globular shape, 3 – Kampos style 'frying pan', 4 – collared jars, 5 – Louros Type figurine, 6 – thick-stemmed chalices, 7 – deep bowls (image Alram-Stern, 2018: 12).

The Kampos Group is undoubtedly Cycladic (Alram-Stern, 2011; Betancourt and Davaras, 2004; Renfrew, 1972; 2010), yet objects of the Cycladic Kampos Group have been found at EBA sites across the Aegean, including the eastern Aegean islands, western Anatolia, and in the area of the eastern Greek mainland (Alram-Stern, 2018: 14). However, outside of the Cyclades, it is the island of Crete which boasts the greatest number of sites to include artefacts which are characteristic of the Kampos Group. One of the most important Cretan EBA sites with a clear Kampos assemblage is that of Ayia Photia (see Davaras and Betancourt, 2004; Betancourt, 2008). A significant number of objects encompassing a wide range of artefact types from the Kampos Group were uncovered at this cemetery site on the north-west of the island (Betancourt and Davaras, 2004). Petrographic analysis of the pottery from Ayia Photia suggests that the majority of the Cycladic styles were produced locally in Siteia, Eastern Crete (Day et al., 2012: 136). The abundance of Kampos Group artefacts at Ayia Photia suggests that the cemetery and associated settlement may have been established by Cycladic migrants, possibly from Ano Kouphonissi or elsewhere in the 'Mikres Kyklades' (Renfrew, 2010: 288). This notion is supported by the apparent similarities with regards to tomb type at the cemeteries of Ayia Photia and Agrilia at Ano Kouphonissi where, in both cases, the tombs are cut directly into the rock, and consist of a small burial chamber closed by stone plaques (Betancourt and Davaras, 2004: 232-4). Grave goods were deposited in the main chamber, whilst an antechamber contained funerary offerings (Alram-Stern, 2011: 10). This particular mortuary behaviour, characterised by its links with the Cyclades, is also witnessed at the EM IB cemetery at Gournes in Northern Crete (see Galanaki, 2021).

This phenomenon of intense Cycladic influence during EM I Crete is also witnessed at the north Cretan site of Poros-Katsambas, which likely served as a coastal outlet for EM Knossos (Dimopoulou-Rethemiotaki et al., 2007: 84). Amongst the extensive ceramic assemblage found within late EM I deposits at Poros-Katsambas (broadly contemporaneous with the late EC I), are many vessel styles found in Kampos Group assemblages from the Cyclades (Dimopoulou-Rethemiotaki et al., 2007: 93). The pottery from Poros has been investigated extensively using petrological techniques, showing that the Kampos-style vessels were made in North-Central Crete (Dimopoulou-Rethemiotaki et al., 2007; Renfrew, 2010: 289). One of the most surprising, yet important, features of the Poros excavation, however, was the presence of substantial evidence for metalworking (Dimopoulou-Rethemiotaki et al., 2007, 91-5; Doonan et al., 2007). It is clear that the sheer number of Cycladic-style vessels, along with the local manufacture of the mid-rib daggers so characteristic of the Kampos Group shows a strong link between the harbour town of EM I Poros, and the craft practices and cultural identities people otherwise inhabiting the Cyclades during the EC I. Therefore, the hearths, crucibles, ingots, and mould fragments found at Poros (Dimopoulou-Rethemiotaki et al., 2007, 92), may be considered as suggestive of typical EC I (secondary) metallurgical practices, highlighting the skills and specialisation of peoples of the Cyclades in terms of metallurgy, alongside raw material, which ultimately has its origin in the Cyclades (the ingot at Poros-Katsambas has been shown by lead isotope analysis to be compatible with a Kythnian source, Doonan and Day pers. comm.) This not only shows that Poros-Katsambas was a centre for importation, but also that the peoples inhabiting the EBA Cyclades played a significant role in the geopolitical landscape of the wider Aegean as early as the EB I-II period. Furthermore, although the settlement at Dhaskalio-Kavos had not yet been established during this period (Renfrew, 2012), the undeniable link between the Kampos group culture and the Mikres Kyklades, and especially the Keros adjacent islands of Kouphonissia, places the region around Dhaskalio-Kavos at the centre of Aegean interaction and metallurgical specialisation from the earliest stages of the Bronze Age.

2.3.3 Early Cycladic IIA/Keros -Syros Culture (ca. 2650-2450/2400 B.C.)

The following phase of the Early Cycladic period, commonly understood as early EC II (Rutter's EC IIA), and coined by Renfrew as the Keros-Syros culture is often characterised as the *floruit* of Early Bronze Age Cycladic culture (Renfrew, 1969:21). Indeed, the emergence of new craft specialisation, an intensification of regional and long-range interaction, and the beginnings of more complex social stratification, renders the mid-third millennium BCE as a period of profound cultural development in not only the Cyclades, but the wider Aegean (Angelopoulou, 2017: 134; Renfrew, 1972: 170-85). The substantial number of settlement sites (Angelopoulou, 2017: 134-39; Barber, 1987: 43-73; Barber and MacGillivray 1980: 149; Renfrew, 1972: 176-77) and cemeteries (Barber, 1987: 74-6; Barber and MacGillivray 1980: 149), known from this period, suggests a growth in population with a handful of larger and more heavily populated villages appearing in the Cyclades (Broodbank, 2008: 55), although the small, dispersed settlement pattern seen in EC I remains the norm (Broodbank, 2000: 177). The relative abundance of excavated EC II sites, and associated material remains, also offers a relatively clear picture of the assemblage which makes up the EC II Keros-Syros material culture.

The Keros-Syros culture of the EC II sees the introduction of folded-arm figurines and, with the exception of seated varieties and the Apeiranthos type which are schematic, all subvarieties (Chalandriani, Dokathismata, Kapsala, Koumasa, and Spedos) belong to this classification (figure 2.6) (Gavalas, 2017; Preziosi & Weinberg, 1970; Renfrew, 2017: 7). As with figurines from the Grotta-Pelos culture, many figurines show evidence for painted decoration (Hendrix, 2003). Marble vases include various shapes, including footed cups, bowls, pyxides, and an occasional marble version of a frying pan or sauceboat (Barber, 1987: 98; Gavalas, 2018).

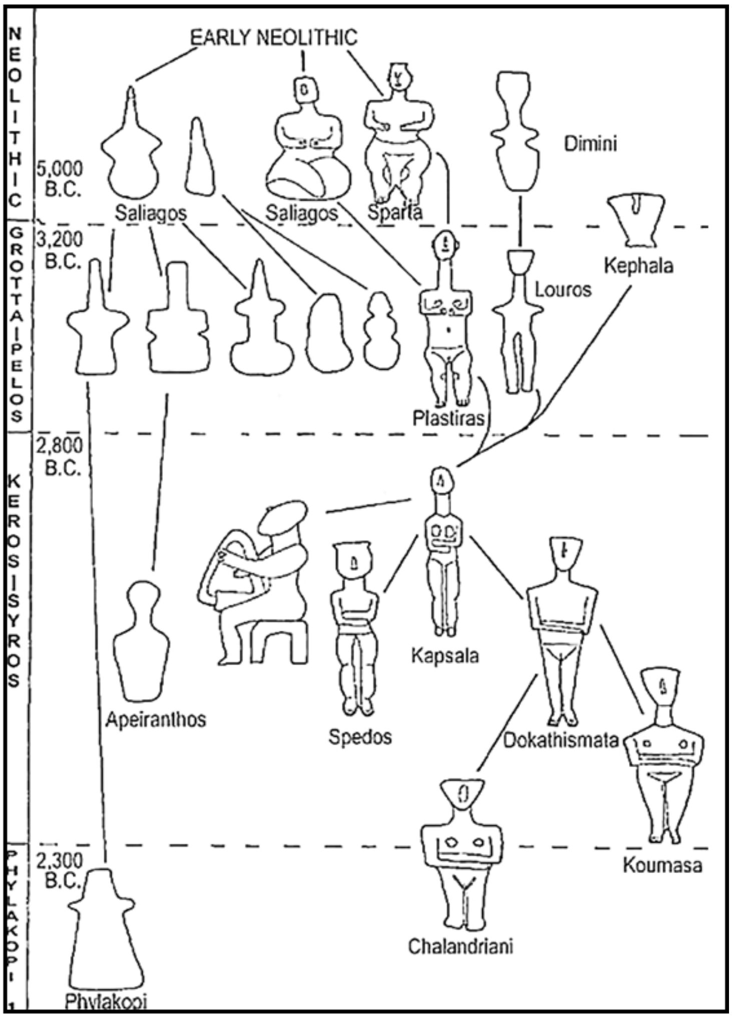

Figure 2.6: Evolution of Cycladic figurine typology. Note the Keros-Syros varieties of 'folded arm figurine' (image after Renfrew, 2017).

The pottery from this period maintains a number of trends witnessed in EC I, with a continuation of certain shapes, and the use of coarse burnished fabrics with incised decoration (Barber, 1987: 28; Wilson, 1999: 20-88). However, whilst this ware can be understood as a direct descendant of Grotta-Pelos pottery, more curvilinear decoration, with the use of stamped concentric circles, spirals, small stars, and 'Kerbschnitt' is witnessed for the first time (Wilson, 1999: 20-88). Common shapes of stamped and/or incised dark-surfaced and burnished ware are the footed jar, the globular pyxis, and the frying pan of the 'Syros type' (Barber, 1987: 90-3; Barber and MacGillivray 1980: 150; Renfrew, 1972: 172, Wilson, 1999: 20-82). In addition to pottery styles which are reminiscent of the Grotta-Pelos (EC I) culture, new shapes, as well as decorative styles and methods, are also evident. The most important EC II developments, in terms of pottery, is the introduction of fine, light-coloured fabrics and painted decoration (Barber, 1987: 28; 90-3), which essentially show the rise in importance of tableware and social practices around commensality and hosting, which is also evident in the mainland and Crete at this time (Day and Wilson 2004). Patterned ware is characterised by painted decoration in a dark-on-light style, utilising geometric ornament, such as zigzags, chevrons, or hatched triangles (Barber and MacGillivray 1980: 150). Common shapes are the pyxis, the jug, and the sauceboat (Barber, 1987: 92; Barber and MacGillivray 1980: 150). Another EC II pottery style which is manufactured from fine, light fabrics is the so-called 'Urfirnis' or Glazed ware (Barber, 1987:92; Renfrew, 1972: 172). Unlike the dark-on-light decoration of Patterned ware, the fabric is coated in a dark slip or glaze and often burnished to a red-brown lustre (Renfrew, 1972: 172). Common shapes are the saucer and the sauceboat (Barber and MacGillivray 1980: 150). Significantly, Cycladic Urfirnis/Glazed ware holds direct parallels with similar vessels found from EH II sites on mainland Greece (Barber, 1987: 28; Barber and MacGillivray 1980: 150) which offers clear evidence for contact between that region and EC II Cyclades.

In addition to presenting evidence for inter-regional connectivity, new characteristic EC II shapes may also offer insight into new social routines of this period. One of the most important examples of this can be seen with the introduction of the sauceboat (figure 2.7). The term 'sauceboat' is a misnomer, and is merely reference similarities in form between these vessels and their modern namesake. Indeed, the precise function of sauceboats is unknown, however Renfrew (1972: 284) suggests that the sauceboat was some sort of drinking vessel, a notion which is widely supported (Pullen, 2013; Rutter, 2017). It is now commonly assumed that these specialised vessels held a ritualised use, likely being central to acts of commensality, or more specifically, feasting (Barrett and Boyd, 2019: 75; Pullen, 2013; Rutter, 2017). The sauceboat likely has a Cycladic origin (Rutter, 2017: 4-5), yet they are found in near equal abundance on the Greek mainland (Barrett and Boyd, 2019: 75; Rutter, 2017: 4). The sauceboat, then, not only represents evidence for regional contact between the Cyclades and mainland during the Early Bronze II, but also the spread of social practices and ways of doing. This is significant, as Renfrew (2013b: 208) suggests that the fragments of marble figurines deposited at the sanctuary at Dhaskalio-Kavos may have been previously associated with ceremonial feasting, a continuation of observations made about their funerary use (Hamilakis, 1998). The ready adoption of Cycladic vessel types, which were associated with specific ritualised practices of consumption, by communities across the Aegean demonstrates the draw and influence that societies of the EC II Cyclades held, and the link between the deposition of marble figurines with acts of Cycladic feasting places Dhaskalio-Kavos at the centre of this influence.

Figure 2.7: *EC II Keros-Syros sauceboat (image after - The British Museum: cat. 1912,0626.10).*

Metal artefacts appear more frequently in the archaeological record from EC II than the preceding EC I period (although reasons for such an observation are discussed above). Lead rich minerals are abundant in the Cyclades, being known from Melos, Kimolos, Antiparos, Thera, Anaphi, Seriphos, Mykanos, and Syphnos, with additional sources at Laurion in Attica (Berg, 2019: 158; Renfrew, 1967: 4) and, with its relatively low melting point (327.5 °C), is easy to work and remains malleable even when solid. Consequently, lead objects represent the most abundant metal finds of the EC II period (Renfrew, 1967: 4). Lead was often used for utilitarian purposes, such as rivets for mending broken pots (Berg, 2019: 158; Renfrew, 1967: 4-5), but more symbolic items are known, such as lead figurines from Ios and Antiparos, and model boats from the island of Naxos (Berg, 2019: 158; Renfrew, 1967: 5; Renfrew, 1972: 318-36).

Copper metallurgy continues to be a feature of Cycladic life during the EC II period. Copper objects are frequently made of arsenical copper alloys which could be the result of smelting arsenic rich copper ores (Tylecote et al., 1977), but also involved deliberate mixing (Doonan and Day, 2007). Smelting largely took place near mineral procurement sites, although Dhaskalio-Kavos remains an isolated exception in the Cyclades (see below), where isolated, windswept coastal promontories were selected for both practical considerations, as well as social concerns (Berg, 2020: 291). A north-facing smelting site would allow metallurgists to utilise the prevailing northerly winds (see Berg, 2019: 44) to supply a natural draught for their perforated furnaces (Berg, 2019: 160; Berg, 2020: 291), whilst an isolated promontory overlooking the sea offered a "deliberate mixture of secrecy and advertisement" (Broodbank, 2000: 294). Indeed, Berg (2020: 292) suggests that the "confluence of an island location, the sea, and northerly winds might have conferred a potential symbolic power to such locales", imbuing the metal with a perceived fusion of energy from the elements (wind and sea) which may have been seen as essential for the craftspeople to create the 'right' kind of copper. Regardless of the exact nature of symbolism surrounding these sites, it should be understood that metalworking was seen as a somewhat mystical and performative, perhaps ritualised practice (Doonan et al., 2007: 117). It is important, then, that one of the main activities seemingly taking place at Dhaskalio-Kavos during this period is associated with metal production (Georgakopoulou, 2007; 2013) (see below). This suggests that the site not only drew special significance from acts of ritual deposition of marble vessels and figurines, but also through the performative acts of transformative metal production. It is this aspect of the activities taking place at Dhaskalio-Kavos, both in terms of the scale of production, but also the spatial organisation of such practices at the site, which this thesis hopes to elucidate further. In terms of copper artefacts, new weapons appear during EC II, including several types of dagger and spearhead (Renfrew, 1967: 10), as well as a high frequency of tools like adzes, chisels, and axes, examples of which can be seen in the so called 'Kythnos Hoard' (it has now established that the hoard actually originated from the Zas Cave on Naxos – Fitton and Niece, 1989).

Other metals being utilised during the EC II period include silver, which was used for objects of personal adornment, such as the silver diadems from Amorgos, bracelets, and silver pins (Renfrew, 1967: 6), and less frequently gold (Renfrew, 1967). However, metal in general represents an important influence on the Cycladic way of life. It was appealing as a symbol of wealth and status (Berg, 2019: 164), and the exchange of metals and ideas surrounding metalworking played a pivotal role in Renfrew's (1972) understanding of the 'international spirit'.

During the early ECII period, there appears increasing evidence for communication and trade on an inter-regional scale, coined by Renfrew (1972) as the 'international spirit'. Concurrently, a handful of larger and more heavily populated villages appear in the Cyclades (Broodbank, 2008: 55). Indeed, despite small-scale, dispersed settlements remaining prominent, the EC I pattern of modest, undifferentiated farmsteads is transformed, as more complex settlement patterns and site functions are witnessed in EC II as compared to those of the preceding phase **(**Angelopoulou, 2017: 134). These developments are notably evident at sites such as Chalandriani-Kastri on Syros, Ayia Irini on Keos, Dhaskalio-Kavos on Keros, and Skarkos on Ios**,** which stand out because of their size, observable wealth, and perceived prominence in Aegean trade networks (Angelopoulou, 2017: 134; Broodbank 2000: 212–21).

The excellent preservation of Skarkos, due to an extraordinarily deep layer of destruction debris, means that the site offers a rare opportunity to scrutinise the architectural features of an EC II Cycladic settlement. The stone walls at Skarkos are preserved in places up to a height of four meters, offering evidence for buildings with multiple stories (Marthari, 2008: 71). They also clearly delineate distinct housing blocks and defined, narrow streets with the addition of communal squares (Broodbank, 2008: 55). This remarkable preservation of architecture, in addition to large quantities of pottery and other material culture found in situ, marks Skarkos as one of the most important sites for exploring domestic life during the EC II period (Renfrew, 2008: 4). However, prestige, symbolic (ritual?) goods, such as marble figurines, are all but absent (Renfrew, 2008: 4). These missing aspects of the assemblage at Skarkos lie in stark contrast to the material evidence found at rich Keros-Syros cemeteries and, indeed, the site of Dhaskalio-Kavos. In fact, beyond the architectural similarities, the presence of deliberately deposited marble vessels and figurines means that Dhaskalio-Kavos may have more in common, in terms of societal function, with burial sites than with the settlement at Skarkos. This suggests that settlements such as Skarkos played a different role within EC II society than more symbolic centres, and offers the suggestion that Dhaskalio-Kavos was not merely one of many substantial EBA settlements.

There is also evidence that the Early Cycladic II period was witness to increased societal organisation in the Cyclades, at least in terms of the production and distribution of produce and materials. Evidence from EC II settlements shows a rise in the use of seals and sealings during this period (Renfrew, 2008: 4). These objects are not only evidenced from sites which may be considered by Broodbank (2000) as 'major centres', but also from smaller settlements, such as Markiani on Amorgos, where a lead seal and three ceramic sealings were uncovered from EC II layers (Marangou et al., 2008; Renfrew, 2008: 4). These finds raise questions pertaining to centralised organisation of trade and regional distribution of items and goods, and certainly indicate that profound administrative and economic changes occurred during EC II as compared to earlier periods of the EBA. This is significant for our understanding of Dhaskalio-Kavos, since ECII represents the period of the site's inception as a significant cultural centre in the region. Indeed, Broodbank (1993), utilising Proximal Point Analysis, characterised Dhaskalio-Kavos as a major trader site due to the island's inferred connectivity and the richness of the material remains present there. This notion is supported by the fact that most, perhaps all of the pottery found on Dhaskalio was imported (Hilditch, 2013). However, Renfrew (2012; 2014) suggests that Dhaskalio-Kavos should be understood as a centre for the performance of rituals of congregation by a community of participating islands, which he labelled the "Confederacy of Keros" (Renfrew, 2014: 208). It is not suggested that these practices represent the development of hierarchically ordered society ('states') (Renfrew, 2014: 192), yet some level of regional social organisation must have existed in order to facilitate such pilgrimages.

2.3.4 Kastri Group Culture/Early Cycladic IIB or IIIA (ca. 2450/2400-2200/2150 B.C.)

The period of the EBA in the Cyclades known as the Kastri Group culture (Rutter EC IIB, Barber and MacGillivray EC IIIA) is named after the fortified settlement on the island of Syros, and is defined by the introduction of material culture with a distinctive Anatolian origin (Broodbank, 2000: 309-19). This period also claims witness to an increased interest in defence, as attested to by the proliferation of fortified sites such as Kastri on Syros, Panormos on Naxos, and Kythnos on Delos (Angelopoulou, 2017), which were seemingly abandoned after only a short period of occupation (Angelopoulou, 2017: 139). The emergence of these fortified centres is one of the most distinctive cultural phenomena of the EBA Cyclades (Angelopoulou, 2017: 142), and their abandonment has often been attributed to turmoil caused by an influx of migrants to the islands from Asia Minor and the north-eastern Aegean (Rutter, 1979: 8-9). However, more recent studies of this critical period of the Early Cycladic Bronze Age have provided further insight pertaining to cultural continuity on the islands (Pullen, 2013).

As discussed above, the addition of fortifications at Markiani dating to the EC I period demonstrates that consideration of defence, and indeed the practice of constructing fortifying architecture, was a long established tradition in the EBA Cyclades, and not an innovation of the Kastri Group period. This defensive mindset is also attested to by the locations of all major settlements throughout the Cycladic EBA, which conveys a choice to occupy naturally defensible hilltops (see Angelopoulou, 2017). Such an unbroken trend of architectural choice suggests that the creators of the EC IIB fortified settlements were likely the Cycladic islanders themselves, rather than migrants seeking a new home (Angelopoulou, 2017: 144). This notion of an unbroken cultural development in the EBA Cyclades is also evidenced by the material culture of the period.

The cultural change witnessed during the Kastri Group period is attested to by the introduction of new cultural elements. In terms of pottery, many of the new Anatolianising forms, such as the tankard, bell cup, and depas amphikypellon (Barber, 1987: 93) reflect the adoption of drinking customs previously unknown in the Cyclades (Broodbank 2000: 316). Their appearance is also associated with the introduction of the potter's wheel (Broodbank 2000: 285; Choleva, 2020; Renfrew 1972: 533; Wilson, 1999: 90-141), a technological innovation which demonstrates a degree of cultural contact and exchange between the Cycladic islanders and the Near East (Kramer, 1963: 290). Furthermore, diagnostic Kastri shapes have been found in association with forms which are characteristic of the earlier EC II Keros-Syros culture, notably at Skarkos (Marthari, 2008) and Dhaskalio (Angelopoulou, 2008: 159; Sotirakopoulou, 2016; Wilson, 1999). The continuation of Keros-Syros pottery traditions suggests an adoption of new technological and social practices, rather than a wholesale replacement of population.

The Anatolian influence of the Cyclades during the late EC II period is also demonstrated by changes in metallurgical practices. The most distinctive difference between late EC II metallurgy and earlier periods of the EBA Cyclades is the increased use of tin-bronze alloys. Objects of a tin-rich copper alloy composition have largely been found at the settlement of Kastri (Renfrew, 1972: 314), and are comparable, in terms of typology and composition, to artefacts from Asia Minor and the north-eastern Aegean (Angelopoulou, 2017: 144; Gale and Stos-Gale, 1984: 268-69). The adoption of tin during the EC IIB period, which is not found in mineral form in the Aegean or mainland Greece, would have created new demands for its acquisition (Angelopoulou, 2017: 144). Indeed, it has been suggested that some Kastri shapes, such as the symmetrical, two-handed drinking cups were created in order to emulate Anatolian metal tableware (Pullen, 2013: 547). This demand for prestigious new commodities and valuable raw materials would have, in turn, opened up new trade routes by which other cultural elements, such as pottery, drinking traditions, and architectural style, could reach the Cycladic islands (Broodbank, 2000: 317-18).

However, this does not imply a straightforward movement of people or an outright Anatolianisation of Cycladic culture. The directionality of Anatolian influence is disputed, with proposed origins including the northeast Aegean islands, particularly Lemnos, and the northwest coast of Asia Minor (Knappett & Nikolakopoulou, 2015). In the Cycladic sites, Kastri Group pottery types often appear as local imitations rather than original imports (Knappett & Nikolakopoulou, 2015), where a number of variations were produced and circulated among the islands (Angelopoulou, 2008). This indicates that the appearance of Kastri Group ceramics does not signify a sweeping Anatolian influence or cultural dominance. Instead, these types appear in the Cyclades as local adaptations rather than direct imports.

Evidence for the Kastri Group phase indicates a temporary influence of Anatolian trends in the Cycladic islands, perhaps due to the transmission of metal technology and circulation of raw materials, where Cycladic communities played a significant role. The Cycladic islands did not function merely as stepping stones for the transmission of Anatolian culture or as trading centres for Anatolian elite groups. Instead, due to their strategic position and maritime involvement, they actively participated in the spread of metal technology and raw metals and ceramic drinking sets in the southern Aegean. The Cycladic islands served both the route from Lavrion, Kythnos, and Siphnos, and the route from the northeast islands and Anatolia.

The term 'Aegeo-Anatolian cultural koine' describes the shared traits in pottery, metallurgy, and architecture from late EB II to early EB III (Sahoglu, 2005). The introduction and increase in production of various drinking and pouring vases, a significant novelty of the 'Aegeo-Anatolian cultural koine,' is seen across the southern Aegean and coastal Asia Minor (Rutter 2008 ; Wilson *et al.* 2008). The control of metal trade by distinct social groups in the Cyclades may have led to early social stratification, with social drinking and feasting reinforcing group identity and inclusion (Knappett & Nikolakopoulou, 2015). Towards the end of the EBA, significant social and political changes occurred in Asia Minor, the Cyclades, and Crete, leading to MBA polities or state formations.

As with the pottery of this period, there is evidence to suggest that metallurgical traditions from the early EC II period persisted throughout the Kastri-Group phase. Numerous metal finds were uncovered from EC IIB layers at Dhaskalio (phases B and C – see below), including a substantial hoard of tools (Georgakopoulou, 2013: 673-75). All copper-based artefacts from the site were manufactured from either copper or arsenical-copper in typical Cycladic styles (Georgakopoulou, 2013), and slag analysis of samples from the smelting site on the nearby Kavos promontory suggest that primary production utilised exclusively copper and arsenic rich copper ores (Brodie and Georgakopoulou, 2015). The inclusion of Kastri Group pottery at the site indicates that those utilising Dhaskalio-Kavos were not immune to new cultural influences. However, since the adoption of tin-bronzes would have had both economic and utilitarian benefits, the continuation of Cycladic metallurgical traditions, utilising pure copper and arsenical copper, suggests that there may have been less practical reasons for the metallurgical practices taking place at Dhaskalio-Kavos.

In conclusion, the Kastri Group period represents an advancement of EC II societies in terms of prosperity, social complexity and cultural growth, where external contacts, recognised through material remains at almost all Kastri-Group settlement sites, demonstrates the active involvement of the Cycladic islanders in trade and cultural exchange, and thus indicates that the communities of this troubled period were not isolated (Angelopoulou, 2017: 145). And persistence of metallurgical traditions between the Kastri Group and earlier periods at Dhaskalio-Kavos demonstrates the continuity between the two cultural traditions.

2.3.5 Phylakopi I Culture/Early Cycladic III (ca. 2200/2150-2050/2000 B.C.)

Evidence for the final phase of the Cycladic Early Bronze Age, the so called 'Phylakopi I' culture (EC III, Barber and MacGillivray EC IIIB, Rutter MC IA) is so rare that it gave rise to the suggestion that there was a hiatus of more than 150 years in occupation of the Cyclades (Berg, 2019: 119; Rutter, 1984). Many of the dispersed EBA sites were permanently abandoned by the end of the third millennium, which saw the dominance of large, nucleated settlements, such as, Paroikia on Paros, and Phylakopi on Melos, for which the period is named (Angelopoulou, 2017: 145; Broodbank, 2000: 326-31). Consequently, the transition between the Kastri Group and Phylakopi I has been the subject of much academic debate (Rutter, 1984). However, the material culture and secure stratigraphic sequence which from at Dhaskalio-Kavos demonstrates a certain amount of cultural continuity at the site. Indeed, radiocarbon dates for Dhaskalio Phase C are comparable with the earlier part the Phylakopi I culture (Renfrew et al, 2012: 157), and some pottery shapes which showing similarities to those associated with the First City at Phylakopi were excavated from Dhaskalio Phase C layers during the 2006-2008 excavations (Renfrew, 2014: 202; Sotirakopoulou, 2015). This would suggest that the EC III 'gap' proposed by Rutter (1984) is not evident at the site. Indeed, Rutter himself (1984: 95) suggested that this gap would be likely to disappear with the excavation of an unbroken stratigraphic sequence, one which is now apparent, at least form radiocarbon analysis, at Keros (Renfrew, 2012). However, the evidence suggests that the symbolic attraction of Keros did eventually lose its power, and by c.2300 BCE all activity at the site had seemingly ended (Renfrew, 2014). Whilst the reason for this abandonment is unclear, it is hoped that by further understanding the scale and spatial organisation of activities, especially metallurgical practice, at Dhaskalio-Kavos, this thesis may draw aid in the interpretation of this final phase at the site.

2.4 Dhaskalio-Kavos, Keros

The today uninhabited island of Keros, located in the central Cyclades between the larger islands of Naxos and Amorgos (see **figure 2.2**), is home to one of the most important settlements and ritual sites in the EBA Cyclades (Renfrew, 2013). On the western coast of Keros lies a stretch of arid land known as Dhaskalio-Kavos (often abbreviated to merely 'Kavos'). The area is recognised as the location of a major ritual centre during the EBA (Renfrew, 2013; Renfrew et al., 2007). The realisation of the importance of Kavos in the broader narrative of the EBA Cyclades, has come about through an extensive history of systematic archaeological investigation since the 1960s. It was on Kavos that the first surface survey of Keros took place in 1963 (Renfrew et al., 2007). The survey, conducted by Renfrew, revealed evidence of extensive illicit excavations, documented by numerous surface finds of pot sherds, as well as fragments of marble bowls and figurines (Zapheiropoulou, 2007). Since then, a number of excavations have sought to investigate the extent of the deposits on Kavos and the nearby islet of Dhaskalio.

Rescue excavations by Christos Doumas, which took place in 1963 subsequent to Renfrew's discovery, revealed an architectural feature in the middle region of Kavos and traces of walls on Dhaskalio (Zapheiropoulou, 2007: 29-30). This was followed by further investigation of the looted area by Photeini Zapheiropoulou in 1967, and a collaborative project between the universities of Athens, Ioannina, and Cambridge in 1987 (Renfrew, 2007). The latter excavations established the extent of the looted area (around 40m by 40m) and concluded that the original deposit (now known as the 'Special Deposit North') had consisted of fragmentary pottery, marble vessels, marble figurines and other artefacts, which had all been deliberately broken before burial during the EBA.

During a further period of excavation between 2006 to 2008, a more extensive region of Kavos was explored (figure 2.8). Significant finds from the southern extent of the area (now the 'Special Deposit South') revealed the site, previously described as an EBA cemetery (Broodbank, 2000: 225), to be an area of significant ritual focus which saw broken ceramics, marble vessels, and marble figurines brought from across a major part of the Aegean for deliberate deposition (Renfrew, 2013). The evidence suggests that Kavos was a major ritual centre, with an influence which extended throughout the Cyclades and as far as mainland Greece (Renfrew, 2013). In this way, Dhaskalio-Kavos can be considered a pilgrimage site; a location where people regularly travelled to perform formalised rituals and deposit offerings (Renfrew, 2014: 192). As such, Dhaskalio-Kavos may represent the earliest ritual centre in the Aegean, and may certainly be considered as the earliest known 'maritime sanctuary' (Renfrew, 2013), with a regional role extending beyond its immediate territory (Broodbank, 2013). However, the fact that Dhaskalio-Kavos was a pilgrimage site and a centre for formalised ritual depositions, does not necessarily indicate that its visitors were part of a religious cult that worshipped a specific deity (Renfrew, 2014). The concept of divinities, as clearly conceptualised supernatural beings, is typically associated with hierarchically ordered societies with powerful rulers, such as state societies (Renfrew, 1985). Societal organisation recognisable as a 'state' had not yet developed in the region during the EBA (Cherry, 1984). Rather, Keros was a 'centre of congregation', likened by Renfrew (2014) to Göbekli Tepe in south-east Turkey, or the Ness of Brodgar in the Orkney Islands: places of congregation where communities of people met together, rather than shrines to specific deities. In the case of Keros, these congregations were marked by the deposition of symbolic materials of broken marble vessels and figurines which Renfrew (2012) signifies as the ikon of the 'Confederacy of Keros'.

Figure 2.8: Plan of the west coast of Keros with the major archaeological features of Kavos, Dhaskalio, the Kavos promontory, and the 'Special Deposits' labelled (image Angelopoulou, 2017: fig. 109).

Surface investigations of the low shelf of land to the north of the Special Deposits, known as the Kavos Promontory, also revealed a concentration of copper slag (Brodie & Georgakopoulou, 2015: Georgakopoulou, 2005). This evidence confirmed that small-scale smelting was taking place on the promontory, despite the lack of nearby mineral source (Georgakopoulou, 2005: 272). It was previously thought that EBA metallurgical remains located away from ore sources could only be attributed to secondary metalworking (Broodbank, 2000: 293-7). However, the examination of metallurgical debris from the Kavos Promontory would suggest that, either this assertion is misguided, or Dhaskalio-Kavos is a unique case. It is not known how, or if, these metallurgical activities were connected with the ritual acts at the Special Deposits. Although the proximity of the Kavos Promontory to the sanctuary at Dhaskalio-Kavos suggests that they are likely to have been, in some way, related.

During the same excavation period of 2006-8, the small island of Dhaskalio was investigated (**figure 2.9**). Dhaskalio lies c. 90m to the west of Kavos and was likely joined to mainland Keros by a thin spit of land during the EBA before rising sea levels disconnected the two landmasses (Lambeck, 1996). The excavation of Dhaskalio revealed multiple phases of architecture, suggesting that the island was once home to the largest settlement of the EBA Cyclades (Angelopoulou, 2017: 136; Renfrew, 2013). The excavation at Dhaskalio also revealed a secure stratigraphic sequence which has allowed for the distinction of three successive phases of occupation, spanning the Early Cycladic II and early EC III periods (Renfrew et al., 2012; Sotirakopoulou, 2016). These phases of occupation are defined as Dhaskalio Phases A, which belongs to the Keros-Syros culture, Dhaskalio Phase B, dated to the early Kastri Group, and Dhaskalio Phase C, which belongs to the late phase of the Kastri Group.

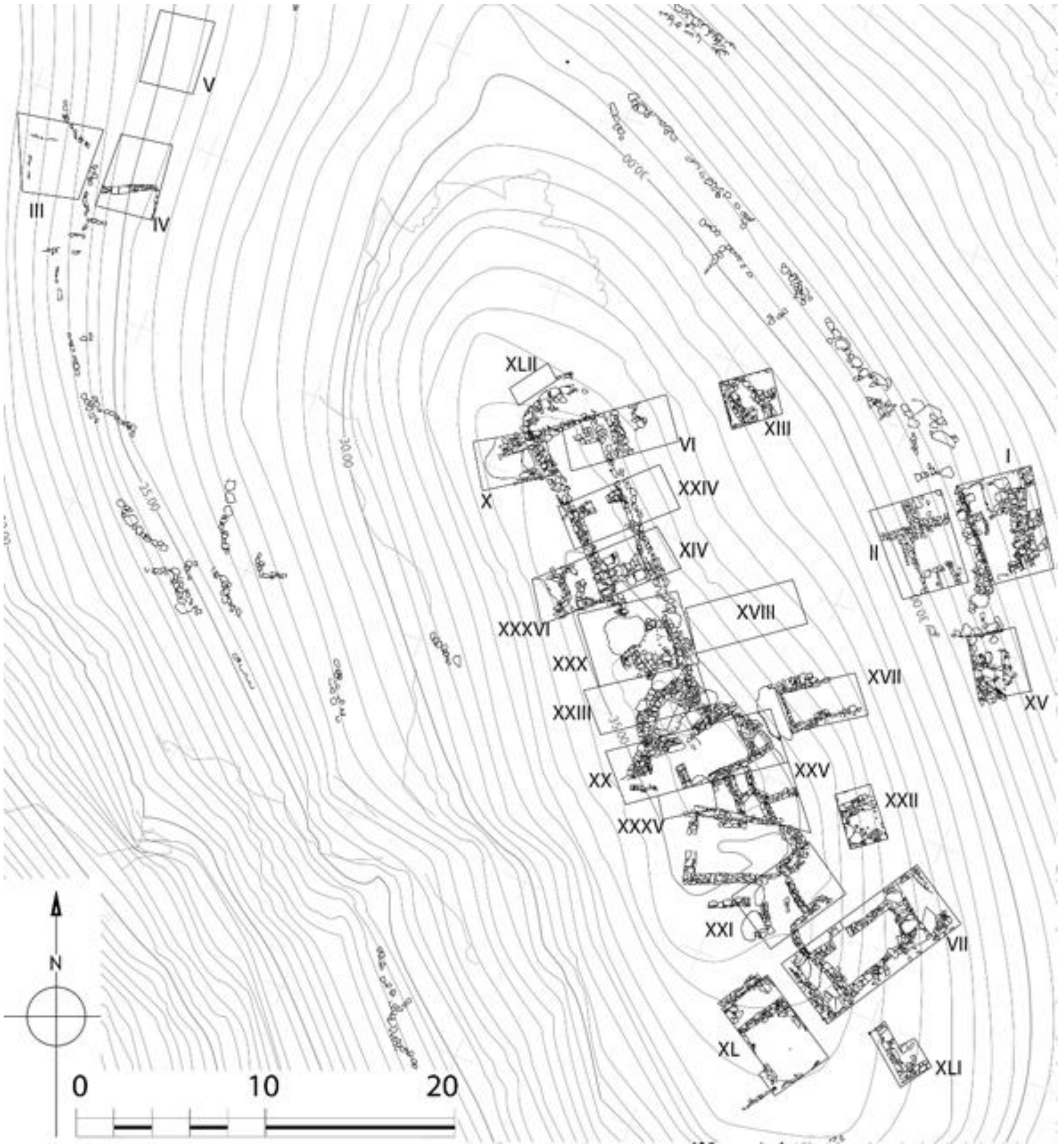

Figure 2.9: Plan of trenches excavated at the summit area of Dhaskalio by the Cambridge Keros Project between 2006 and 2008 (image Angelopoulou, 2017: fig. 112).

Although the recent excavations revealed that the extensive, dense architecture occupied both the summit of the islet as well as its slopes (Boyd 2013: 341–85; Renfrew 2013: 705–21), with the exception of the structures that occupy the summit, no complete buildings have so far been revealed (Boyd 2013: 377). However, the surviving remains do reveal a number of characteristics pertaining to the domestic architecture (Boyd 2013: 371–77). Because of the aggressively sloping nature of the terrain, terraces with stone-built retaining walls were constructed in order to facilitate the construction of buildings (Boyd 2013: 372–74). The buildings in question were built from marble imported from Naxos (Dixon, 2013: 321-23) and were generally single-storeyed with flat roofs, made of wood and schist slabs (Angelopoulou, 2017:137). Due to the extent of the 2006 to 2008 excavations, the region of the islet which is best understood is that of the summit area, which consists of building, possibly with multiple stories, of a suggested communal character and dated to the Early Cycladic (Boyd 2013; Renfrew 2013: 714). Of particular interest is the addition of a large, elongated 'megaroid' building, and a semicircular enclosure (Renfrew 2013: 713, 715), both of which would be suitable for small gatherings, and may have fulfilled a public or ritual function (Angelopoulou, 2017: 137).

Despite its extensive character, habitation on Dhaskalio is thought to have been predominantly seasonal, rather than permanent serving as an ancillary settlement to the ritual sanctuary of Kavos (Renfrew 2013: 709–11). This is predominantly evidenced by the large amount of imported material found at the site which, it is claimed, is suggestive of seasonal occupation of the site by people arriving by sea who brought with them everything which was required for subsistence at the settlement (Sotirakopoulou 2016: 390–91). Interestingly, there is also evidence for secondary metallurgical processes taking place at the site (Georgakopoulou, 2016), which suggests that either the occupants of Dhaskalio, whether seasonal or permanent, were more self-sufficient than the extensive imports suggest, or metalworking fulfilled a role other than a more utilitarian function at the site. Regardless of the reason for such an abundance of imported resources, however, these aspects of the site suggests that Dhaskalio-Kavos was a prominent place in Cycladic communication and trade systems (Angelopoulou, 2017: 137; Broodbank 2000: 260–62; Sotirakopoulou 2016: 390).

2.5 Chapter Summary

The Early Bronze Age represents a period of dramatic social and cultural change in the Cyclades. This notion is clearly demonstrated by the complex evolution of archaeological understanding which has taken place since the late 19th century. From Neolithic origins, to the emergence of the 'international spirit', the Early Cycladic period is a unique era for studying aspects of changing human interaction and material being. The Keros-Syros culture is often considered the *floruit* of the Early Cyclades (Renfrew, 1969: 21), and the Kastri Group represents a period of unparalleled cultural change. The sanctuary site and associated settlement at Dhaskalio-Kavos on Keros bridges these two phases and offers an unparalleled view into cultural continuity during what is often regarded as a tumultuous time for the Cycladic islanders. Furthermore, the close proximity of Dhaskalio to the special deposits on Kavos necessitates questions as to the extent that the occupants of Dhaskalio were involved with the ritual practices taking place on Kavos. Did the sanctuary on Kavos play a dominant role in the life of the settlement on Dhaskalio? In what ways might the settlement have assisted the enactment of such ritual practices? And, given the evidence for both primary and secondary production, what role did metallurgy play at the site, in an Aegean world where the role of metals played such an important role in social and economic change? These important questions may be answered through exploring the nature of activities taking place on Dhaskalio-Kavos, and how the space was organised in order to facilitate the activities taking place at the Special Deposits.

Developments in the production and subsequent use of metal during the Cycladic EBA is attested to by the numerous metal objects which have been uncovered from associated Early Cycladic contexts. The most frequent metals being used during this period are copper and its alloys, lead, silver, and on occasion, gold. Unlike other contemporaneous metal producing centres which had access to large, rich ore deposits, such as Rudna Glava in Serbia (Jovanovic, 2009), the islands of the Cyclades are known for their smaller, albeit abundant, mineral deposits with copper and lead/silver rich deposits existing across the Cyclades (Gale & Stos-Gale, 2008; Georgakopoulou, 2005: 39). EBA copper mineral extraction and smelting sites are known on Kythnos (Bassiakos & Philaniotou, 2007), Seriphos (Georgakopoulou, 2005: 40), and Keos (Gale & Stos-Gale, 2008), with similar evidence for lead/silver mining and production also existing on Siphnos (Gale & Stos-Gale, 1981) and Seriphos (Gale & Stos-Gale, 2008). EBA sites associated with primary metal production tend to be associated with large quantities of slag and other metallurgical debris, and are usually located on exposed costal promontories away from associated settlements (Barber, 1987: 108; Georgakopoulou, 2007).

The production of a metal object involves several stages of processing in order to get from raw mineral to finished artefact. These processes can be broadly defined as mining, primary production methods (such as smelting of ore), and secondary production methods (such as casting and finishing - for an in-depth overview of prehistoric metallurgy, see Tylecote, 1987). EBA evidence for these separate metallurgical stages are often found at different locations in the Cyclades, with smelting taking place on the resource-rich western islands before the refined metals are transported to settlements for further processing (Broodbank, 2008: 64; Georgakopoulou, 2007: 123). Efforts to understand the spatial distribution of these activities have been undertaken in order to further understand the organisation of metallurgy within an island environment (Broodbank, 2000: 293-7; Broodbank, 2008: 64; Georgakopoulou, 2005). However, these studies have largely focussed on broad, Cyclades-wide perspectives of metallurgical organisation, rather than the spatial organisation of a single settlement site. This is an area which this thesis hopes to address through high-resolution spatial analysis of the settlement on Dhaskalio and Keros coastline. The importance of metals to the EBA Cycladic peoples, facilitating an 'international spirit' (Renfrew, 1972) of trade and dispersion of highly valued, socially significant objects, cannot be understated. This makes any effort to further characterise how metallurgical practices were organised within EBA Cycladic society of salient importance.

Rather than a macro investigation of EBA Cycladic life (e.g. Broodbank, 2000; Jarriel, 2018), the latest excavations of Dhaskalio-Kavos offered a unique opportunity to explore the relationship between two distinct parts of this EBA centre. Generating a detailed view of spatial organisation on Dhaskalio is critical for understanding the wider environment and infrastructure that supported the specific practices identified at Kavos itself. Evidence suggests that Dhaskalio-Kavos saw three periods of occupation spanning the Keros-Syros Culture (Phase A), the Kastri Group phase (Phase B), and possibly into the Phylakopi I (Phase C) (Renfrew et al., 2012). However, this late phase of occupation would be almost unique in the Cyclades which saw widespread abandonment of settlements in a cultural hiatus which lasted until the MC I period. This necessitates questions as to the changing character of activities at this special site during the different phases of occupation. This is an area which this thesis aims to address through high-resolution soil chemical survey.

CHAPTER 3: Geochemistry in Archaeology

3.1 Introduction

This chapter considers the application of geochemical survey in archaeology. As a method of archaeological prospection and spatial characterisation, geochemical survey is unique in its ability to analyse contexts of human occupation and activity at a resolution unachievable through other methods of non-invasive survey, such as geophysics. However, geochemistry has not yet achieved common acceptance within archaeological investigation. Reasons for the limited commitment to soil chemical analysis in archaeology may be seen as the result of a long history of a developing understanding of how past human activities may affect the chemical composition of soils, as well as conflicting ideas pertaining to a methodological 'best practice'. Therefore, the following chapter will outline the principles of geochemical survey as well as document changes in the utility of certain elements as anthropogenic indicators, the uptake of different instruments for chemical analysis, and the development of new methods for geochemical survey in archaeology. This critical discussion of past implementation and changing aspects of soil chemical analysis in archaeology will be used in order to offer an understanding for methodological choices employed for this research project.

3.2 Defining Geochemical Survey

3.2.1 Introduction to geochemical survey

Geochemical survey may be considered as an interdisciplinary technique which incorporates elements from a broad range of fields, including geology, chemistry, statistics, geophysics, and archaeological survey (Carey, 2007: 1). Although far from routinely undertaken, the application of geochemical survey in archaeological investigations is not a recent development. As early as the 1950's, archaeologists sought to increase the scientific analytical techniques utilised for the investigation of the past. As a result, there was a move away from the artefact focussed research which had previously dominated archaeology, and a shift towards a more holistic approach which incorporated many facets of evidence, including archaeological soils. Indeed, the opening lines from Cornwall (1954: 129) suitably demonstrates this attitude:

> *"Archaeologists of earlier generations were often interested exclusively in the artefacts of early man. We have now learned that the geological context in which they are found… are often as important as the artefacts themselves for reconstructing the way of life of ancient peoples. The soil itself, in which the archaeological objects occur, can, in certain cases, tell us about the way in which it has been formed and therefore about the environment and habits of the people concerned".*

As illustrated by this point, soils are a key factor in archaeology, forming the matrix that contains the majority of the structural, artefactual, palaeoenvironmental, and geomorphological record of the past (Carey, 2007: 4). Saliently, at least for the purpose of this thesis, soils also contain a chemical record of past human activity. Indeed, archaeological geochemical survey concerns the measurement of concentrations of elements within soil samples. For a specific elemental concentration in soil to be useful for archaeological characterisation, Entwistle et al. (1998: 53) suggest that it must fulfil three criteria. Firstly, human activity must alter the concentration of the element. Secondly, this alteration must be readily observable with respect to background concentrations. Thirdly, any alteration by human activity must be 'fixed' in the soil in a stable form in order to preserve a record of these human activities. However, soils are not static things. Instead, they are dynamic, open systems, formed and evolved through the input and output of a multitude of minerals, nutrients, and energy (Carey, 2007: 4; Oonk et al., 2009b). Therefore, the geochemical record is closely connected to the biochemical cycles of the soil system in which it is deposited (Entwistle et al., 1998: 53).

Soil formation, or pedogenesis, occurs initially through the accumulation of unconsolidated parent material called regolith (Waugh, 2002: 260). Regolith may be derived from either the in situ weathering of bedrock, the deposition of, for example, alluvium, colluvium, loess, or volcanic material, or a combination of the above. This material is then formed into soil through the addition of water, gases (air), biota (living organisms), and humus (decayed organic matter) (Waugh, 2002: 260). With regards to the chemistry of the soil, most mineral (inorganic) matter in natural soils is obtained from the parent material (Sposito, 1989; Waugh, 2002: 263) and so the chemical makeup of natural (non-anthropogenic) soil will largely depend upon the geology of the surrounding region.

Following the onset of sedentary agricultural subsistence, the enrichment and depletion of specific elements during the formation of archaeological soils can be particularly evident (Entwistle et al., 2000: 287; Oonk et al., 2009: 36). Furthermore, certain chemical concentrations have been shown to be indicative of specific past activities (e.g. Aston et al., 1998; Haslam & Tibbett, 2004; Middleton & Price, 1996; Oonk et al., 2009). This offers the ability to not only identify the broad presence of human activity, but also determine the specific use of defined spaces. In this manner, archaeological soils may be considered as much an artefact of past human activity as any form of classically defined cultural material. However, to date, the geochemical analysis of archaeological soils has had limited impact and remains far from routine during programmes of archaeological investigation. To offer context for the research undertaken for this thesis, the following section will evaluate the evolution of geochemical analysis in archaeology and how different elements within soils have come to be understood from an anthropogenic perspective.

3.2.2 Phosphorus analysis

Since it was first recognised that past human activity can alter the chemical composition of soils, archaeologists have been striving to develop an understanding of which specific elements may be indicative of anthropogenic activity. However, the processes by which human activity may alter the chemical composition of soils is often extremely complex (Oonk et al., 2009: 38). Indeed, archaeological soils may be built up over many hundreds, if not thousands of years. Therefore, the exact geochemical processes that took place during and after the occupation of a site are still not yet fully appreciated (Oonk et al., 2009b). However, as advances are made to our understanding of how human activity may affect soil chemical composition, the range of elements considered useful in the analysis of such activities grows.

Early studies of soil chemical analysis in archaeology often focussed on the element phosphorus (P). This is because heightened concentrations of P are often prevalent in pre-industrial human occupational waste (Holiday and Gartner, 2007). Common sources of anthropogenic P among pre-industrial populations include ashes from fires, human, animal and plant remains, human waste, in the form of faeces and urine, and refuse, particularly in the form of organic discard (Bethell and Máté, 1989: 5-10; Holiday and Gartner, 2007: 302; Oonk et al., 2009: 36). With the development of agricultural economies, techniques of fertilisation, from green manures to the application of human and animal waste, became a necessity (Miller and Gleason, 1994). These processes can have the effect of adding significant amounts of P to archaeological deposits which may accumulate over periods of persistent occupation and land use.

Upon deposition, P rapidly bonds with iron (Fe), aluminium (Al), manganese (Mn), or calcium (Ca) ions, depending on the local chemical and geological conditions, to produce relatively stable organic and inorganic phosphate compounds (Holiday and Gartner, 2007: 302; Kabata-Pendias and Pendias, 1984: 38; Oonk et al., 2009: 40). In addition, soil P can be extremely resistant to typical reduction, oxidation, and leaching processes (Proudfoot, 1976). Therefore, with prolonged occupation, the concentration of anthropogenic P on a site can become very large with respect to the natural levels of P in the soil. These anomalous values of soil P can be seen as markers for past human occupation.

This understanding of phosphate accumulation in archaeological soils led to the persistent use of soil P analysis as an aid for the prospection and characterisation of archaeological features throughout the 20th century. As a result, the analysis of anthropogenic P on archaeological sites makes up the majority of past geochemical investigations in archaeology, with studies having been conducted on archaeological sites across the globe (see Holliday & Gartner, 2007 and references therein).

3.2.3 Multi-elemental analysis

Due to its interpretive value, as well as the relative stable nature in soils, the analysis of soil phosphorus concentrations remains an important tool in the prospection and characterisation of archaeological sites (Holliday & Gartner, 2007; Oonk et al., 2009: 36). However, as analytical technology has advanced, archaeologists have made efforts to increase the catalogue of elements which may been seen as useful anthropogenic indicators. Soil has the capacity to isolate and retain various elements from human inputs over the course of many years, and certain elements are known to occur in anomalous concentrations in archaeological soils as compared to the background geochemistry (Oonk et al., 2009). Aston et al. (1998: 465) suggest a number of ways in which the chemical character of archaeological soils may have been enhanced by human activity. This is salient when considering questions which pertain to the use of space and characterisation of past-human activities, as the observation of anomalous concentrations of different elements may be considered indicative of different activities and their distribution can indicate the spread and unique spatiality of such practices.

Several key studies have noted the interpretive potential of a number of elements for the identification of archaeological sites, due to their presence at anomalous levels in archaeological soils. As a result, the suite of elements (with the exclusion of phosphorus) suggested to hold the most utility for archaeological investigation are barium (Ba), calcium (Ca), copper (Cu), potassium (K), manganese (Mn), lead (Pb) and zinc (Zn), and to a lesser extent iron (Fe), magnesium (Mg), sodium (Na) and strontium (Sr) (Middleton & Price, 1996; Aston et al., 1998; Haslam & Tibbett, 2004; Oonk et al., 2009). Other trace elements have been routinely scrutinised by archaeological geochemists, such as arsenic (As), cerium (Ce), cobalt (Co), chromium (Cr), cesium (Cs), gallium (Ga), gadolinium (Gd), holmium (Ho), lanthanum (La), lutetium (Lu), nickel (Ni), molybdenum (Mo), rubidium (Rb), scandium (Sc), samarium (Sm), thorium (Th), titanium (Ti), vanadium (V) and zirconium (Zr) (e.g. Bethell & Smith, 1988; Butler et al., 2015; Costa et al., 2013; Couture et al., 2016; da Costa & Kern, 1999; Dirix et al., 2013; Entwistle & Abrahams 1997; Entwistle & Abrahams, 2000; Hayes, 2013; Hunt & Speakman, 2014; Hunt & Speakman, 2015; Kanthilatha et al., 2017; Lubos et al., 20167; Prosch-Danielsen & Simonsen, 1988; Sharma et al., 2015). However, anomalous concentrations of Ba, Ca, Cu, Fe, K, Mg, Mn, Na, Pb, Sr and Zn are the most common elements found in association with archaeological soils and, therefore currently hold the greatest interpretive value (Oonk et al., 2009: 38).

Whilst the acknowledgement of these elements as often being present in archaeological soils is helpful for investigations pertaining to archaeological prospection, much work in this field has also been aimed at identifying specific activities associated with anomalous concentrations of specific elements. For example, Misarti et al. (2008) conducted a multi-elemental investigation of soils associated with various archaeological features on prehistoric village sites in Alaska using inductively coupled plasma-mass spectrometry (ICP-MS). As a result of this study, they were able to identify particular activity areas through specific groups of elements. This included an association of Ba, Zn, Sr and Ca with midden soils, high concentrations of Mn, Mg, and K associated with house floors, and high concentrations of K and Mg and low concentrations of Mn associated with house berms (Misarti et al., 2008: 1453).

Further studies over the past decades have offered additional correlation between the presence of certain elements in soils and specific activities. For example, Ba is often present in marine plants, bones and bone ash, and mollusc shells (Burton and Price, 1990; Entwistle et al., 1998). Elevated concentrations of calcium Ca have been noted in association with kitchens, dwellings, shell, bone, and middens (Barba and Ortiz, 1992; Entwistle et al., 1998; Hurley and Heidenreich, 1971; Knudson et al., 2004; Lambert et al., 1984; Linderholm and Lundberg, 1994; Middleton and Price, 1996; Stimmell et al., 1984; Sullivan and Kealhofer, 2004). Potassium (K) may be connected to cooking and burning, whilst also being present in food scraps, animal fodder, and bedding (Entwistle et al., 1998; Middleton and Price, 1996; Schuldenrein, 1995). Magnesium (Mg) has been shown to be concentrated in ash and burnt features (Knudson et al., 2004; Moore and Denton, 1988), with increased concentrations having been interpreted as cooking areas, animal food processing locations, and middens (Heidenreich and Konrad, 1973; Hurley and Heidenreich, 1971; Knudson et al., 2004; Middleton and Price, 1996; Schuldenrein, 1995). Strontium (Sr) can be a good dietary indicator as elevated concentrations are often found in bone and plant material (Lambert et al., 1984). Elevated concentrations of Na have also been linked to food processing, specifically the use of saltwater fish (Knudson et al., 2004). Alongside this suite of elements which have been shown to be associated with specific activities, Cu, Fe, Mn, Pb and Zn have been interpreted as general indicators of anthropogenic activity (Barba and Ortiz, 1992; Linderholm and Lundberg, 1994; Middleton and Price, 1996; Wells et al., 2000).

These studies have gone a long way in identifying certain suites of elements which may be used as proxy for certain past human practices when observed in anomalous concentrations in soils. However, a problem often faced when conducting multi-elemental geochemical survey, is that of identifying a base chemical composition of soils by which an 'anomalous' level may be ascertained. Indeed, knowledge of the geochemical background is often considered a basic question when considering the human impact on geochemical parameters of soils and sediments, as it enables the qualification of the parts of the overall chemistry of the soil that are natural and those that are a result of human activity (Zgłobicki et al., 2011: 347). Consequently, multiple methods of identifying geochemical background levels have been used in archaeological research. These methods of quantifying the geochemical background may be divided into roughly two groups: direct geochemical examination, and indirect statistical analysis.

The method which is most often used for establishing direct geochemical background chemical concentrations involves the comparison of 'on-site' and 'off-site' analyses. This method relies upon a large quantity of samples being taken from an area which displays similar geology to the archaeological site in question yet has not been impacted by human habitation or activity. These off-site results are subsequently used in order to determine base concentrations of each element through averaging of results. Any elements from the on-site analyses which display concentrations above or below this off-site average are then considered anomalous and of possible anthropogenic origin. However, this method can be problematic as the boundary between naturally formed soils (not affected by human impact, or 'off-site') and those contaminated by human activity may be ambiguous (Zgłobicki et al., 2011: 348), and this method does not account for natural variability of chemical concentrations in soils. A similar method for determining direct geochemical background concentrations is the use of basis rocks as natural values for concentrations of studied elements (Zgłobicki et al., 2011: 347). This may also present issues as many factors influence the naturally occurring chemical concentrations in rocks and the spatial distribution of such concentrations may not be equal and, therefore, requires specialised knowledge of regional geology (Reimann & Garett, 2005).

Other approaches utilise statistics. Statistical methods for determining geochemical background concentrations are numerous, but generally depend upon the elimination of extreme samples in order to obtain a normal distribution of concentrations for the analysed population (Matschullat et al., 2000; Zgłobicki et al., 2011). Such methods often rely on removing results which may be considered as outliers, such as the 2σ outlier test whereby extreme values ±2σ are eliminated, and the 4σ outlier test whereby extreme values ±4σ are eliminated (Matschullat et al., 2000: 992-3). Comparable with these outlier tests is the iterative 2σ technique, whereby the mean and standard deviation are calculated from the original data and all values beyond the mean ±2σ are then omitted, this procedure is then repeated until all remaining values lie within this range (Zgłobicki et al., 2011: 350). With all these techniques, the values that remain subsequent to omitting outliers are considered to represent the geochemical background concentrations (Matschullat et al., 2000). Whilst these methods are appropriate for rapid and reliable assessment of upper limits of results, most statistical tests are only helpful in removing so-called outliers as opposed to methods of true quantification of natural background geochemical concentrations. A combined method of off-site analysis and statistical techniques is therefore offered as a favourable solution (Zgłobicki et al., 2011).

However, these methods, both off-site comparison or statistical smoothing, assume that chemical evidence for human activity in soils are present in concentrations far higher or lower than the assumed background (≥±2σ). Indeed, Oonk et al (2009) contended that a major issue in archaeological geochemistry is that determining a background or a natural baseline is problematic, and that the connection between the level of any elemental enhancement or depletion remains undefined. Therefore, contextual observation, where the variability within a site is analysed and interpreted, is crucial in determining the validity of interpretation. In addition, statistical methods, such as Principal Component Analysis (PCA) may be used as a means of reducing a large data set into dominant covariant clusters in order to extract what may be a product of soil processes and composition, and what may be archaeological (Cannell, 2016). There are also circumstances where there is little need for establishing a geochemical background concentration, even if such an endeavour posed no issues. For example, areas which have been exploited for past metallurgical practices are likely to have concentrations of heavy metals, such as Cu or Pb, far above any normal geological background (Slater, 2016: 84). The chemical signatures of metallurgical practices have been shown to be both significant beyond ambiguity, and enduring (Carey et al., 2014). Because this thesis is largely concerned with identifying areas of metallurgical practice (and those with an absence of such evidence), the study utilises both PCA analysis for identifying likely anthropogenic inputs, as well as the assessment of intra-site variability for determining areas of enhanced activity across the site. In this way, the issues pertaining to establishing a true geological background are negated, since variability is assessed between samples from within the same site. However, as with geochemical analysis in general, but especially with regards to in situ, on site analysis, results are not suitable for inter-site comparisons (Cannell, 2016: 45). Rather, it is the intra-site variability that is interpreted.

3.3 Changing Methods of Geochemical Analysis and Survey

3.3.1 Laboratory-based methods of soil analysis

Since the mid-20th century, various methods of chemical analysis have been developed and subsequently adopted by archaeologists for the analysis of archaeological soils. Early studies in geochemical analysis in archaeology relied upon laborious methods of P analysis. Although over thirty methods of P analysis have been used in archaeology (Hilliday & Gartner, 2007: 309), most methods involve the extraction of P from the soil, and the subsequent analysis of P in the extractant. Various acid solutions may be used for the extraction depending on the analysis type, such as sodium carbonate (Na2Co3) (Davidson, 1973; Dormaar & Beaudoin, 1991; Simpson, 1994), sodium hydroxide (NaOH) (Davidson et al., 2006; Simpson et al., 1998), or nitric acid (HNO3) (Linderholm & Lundberg, 1994). Analysis of extracted P is usually undertaken by colorimetry (e.g. Davidson, 1973; Davidson et al., 2006; Dormaar & Beaudoin, 1991; Simpson, 1997; Simpson et al., 1998) or by way of inductively coupled plasma spectrometry (ICP) (e.g. Linderholm & Lundberg, 1994). Colorimetry involves the chemical reduction of molybdophosphoric compounds in an acid compound which creates a sample with a blue coloration, the shade of which is proportional to the concentration of P in the sample (Holliday & Gartner, 2007: 309). ICP analysis, on the other hand, involves the atomisation of the digested sample through the introduction of a plasma torch consisting of super-heated argon gas. Atoms in the sample become 'excited' and emit a distinctive light spectrum which is then analysed for relative concentration of the desired element (in this case phosphorus) (Holliday & Gartner, 2007: 309). In both cases, analysis must be conducted in the laboratory under controlled conditions.

Similarly, the majority of hitherto multi-elemental analysis of archaeological soils have been conducted with infield sampling and laboratory extraction and analysis by way of ICP-OES (Entwistle & Abrahams, 1997; Entwistle et al., 1998; Fernandez et al., 2002; Grattan et al., 2013; Homsey & Capo, 2006; Hutson & Terry, 2006; Linderholm & Ludberg, 1994; Middleton, 2004; Milek & Roberts, 2013; Misarti et al., 2011). As with P analysis by ICP, this method determines the chemical composition of a sample through the measurement of excited atoms and ions at the wavelength which is characteristic for the specific elements being measured.

In rarer cases, multi-elemental analysis of archaeological soils has been conducted by X-ray fluorescence spectroscopy (XRF) of homogenised bulk soil samples (Abrahams et al., 2010; Banerjea, 2008; Banerjea et al., 2015; Banerjea et al., 2017; Butler et al., 2015; Cook et al., 2005; Cook et al., 2010; Cook et al., 2014; da Costa & Kern, 1999; Oonk et al., 2009). Unlike ICP-OES, X-ray fluorescence is a non-invasive analytical technique used in order to determine the chemical composition of various materials. XRF instruments determine the elemental makeup of a sample by measuring the fluorescent (secondary) X-rays emitted from the sample when electrons are displaced from their atomic orbital positions by a high energy, primary X-ray source. Each of the individual elements present in a sample produce a set of characteristic fluorescent X-rays that are unique for that specific element (Shackley, 2011). For the purpose of the analysis of archaeological soils, samples are often ground and homogenised before being analysed in a laboratory setting (e.g. Abrahams et al., 2010).

These laboratory based analysis techniques which have been commonly used for geochemical investigations offer a significant drawback, namely their time-consuming and expensive nature. Consequently, the selection of sampling strategies for laboratory methods tends to be influenced more by logistical considerations, such as the transportation of soil samples and the cost of specialised laboratory analysis, rather than by the intellectual framework of the study (Frahm & Doonan, 2013: 1427). This poses a problem, as geochemistry has the potential to provide detailed answers to specific spatial questions if utilised within an appropriate methodological framework. Additionally, laboratory based analysis tends to isolate geochemical approaches from on-site methodologies, such as other in-field survey methods and excavation, thus reinforcing the separation between fieldworkers and post-excavation experts (Andrews et al., 2000; Andrews & Doonan, 2003). Therefore, in order to obviate the need for costly and time-consuming laboratory techniques, the ability to collect extensive soil samples from a site and perform chemical analysis using field-based, portable equipment, is crucial (Derham et al., 2013: 48).

3.3.2 In situ methods of soil analysis

Acknowledging the limitations of laboratory based methods for conducting rapid, high-resolution geochemical analysis, the use of handheld portable X-ray fluorescence (HHpXRF) analysers has gained popularity in the archaeological community, and offers the potential to revolutionise in situ geochemical methodologies. Although various manufacturers and models exist, in general HHpXRF analysers are roughly the size and morphology of an electric hand-drill and represent a miniaturisation of laboratory-based X-ray fluorescence analysis equipment. However, with this reduction in size and weight in order to facilitate portability, comes a trade-off in performance. This can be attributed to constraints in power consumption and the miniaturisation of analytical components (Frahm & Doonan, 2013: 1426). Nevertheless, development of software 'correction schemes' (Frahm et al., 2014: 233), such as Compton normalisation (CN) and fundamental parameters (FP) calibration has gone some way in broadening the appeal of such devices. CN measures X-rays that are inelastically scattered by samples in order to normalise the internally measured X-ray count and compensate for irregularities to the texture, density and morphology of the specimen (Frahm et al., 2014: 233). In contrast, FP employs mathematical algorithms based on independent elemental parameters and internal instrumental conditions to solve a range of nonlinear equations describing the relationship between X-ray intensities and concentrations of elements in samples (Frahm & Doonan, 2013; Omote et al., 1995; Thomsen, 2007). This enables the performance of quantitative analysis using only a few standard reference samples to calibrate the internal analytical mechanisms, a process usually undertaken by the manufacturers. Consequently, calibrated instruments may be used effectively in a wide range of applications where only a broad material type, such as soils or metals, needs to be identified.

Although corrective software and technological advancements have improved the precision of HHpXRF instruments, portable analysers are not currently capable of detecting a broad range of elements with the same precision as laboratory based analysers (Shackley, 2011; Frahm, 2013). However, the adoption of HHpXRF technology within the archaeological community is primarily driven by the portability of the device, despite its slightly lower performance (Frahm, 2013: 1080). Indeed, archaeologists have successfully utilised HHpXRF technology for characterizing the chemical composition of material artifacts (Shugar & Sirios, 2012; Smith, 2012), as well as provenancing ancient materials, particularly obsidian (Burley et al., 2011; Craig et al., 2010; De Francesco et al., 2011; McCoy et al., 2011; Phillips and Speakman, 2009; Sheppard et al., 2011).

Despite the obvious draw of HHpXRF for in-field use, Frahm and Doonan's (2013) extensive literature review of HHpXRF use in archaeology suggests that only a small percentage (18%) of studies utilising this technology involve taking the instrument into the field. Instead, the majority of analyses are carried out in laboratory or museum settings (Frahm & Doonan, 2013: 1430). This tendency may be attributed to the emergence of archaeological science as a distinct specialisation that prioritises laboratory-based analyses as "proper" scientific practice, thereby reinforcing the longstanding dichotomy between science-led archaeology and more humanities-led approaches. However, the portability of HHpXRF instruments has the potential to bridge the gap between scientists, scientific practice, and archaeologists by enabling in-depth analysis in the field (Frahm & Doonan, 2013: 1430).

Researchers using HHpXRF instruments in laboratory-based settings tend to limit themselves to research questions that can be addressed using laboratory-based methods (Frahm & Doonan, 2013). However, this approach does not fully utilise the strengths of portable devices. HHpXRF instruments are not as precise as laboratory-based instruments in laboratory settings (Shackley, 2011). Therefore, there is a need to develop sound methodological approaches to make the most of the specific capabilities of HHpXRF instruments in the field. Recent research has shown that portable instruments may be particularly useful for answering questions related to spatial characteristics of past site use and the geochemical prospection of habitation and production centers (Derham et al., 2013; Gauss et al., 2013; Hayes, 2013; Vyncke et al., 2011; Welham et al., 2016). Additionally, these studies highlight the advantages of using portable devices in the field, such as the ability to quickly generate in situ analytical data and adapt survey methods (Boyd et al, 2021; Welham et al., 2016). For instance, rapid and extensive geochemical survey of archaeological sites with HHpXRF can inform real-time excavation strategies (Boyd et al, 2021). Indeed, the use of HHpXRF instruments in the field can greatly enhance the ability of archaeologists to conduct in-depth analysis, investigation, and interpretation of archaeological sites. The ability to generate rapid in situ analytical data allows for adjustments to survey, fieldwork, and excavation strategies to be made immediately on site, which can lead to more effective and efficient research outcomes. Moreover, the integration of varied methods of analysis within a set of shared, coherent project objectives is facilitated by the use of portable instruments (Frahm & Doonan, 2013: 1430). The full potential of portable instruments may only be realised when such integrated methods are regularly implemented (Oonk, 2009). However, these recent studies go some way to establishing a working methodology for the in-field use of HHpXRF, which can be applied in the geochemical analysis of anthropogenic indicators in archaeological soils.

3.3.3 Sampling strategies

Whilst much work has been achieved in acknowledging the interpretive value of anthropogenic indicator elements in relation to a wide-range of categories of past human activities (e.g, Aston et al., 1998; Oonk et al., 2009), the use of geochemical analysis in archaeological investigations has been largely focussed on simply highlighting areas of increased human activity or merely the general presence of 'archaeology' (e.g. Bintliff et al., 1992; Dockrill & Simpson, 1994; Keeley, 1981). This may be seen in the prevalence of geochemical survey used for archaeological prospection and the relative lack of studies which focus on geochemical interpretation within open excavations. This is problematic, as there remains a clear potential for soil chemical analysis to aid in the understanding of more complex aspects of past human behaviour. Unlike other more conventional forms of archaeological survey, such as geophysics, there are hitherto no commonly accepted standards for sample intervals for geochemical survey (Carey, 2014: 3). However, when samples are collected at large intervals (>5-10m), identifying individual features becomes difficult, thus consigning geochemical survey to the application of identifying broad 'hot-spots'. Instead of merely defining areas of increased human activity within archaeological sites, soil chemical analysis may be used in order to offer an insight into the organisation of space and the spatial routines associated with past human habitation and craft practices.

Space is not merely a backdrop to human activity, but intrinsic to it (Hiller, 2014). Understanding how we use and relate to space is fundamental to how we interact with the world around us. Space is not simply a label we give to our surroundings; it is something that is constantly being created and influencing our social constructions (Lefebvre, 1991; Taun, 1977). We exist in a world that we understand through our experiences (Thomas, 2012). We divide spaces, whether urban areas, rural landscapes, or architectural features, based on the things around us and how we interact with them (Cannell, 2016: 20). Yet, rather than viewing objects as inherently meaningful and the landscape or architectural features as static, space can be seen as a product of socially constructed and accepted behaviours that are responsive to the environment (Ingold, 1993). How people interact and live within different spatial divisions is an accumulation of learned behaviours and responses to cultural, environmental, and material factors. It is important to understand that this sociality exceeds human relationships, instead representing an inherently more-than-human phenomenon (Ingold, 2000: 199–200). Indeed, the advances of more-than-human approaches within archaeology through the development of new ontological claims about the world are crucial in developing a detailed understanding of not only past craft practices, but of the social world in general.

In order to redefine the boundaries of the human, posthumanism has promoted ideas which bring focus to non-human entities (Núñez-García, 2019: 26). These perspectives, particularly through the lens of new materialisms, provide a unique understanding of human-nonhuman interaction within the material world by challenging the traditional human-centric ontology and emphasising the agency and ‘vitality’ of non-human entities. Within this paradigm shift, various philosophical theories, such as Barad’s (2007) agential realism and Bennett’s (2010) vital materialism, blur the boundaries between the human and non-human by conceiving matter as self-transforming and self-organising.

Stemming from symmetrical archaeology, and influenced by Latour's Actor-Network Theory (ANT), these approaches initially aimed to decentre human agency, considering societies as networks of entities, both human and non-human, with equal capacities (Latour, 1993, 1999, 2005). This 'first wave' of symmetrical theory focused on the fluidity and interconnectedness of entities, forming temporary arrangements known as assemblages, where both humans and things coexist on an equal footing leading to a 'flat ontology' (Webmoor, 2007; Witmore, 2014). However, a 'second wave' emerged, led by Olsen and others, which delved deeper into the individual properties of things, inspired by Object-Oriented Ontology (Harman, 2011), shifting focus to the inherent qualities of things themselves and recognizing them as active agents with unique qualities and contributions to social dynamics (Olsen, 2010; Harris & Cipolla, 2017; Núñez-García, 2019). These fluid, self-sufficient arrangements question traditional distinctions between the material and the social by challenging anthropocentric views of agency and ontology.

By incorporating posthumanist perspectives into the study of EBA metallurgical practice, we can gain a deeper understanding of the intricate relationships between humans, materials, and space. Rather than viewing craft practice as solely a human endeavour, symmetrical archaeology encourages us to recognise the agency of non-human entities and the reciprocal influences between material properties, bodily movements, and spatial configurations. Indeed, the bodily movements of the smith, for example, are not only influenced by the properties of materials but also by the spatial organisation of the crafting space. Within the metallurgical workspace, the arrangement of tools, furnaces, and workbenches shapes the smith's movements and interactions with materials. The spatial layout of the workshop thus becomes integral to the craft process, facilitating or constraining the smith's actions and creativity. Furthermore, the material properties of tools, artifacts, and raw materials themselves not only influence the craft process but also shape the physical embodiment of the smith over time. As the smith engages in repetitive movements and interactions with materials, their body adapts to the demands of the craft, resulting in specialised physical shapes and gestures (Núñez-García, 2019). This embodied knowledge is passed down through generations, contributing to the development of distinct craft traditions and techniques within metallurgical communities.

However, while symmetrical archaeology and new materialism offer valuable insights into the reciprocal relationships between humans and non-humans, they risk overshadowing the crucial role of human craftsmanship and knowledge embedded within material culture (Barrett, 2016; Ingold, 1993; 2000; 2017). While symmetrical archaeology highlights the active participation of things in social networks, it often neglects the intricate human practices and skills involved in their creation (Núñez-García, 2019). Indeed, symmetrical archaeology's emphasis on de-centring the human and prioritising the agency of materials risks overlooking the intricate human practices and skills involved in craft production (Barrett, 2016). Each artifact within an EBA metallurgical assemblage reflects not only its material properties but also the accumulated human knowledge of crafting processes, raw materials, and cultural significance. Ignoring these human attributes within a symmetrical framework leads to a static portrayal of humans within the assemblage, detached from their active engagement with the material world. Rather than achieving true equality between humans and non-humans, this approach results in an almost-homogenous ontology that fails to acknowledge and celebrate human diversity and agency.

Therefore, a balanced approach is needed—one that acknowledges the coexistence of humans and materials within craft practices while valuing the unique contributions of each. Rather than displacing the human-cantered perspective entirely, there should be a shared centre where humans and materials embrace their differences and mutual dependencies. This entails recognising and valuing the crafted qualities of artifacts within the context of human creativity, skill, and socio-cultural practices. True understanding and appreciation of craft practices, such as EBA metallurgy, require a balanced approach that acknowledges the reciprocal influences between humans, materials, and spatial configurations. One such approach is that of Material Engagement Theory (MET). MET posits that cognitive processes are deeply intertwined with the material environment, and that the mind extends into the world through interactions with it, and that agency emerges from the relationship between individuals and their activities within specific contexts, rather than from the individual alone (Malafouris, 2013). In this way, human cognition arises from the dynamic interplay between neural, material, and cultural adaptability (Aston, 2020). While symmetrical archaeology has paved the way for a more inclusive understanding of human-nonhuman interactions, it must avoid reducing humans and things to mere equals in social networks. True equality lies in recognising and embracing the unique qualities and contributions of both humans and non-humans within the assemblage, fostering a more holistic and dynamic approach to archaeological interpretation. By acknowledging the crafted attributes of material culture, we can ensure a more nuanced and respectful portrayal of past societies and their intricate relationships with the material world.

Furthermore, focusing on objects and their physical properties, whilst valuable, may reflect our limited ability to see beyond the material world and consider alternative perspectives (Cannell, 2016: 20). This is especially challenging in archaeology, where we must accept that the objects which are preserved and are, therefore, available for study, usually those that are durable and prestigious, can only offer a partial understanding of past cultural beliefs and attitudes. Instead, we need to take a more comprehensive and thoughtful approach that incorporates both our understanding of knowledge and that of the society being studied. This includes examining how people lived in and used space, as well as the objects they placed within it, even though our knowledge of the past is limited by the scarcity of physical evidence. While objects are important in our understanding of social and cultural constructs, they are not the only way we interpret how people divide the world around them. Actions, such as learning through experience, are also essential to how people mentally and physically divide space (Bourdieu, 1977). Objects serve as a tool to focus our cognitive responses in time and space (Cannell, 2016; Keller & Keller, 1996), but they do not provide the full picture.

Viewing technology and past craft activities simply as passive technical processes denies the social aspects of craft practice, reducing complex, fluid human behaviour to the analysis of static objects (Slater & Doonan, 2012: 113). Instead, technology represents a multifaceted sociotechnical system of diverse cultural choices (Pfaffenberger, 1992). It is through the skilled manipulation of materials and spatial routines that social traditions and habits are learned and subsequently materialised through craft traditions (Barrett, 1989; De La Fuente, 2011; Dobres, 2000; Lemonnier, 1993; Martinon-Torres, 2002). This is important for archaeological geochemistry, as specific choices of material and bodily habit will result in particular manifestations of distinct chemical signatures in archaeological soils (Slater & Doonan, 2012: 114). Consequently, enhancements of anthropogenic elements may be understood as cultural signatures, organised through socially learned patterns of movement, and retained in the soil through routine use. Therefore, by studying the spatial organisation of enhanced anthropogenic elements in areas of craft activity, a deeper sociocultural understanding of such activities may be achieved. In this way, rather than merely remaining a means of prospection and delineation of specific site activities, soil chemical analysis becomes a critical way of aiding the characterisation of past social complexities.

Since each kind of human activity has its own natural geometry (Hillier, 2014), for this level of interpretation to be possible geochemical surveys must be conducted at resolutions which are consistent with the routines of craft practice. Indeed, Slater (2014: 87) suggests that, when concerning questions related to craft practice, geochemical survey sampling strategy should have a resolution of no more than 1m as this is representative of the spacing that can capture signatures of movement of the human body. Additionally, smaller sampling intervals allow geochemical characterisation to be related to individual archaeological contexts (Carey et al., 2014: 3). When high resolution geochemical analysis is performed on the surface, it becomes possible that multiple archaeological contexts are being analysed within one survey. By utilising geochemical survey within archaeological excavation, with samples analysed at high resolution within individual contexts, geochemical survey can be better related to intricate human activity (Davis et al., 2012).

3.4 Selected Methodology

The exact methods of geochemical survey employed for this research will be detailed in 'Chapter 4: Methodology'. However, it is important at this stage to reflect upon the above critique of geochemistry in archaeology as it has evolved over the past decades to offer a rationale for methodological choices taken with regards to this research.

The aim of this research is directed at defining archaeological features, understanding areas of activity, and characterising the use of space on the EBA settlement of Dhaskalio and contemporaneous infrastructure on the neighbouring island of Keros in the Cyclades, Greece. The topography, vegetation, and density of architecture on Dhaskalio prevent the use of traditional forms of archaeological survey, such as geophysics. Therefore, geochemistry is uniquely situated to answer these questions on the site. Since the research questions pertain to both prospection of activity areas, as well as the small-scale characterisation of individual activities, the sampling strategy was necessarily multi-scalar. This consisted of broader landscape surveys on Dhaskalio and regions of Keros as well as high-resolution sampling strategies on individual contexts within excavated areas of Dhaskalio. As highlighted above, this latter method allows for geochemistry to capture signatures of movement which relate to intricate human activities.

It has been demonstrated that the interpretive value of multiple elements exists for defining archaeological features and categories of human activity. Previous excavations have shown that a range of features and evidence of craft activities exist on the settlement at Dhaskalio. As such, a suite of elements was selected for analysis in order to offer the best results for characterising a variety of anthropogenic inputs. These analyses were undertaken in situ using a HHpXRF instrument as the number of samples needed for high-resolution analysis necessitated a rapid method of analysis. Furthermore, it is apparent that the slight trade-off in instrument performance is outweighed by the effectiveness of rapid, high-resolution survey strategies (only achieved through the use of portable instrumentation) for answering questions specific to small-scale human activities. This method also permitted geochemical data to be informative to excavation strategy as areas of geochemical interest could be prioritised. This allowed for geochemistry to be fully integrated within the framework of the excavation, as opposed to an ancillary survey method. It is this implementation of geochemistry which fully utilises the strengths of HHpXRF instruments in archaeological research.

3.5 Chapter Summary

It is well established in archaeological thought that human activity may significantly affect the formation and chemical composition of archaeological soils (Entwistle et al., 2000; Middleton & Price, 1996; Oonk et al., 2009). This information has been utilised in the prospection of archaeological sites (e.g. Aston et al., 1998), the study of land use and specific practices (e.g. Konrad et al., 1983; Muhs et al., 1985), and the interpretation of archaeological soil features (e.g. Lillios, 1992), yet its use remains infrequent in routine fieldwork and especially in commercial practice. This is due to a number of factors, including time and cost, but also the uncertainty that surrounds the meaning of geochemical variation is also an important issue to acknowledge in explaining its absence in most work. The process by which anthropogenic matter may become concentrated in archaeological soils is often extremely complex (Oonk et al., 2009: 38). Consequently, the exact chemistry of archaeological soils and the geochemical processes that took place during and subsequent to the occupation of a site are not yet fully understood (Oonk et al., 2009). Furthermore, interpretive challenges are not restricted to soil ecology, but also include basic understandings of how specific human practices imprint themselves on open soil contexts. Therefore, geochemical investigations have largely been used in order to simply highlight areas of increased human activity or merely the presence of archaeological features (e.g. Bintliff et al., 1992). However, there remains a clear potential for understanding more complex aspects of past human behaviour. Instead of merely delineating areas of increased activity within archaeological sites, soil chemical analysis may be used in order to offer an insight into the organisation of space and the spatial routines associated with past human habitation and craft practice.

Conventional geochemical analysis, utilising laboratory-based methods, operate with restricted sample numbers due to limitations of sampling time and costs of analysis (e.g. Entwistle et al., 2000; Maskall et al., 1995; Middleton & Price, 1996; Wilson et al., 2008; Wilson et al., 2009). As such, sampling strategies employed when utilising laboratory have rarely been employed to identify spatial patterning at a level of resolution commensurate with human practice, instead being used for broadly descriptive programs of soil characterisation (Frahm & Doonan, 2013). In light of the centrality of space in theories of agency and practice, alongside the burgeoning importance given to context, the ability to characterise space through the analyses of soil matrices is of critical importance. Developments in portable analytical instrumentation (HHpXRF) enables the ability to undertake rapid in situ analysis in a cost-effective manner and permits high resolution analysis of spatial patterning as a way of defining signatures of practices as they are manifested in extended regions of the soil matrix. In this manner, such arrays of elevated anthropogenic matter in archaeological soils may be understood as soil artefacts. Such “artefacts” do not obey strict formal characteristics in the same way that more usual material culture might, but signatures of practice as embedded in the soil matrix can certainly be considered as cultural artefacts. It is of course impractical to ever considering removing these and “bagging” them, but it is now apparent that, with the arrival of HHpXRF, such culturally meaningful signatures can be measures, recorded, and preserved in record routinely on archaeological sites. Furthermore, feedback from HHpXRF, at the point of analysis, allows adjustments to survey, fieldwork, and excavation strategies to be conducted immediately on site. This allows for varied methods of analysis, investigation, and interpretation to be integrated within a set of shared, coherent project objectives. This is something which is not permitted by processes which involve the export of samples and subsequent laboratory processing.

This evaluation of how geochemical survey in archaeology has been adopted and evolved over the past decades has been offered as a means of establishing a rationale for methods used during this project. There are still yet to be devised standardised methods for geochemical survey, especially with concerns to analytical instrumentation and survey strategy. By comprehensively evaluating multiple methods of characterising anthropogenic geochemical signatures, the appropriate framework for answering the questions posed by this thesis have been established.

CHAPTER 4: Methodology

4.1 Introduction

One of the main aims of this study is to understand the character and spatial organisation of activities associated with the EBA cult centre at Dhaskalio-Kavos through high-resolution geochemical survey. However, the methods employed for the geochemical survey were also influenced by the methodological framework of the wider Keros-Naxos Seaways Project through which this study was made possible. As such, practical considerations were necessarily taken whilst developing a sound methodological approach to high-resolution geochemical survey in order to successfully fulfil the aims of this research whilst working within a 'just in time' excavation strategy. The dense and extensive character of architecture on Dhaskalio prevented total excavation, and the topography and vegetation does not permit geophysics. Therefore, geochemistry represents one of the few methods available that could characterise the site to both inform excavation planning through prospection, and to define variability across the site. Consequently, this project presented an opportunity for establishing a methodological framework for rapid in situ HH-pXRF analysis within the contexts of excavation in order to better explore the role that geochemistry can play in archaeological research.

This chapter constitutes a summary of the field and desk-based methods employed in this research and is divided into three broad sections. The first section (4.2) offers a summary of the broader *Keros-Naxos Seaways Project*. The second section (4.3) concerns the field methods employed for both the wide-area geochemical surveys on the settlement site of Dhaskalio, and the sanctuary site of Dhaskalio-Kavos, as well as high-resolution surveys of individual contexts from excavations on Dhaskalio. This section includes survey and recording methods, as well as sampling strategies for both wide-area and single context methods. The third section of this chapter (4.4) outlines the method of geochemical analysis using hand-held portable X-ray fluorescence analyser (HH-pXRF). This includes details of the specific instrument used for analysis, internal calibration and mode selection, filter selection and timings, and the choice and use of standard reference materials (SRM). The final section of this chapter (4.5) details the methods of data processing. This includes methods of data validation, 'on-site' data analysis used to inform excavation strategies, spatial plotting of individual elements, and methods of statistical analysis.

4.2 The Keros-Naxos Seaways Project

The Keros-Naxos Seaways Project was borne from previous excavations between 2006 to 2008, where an extensive region of Dhaskalio-Kavos was explored (**figure 4.1**). Significant finds from the southern extent of the area revealed the site to be an area of significant ritual focus which saw broken ceramics, marble vessels, and marble figurines brought from across a major part of the Aegean for deliberate deposition, suggesting that Kavos was a major ritual centre, with an influence which extended throughout the Cyclades and as far as mainland Greece (Renfrew, 2013). The 2006 to 2008 excavations also showed that extensive, well-preserved deposits of EBA date were present at the islet of Dhaskalio, c. 90 metres from the coast of Keros, opposite Kavos. Activity at Dhaskalio seemed to have begun as an adjunct to the activities in the sanctuary, yet grew to become the central focus, as the rituals in the sanctuary became more sporadic (Renfrew, et al., 2012). Therefore, some of the main aims of the 2016 to 2018 excavations were to answer questions pertaining to the functionality and development of Dhaskalio, gain an understand of its initial foundation, and investigate the overall structure of the settlement. The project also sought to recover indications of daily and habitual practice, as well evidence for specific craft practices. One form of activity already evidenced through previous excavations (2006 to 2008) at Dhaskalio is that of metalworking which seems to have taken place on a small scale widely throughout the settlement (Georgakopoulou, 2016).

The intention of the Keros-Naxos Seaways Project was to create an on-site archaeological laboratory in one of the most remote locations in the Aegean, with the aim of utilising a range of up-to-the-minute scientific techniques in order to redefine what archaeology is capable of telling us about this unique site, while acting as a valuable case study for the wider development of method. It is within this methodological framework which the research outlined in this thesis is placed.

The initial field role of soil chemistry was to provide excavators, specialists, and field directors with high-resolution data at the point of analysis in order to form part of the ongoing decision-making process and shape the overall interpretation of the site. The intensive application of on-site soil chemistry techniques enabled real-time feedback to excavators, and because this method was applied, as best as possible, to every context excavated on the site, an emerging picture of the soil chemistry was constructed in order to make variations to similar contexts easier to spot. The next section of this chapter details these in-field methods for soil chemical analysis.

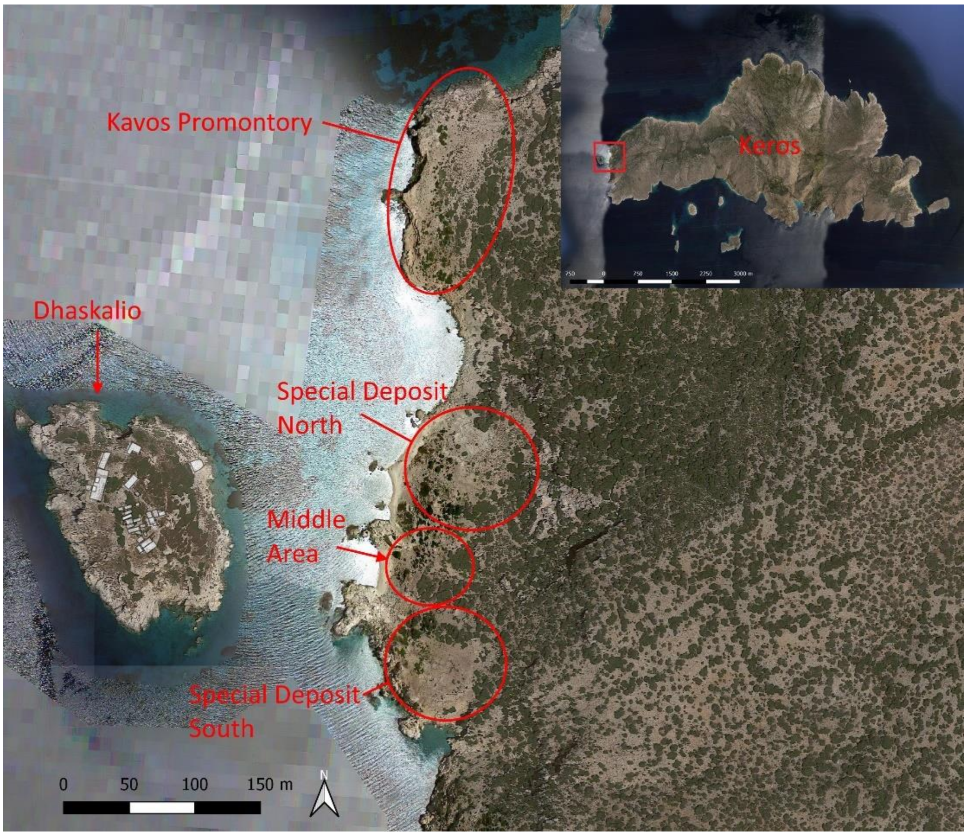

Figure 4.1: Image showing the area of study and location of Dhaskalio-Kavos on the island of Keros (image source: author/Keros-Naxos Seaways Project 2018).

4.3 Field methods

4.3.1 Wide-area surveys

As part of the wider *Keros-Naxos Seaways Project*, several areas of EBA activity were identified on the island of Keros between 2012 and 2013 through pedestrian survey. The areas identified for further investigation during the 2016-2018 field seasons were *Polygon 2* on the northern of Keros, and *Polygon 4* on the north-eastern coast of the island. In addition to Polygons 2 and 4, the stretch of coastline known as Dhaskalio-Kavos, and the islet of Dhaskalio, which was the main focus of archaeological investigation during the 2016-2018 project, were selected for wide-area geochemical survey. These large surface surveys were undertaken for a number of reasons: firstly, in order to serve as an additional level of archaeological prospection in regions which had only been scrutinised through pedestrian survey or minimal excavation; secondly, for the purpose of establishing regional differences in past land use within the island landscape; and thirdly, in order to produce a chemical baseline from surface analysis by which anthropogenically enhanced concentrations of elements from excavated contexts on Dhaskalio could be assessed. Due to the limitations of doctoral research, the results and subsequent discussion presented in this thesis are focussed on the EBA sanctuary of Dhaskalio-Kavos and the settlement at Dhaskalio. However, the following methods for wide-area surface survey remain relevant for additional areas surveyed within the wider Keros landscape, and data from those supplementary geochemical surveys provided valuable context to the researcher pertaining to baseline chemical concentrations on the island.

The following section outlines the methods used for the wide-area geochemical surveys, starting with an overview of methods which were consistent across each survey, followed by a summary of methods which were specific for each site.

Consistent methods

The survey strategy for each site differed slightly, and exact methods utilised depended upon the size of the survey area, as well as the density of vegetation and local topography. However, certain practices remained consistent across all wide-area surface surveys. This included the methods used for establishing the location of sample points. In all cases, a Garmin eTrex 30 hand-held Global Positioning System unit (HH-GPS) was used for locating both the broad area of the site, as well as locating sample points. The eTrex 30 is a commercial HH-GPS unit designed for recreational pursuits, such as hiking and geocaching. Unlike Differential Global Positioning Systems (DGPS) which use a fixed, known position to adjust real time GPS signals in order to eliminate pseudorange errors (Shao and Sui, 2015), commercially available HH-GPS units can vary widely in accuracy. The accuracy of these devices is dependent upon a several factors, including the number of simultaneous satellite signals available and the characteristics of the local landscape. The eTrex 30 is capable of receiving numerous GNSS (Global Navigation Satellite System) signals at the same time, including GPS and GLONASS, which generally allows for more consistent connection to multiple satellites. This reliability in connection, as well as the relatively open island landscape of Keros and Dhaskalio, allowed for an accuracy of 2-5m whilst conducting the wide-area surveys. Although this level of accuracy is far below that which is necessary for most systematic geographical recording in archaeology, it was deemed adequate for locating sample points at the chosen survey resolution (5-10m).

For each wide-area geochemical survey, the method of establishing the survey area and locating sample points was conducted as follows:

- The extent of survey area was determined from pedestrian survey and/or previous excavation records using QGIS.
- Survey resolution was determined by the size of the survey area, density of vegetation, and character of the topography (which affected both GPS accuracy and the rate of survey).
- The start point of each survey was established once at the site and sample points were recorded in transects using the Garmin eTrex 30 HH-GPS to form a regular survey grid at the chosen resolution.

In addition to establishing the extent of survey areas and resolution of sample points, the in situ sampling strategy remained consistent between all wide-area surveys. The method for in situ sampling was as follows:

- Sample points were located by way of HH-GPS and visual observation, where possible, of previous survey transects.
- The area to be sampled was prepared by removing the immediate layer of topsoil using a standard 4-inch trowel, so as to mitigate contamination from recent activity in the area.
- The sample area was then cleaned of loose material in order to produce a uniform surface for analysis.

Soil depth at Dhaskalio-Kavos varies, often only representing a few centimetres above the bedrock, and the abundance of surface finds indicates the immediacy of archaeological layers (Brodie and Georgakopoulou, 2015: 510). For this reason, samples taken during the wide-area surveys were necessarily shallow (<10cm) as compared to samples taken when conducting geochemical analysis of areas with more substantial soil development, which often requires a corer in order to analyse beneath the O horizon. This method of shallow sampling also better facilitated a more rapid survey strategy which was necessary for completing the number of analyses needed for high-resolution spatial characterisation within the time constraints of the project. Wide-area geochemical survey is inherently time consuming. The time needed for the actual analysis is an obvious variable, yet the time required for movement between sample areas and accurately locating sample points using HH-GPS also needs consideration. The time necessary for this aspect of a survey may vary drastically, and is dependent upon various factors, including topography and vegetation. By removing the need to take cored samples, which is inherently time consuming, a quicker work rate could be achieved.

Dhaskalio survey

Despite the consistency in sampling strategy between all wide-area surveys, certain site-specific considerations affected the precise method by which each geochemical survey was undertaken. The wide-area survey of Dhaskalio was carry out during the initial stages of the excavation at the site. This is because, for results to be comparable across the entire survey, it was important that all samples were taken from the 'surface' of Dhaskalio (using the sampling strategy described above). Several trenches were opened during these initial stages of the project. Had the wide-area survey of Dhaskalio been implemented later in the excavation, a number of sample points, defined by way of HHGPS, would have been located within the boundaries of an open excavation. This means that either the location of the sample points would need to be ignored, be taken outside of the trench boundary, thereby falling outside the regular grid, or the sample would necessarily be taken from an archaeological context. This would have been problematic, as it was important that results from the Dhaskalio survey should reflect the entire site as it was before excavation so that areas of the settlement which would not be excavated could be compared with surface results from known later known archaeological features. Had sample points been taken from outside the trench boundaries, the results would not accurately reflect the surface soil chemistry across the site and taking samples from open contexts would have added bias to the data. Furthermore, by having comparable data from a complete surface survey of the site, the results could be used for the prospection of further areas of interest which would aid in establishing new areas of excavation later in the project. For these reasons, it was deemed important that the wide-area survey of Dhaskalio be completed early in the season, and in a timely manner.

The precise method for conducting the surface survey of Dhaskalio also differed from the surveys undertaken on the Keros mainland. This was largely due to the topography of the islet which made it difficult to follow transects of a regular survey grid in a conventional fashion. This was largely because the harsh slopes around the island restricted movement to various degrees, but also because of very real health and safety concerns. Therefore, the method for conducting the geochemical survey of Dhaskalio was as follows:

- An interval of 8m between sample points was chosen for the surface survey of Dhaskalio. This allowed for the timely completion of the survey whilst also offering a high enough resolution for observing differences to the spatial character of chemistry across the site.
- Initially, a transect running approximately S-N across the summit area of the site was surveyed. This created a baseline which acted as reference for subsequent survey points.
- The remaining sample points were subsequently surveyed in a more organic manner, with transects being surveyed on either a N-S/S-N or E-W/W-E basis. The choice of transect direction for this phase of the survey was dictated by the unique topography and vegetation of each area, and how best to facilitate the ease of movement in line with the contours of the islet.

This unconventional survey method was necessary for the reasons stated above, and allowed for the completion of the Dhaskalio surface survey without excessive hindrance or harm to the surveyor. The method of in situ sampling strategy remained consistent with other wide-area surveys.

Kavos survey

The wide-area surface survey of Kavos also presented unique issues related to topography. The area of Kavos can be separated into four distinct archaeologically significant areas: the Special Deposit South, the Special Deposit North, the Middle Area, and the Kavos Promontory. The Special Deposits and Middle Area are located on the same outcrop of land, directly opposite the islet at Dhaskalio to the west, and set against a steep cliff to the east. However, the Kavos Promontory is positioned on separate outcrop to the north of the Special Deposits, with access between the two limited to a small goat-path passing around the edge of a small coastal inlet. Therefore, instead of conducting the geochemical survey of Kavos (which can be seen as a distinct archaeological site) concurrently across all areas, the Special Deposits and Middle Area were treated as separate to the Kavos Promontory. Conducting the survey of Kavos removed the requirement to traverse unfavourable terrain more than necessary which allowed for the timely completion of each survey, as well as mitigated the possibility for damage to equipment or personnel when crossing between the two outcrops.

Both parts of the overall Kavos survey were conducted at a resolution of 5m. This allowed for high-resolution spatial analysis, but also resolved an additional practical concern related to the Special Deposit South. The site of the Special Deposit South was excavated by the Cambridge Keros Project in 2006. The excavation strategy involved the establishment of a 5x5m grid with an excavated area of 4x4m within each grid square (Renfrew et al., 2015). This left a 1m wide baulk at each trench edge with a distance of 5m between the centre point of each baulk. As a consequence, conducting the surface survey of Kavos at a resolution of 5m meant that analyses could be taken from hitherto undisturbed areas of the Special Deposit South without the risk of analysing modern backfill. This was not, however, possible at the Special Deposit North, which has been subject to extensive looting since before Renfrew's initial investigations in the 1960s (see chapter 2). There, the analysis of post EBA disturbance was unavoidable, and the results reflect this fact (see chapter 5).

As with the survey of Dhaskalio, the in situ sampling strategy remained consistent with the outlined method above. Subsequent to completion of both surveys, the data were combined in order to produce a single, coherent set of results for the site at Kavos.

4.3.2 Analysis of single contexts

The main focus of geochemical analysis during the latest investigations of Dhaskalio-Kavos was that of analysing archaeologically distinct layers within the excavation trenches. This was to facilitate high-resolution spatial characterisation of craft practice and domestic activity within the architectural spaces of the settlement. The theoretical framework for conducting soil chemical analysis on individual contexts is discussed in chapter 6. During the three field seasons (2016, 2017, and 2018), eight trenches were opened and excavated (Trenches A, B, C, E, F, H, L, and N, see figure 4.2). Soil analysis was used to characterise a total of 553 individual archaeological contexts ranging in size from

<1m^2 to 180m^2. The following section details the methods used for obtaining samples for high-resolution geochemical analysis of single contexts from excavations at Dhaskalio.

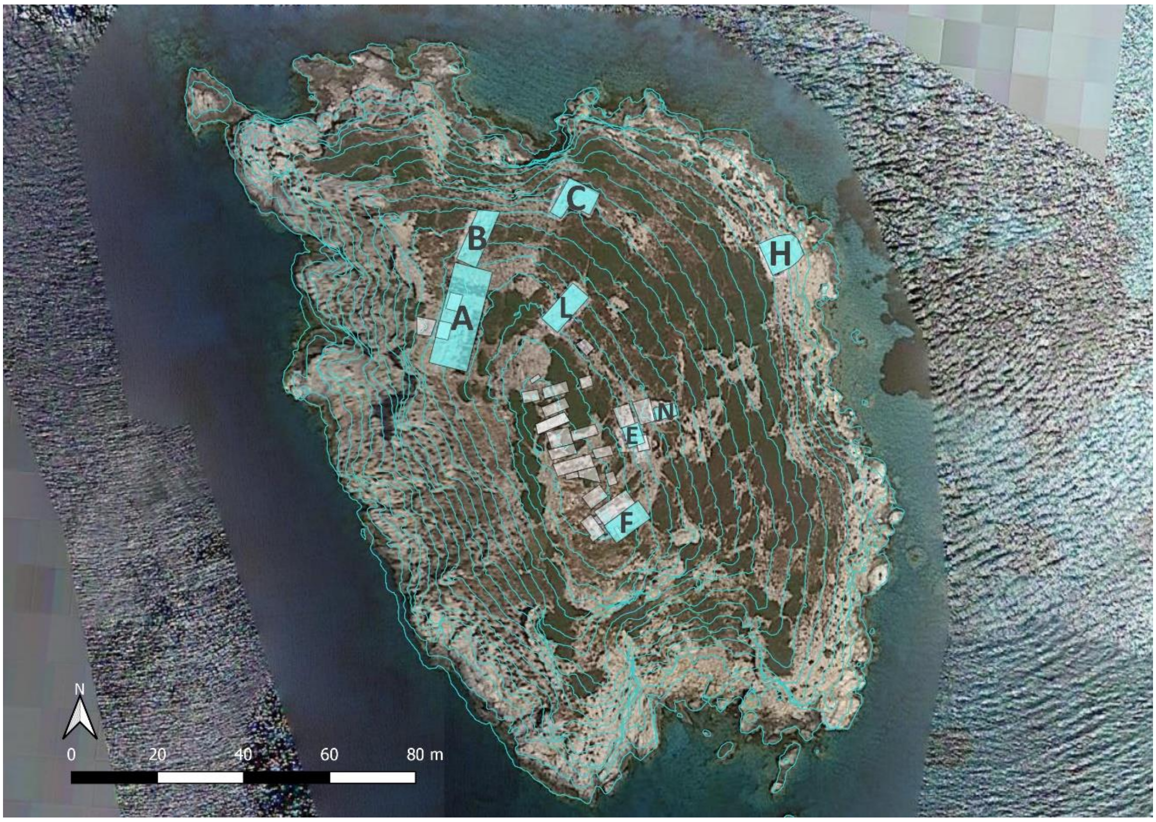

Figure 4.2: Image showing the location of excavation trenches on Dhaskalio (image source: author/Keros-Naxos Seaways Project 2018).

Context selection

In the absence of any conflicting factors, every context from each individual trench would have been surveyed using geochemical techniques. However, the realities of conducting research within the limits of an overarching excavation strategy and working towards strict deadlines meant that certain types of contexts needed to be prioritised for analysis. The different types of contexts recorded during the excavation of Dhaskalio were:

- Cuts – negative features such as ditches or pits.
- Fills and Deposits – constituting areas of deliberate or natural material accumulation within a negative feature (cut).

- Surfaces - defined as exposed areas which became the focus of activity over a period of time.
- Structures – such as walls, terraces, stairways, or other fixed, permanent features.

Single contexts were selected for geochemical analysis based on a number of characteristics. Firstly, contexts which were characterised as EBA 'surfaces' were prioritised over any other context type. This is because these features represented the direct layers of activity, meaning that any sample taken from a defined surface can be regarded as explicit evidence of the past human activity. Since the aim of this study is to characterise areas of EBA activity at Dhaskalio-Kavos, defining as best as possible every surface from the excavation was of significant importance. This meant that, regardless of other contexts which may be ready for analysis concurrently, surfaces were prioritised for geochemical analysis.

The second priority for analysis were those contexts defined as 'fills or deposits' which may be directly associated with craft activity. These features included hearth fills, middens, or other deposits of occupation waste. These features are important as they may offer substantial information pertaining to activities on the site, such as food production, waste management, or craft practice, which provides insight into how space was organised at the settlement.

Other forms of fills or deposits were prioritised to a lesser extent, such as those characterised as post-abandonment build-up, or downslope accumulation of building debris. These features were archaeologically significant for reconstructing patterns of collapse and site formation yet presented little value for characterising the spatial organisation of EBA anthropogenic activities. However, these types of context were prevalent at Dhaskalio, especially during the 2016 season and early on in the excavation of newly opened trenches, and routine analysis of these layers provided chemical context for subsequent characterisation of anomalous chemical concentrations at the site.

Finally, cuts and structures were omitted from routine geochemical survey. Cuts have no material properties of their own and are instead defined by the limits of other contexts. This precluded cuts from consideration for soil chemical analysis since they represent the absence of soil. Structural features at Dhaskalio were predominantly constructed from stone, which made them inappropriate for soil chemical characterisation.

Single context sampling strategy

The first stage of conducting geochemical analysis on contexts of excavation was establishing the extent of the area to be surveyed. This was achieved through the on-site digital recording system *iDig*. This innovative platform allowed for the paperless recording of archaeological elements and offered georeferenced spatial plans of open contexts and previously excavated features to be accessed in the field with the aid of a handheld tablet computer. Newly established contexts were defined by way of total station or Differential Global Positioning System (DGPS) by trench supervisors. These data were uploaded at the point of collection to the main trench tablet, and subsequently synchronised to further devices using on-site wi-fi modules. This meant that specialists in the field, such as archaeological geochemists, could obtain up-to-date contextual data from across the excavation in order to prioritise and manage areas which demanded immediate analysis, as well as contribute to the on-site record.

Subsequent to establishing the extent of archaeological contexts on the iDig platform, survey resolution could be determined. This determination was based on the perceived importance of the archaeological feature, as well as the spatial extent of the context. For example, an area of 10 x 2m which was defined as post-abandonment debris would be analysed at approximately 1m resolution for a total of 20 analyses, whereas a surface with the same spatial dimensions would be surveyed at a much higher resolution (<50cm). Other factors, such as time limitations and the number of high-priority contexts which were prepared for analysis, were also taken into consideration when establishing the resolution of survey for individual contexts. However, surfaces were always prioritised and, where possible, surveyed at as high resolution as time would allow (often <30cm).

Once the extent of the archaeological feature and resolution of survey were determined, the location of each sample point was recorded. This was done through the digital interface using a tablet. As explained above, each entry in the iDig system contained a georeferenced plan of the associated feature. Within the digital interface, an accurate regular grid with intersections at 10cm intervals could be toggled as an overlay. This allowed for the input of accurate georeferenced sample points using minimal measurement in physical space (figure 4.3).

Figure 4.3: Image displaying an example of sample point input using the iDig interface (image source: author/Keros-Naxos Seaways Project 2018).

Once sample points were established, analyses were made in sequence directly on the surface of excavation. For the most part, contexts were analysed immediately after the routine process of cleaning and recording by excavators. This meant that no subsequent preparation of the surface was needed in order to conduct accurate in situ analyses. Furthermore, some surface features were defined by very thin, laminated layers. Any process of additional cleaning or other intrusive action in order to analyse below the exposed layer may have resulted in samples taken from subsequent stratigraphic layers, rather than the surface of activity. However, where contexts were less archaeologically secure, such as downslope tumble, or where the surface due for analysis was coarse, additional cleaning with a standard 4" trowel was undertaken in order to provide a suitable surface for geochemical sampling.

4.4 Method of Analysis

4.4.1 Instrumentation and analysis

The following section details the method of geochemical analysis. These methods remained consistent across both the wide-area surveys and analysis of single contexts. A summary of analytical methods are as follows:

- Chemical determinations were made using a Niton XL3t handheld portable X-ray fluorescence analyser (HHpXRF) manufactured by Thermo Scientific. The analyser is equipped with a 50kV X-ray tube, Ag anode, and silicon positive intrinsic negative (Si PiN) detector.
- Prior to every use, the analyser was allowed to stabilise, and a systems check was performed in order to calibrate the instrument and verify that it was operating to designed specification.
- Samples were analysed in standard 'Soil' mode which utilises the Compton peak normalisation internal calibration method.
- The XL3t is equipped with three excitation filters in soil mode which are used in order to optimise sensitivity for various elements. For this study, the 'Main Range' and 'Low Range' filters were used as these provided analysis for a range of anthropogenically significant elements.

- Elements analysed were: Mo, Zr, Sr, U, Rb, Th, Pb, Au, Se, As, Hg, Zn, W, Cu, Ni, Co, Fe, Mn, Cr, V, Ti, Sc, Ca, K, and S.

- Filter timings were determined through experience of the researcher and supervisor in order to maximise the number of samples which could be evaluated in one working day without compromising the precision of analysis.
    - Filter times were as follows: Main Range = 35s, Low Range = 15s, for a total of 50s analysis.
- A number of standard certified reference materials (SRM) were routinely analysed in order to establish and monitor accuracy and the long-term precision of the of the instrument. SRMs used were: GBW-7411, TILL-4, and SOIL-7.
- Analysis was conducted in situ using the methods outlined previously.
- Limit of detection (LOD) is determined internally on an element by element basis and are calculated to 3σ (99.7% confidence interval).

4.4.2 Analytical performance

The HHpXRF instrument used for this study is internally calibrated using a number of methods determined by the manufacturer which change depending on which mode of analysis is used. For standard Soil mode, the Compton normalisation method is used. Compton normalisation (CN) is a calibration technique which uses the ratio of elemental peak to the Compton scatter peak in order to give a measure of density of the sample, which works well for soil samples as normalising to the Compton peak can reduce problems associated with matrix effect (Shugar, 2009). The penetration for the analysis of heavier elements using XRF instruments can be up to 2 millimetres in highly porous samples (Cannell, 2016: 42). However, when analysing lighter elements, only the surface is excited due to the lower KeV required (Berger et al, 2009). Soil mode assumes that the sample being analysed is not ideal and has a porous and uneven surface geometry. Consequently, the results obtained are not solely a reflection of the sample processing, but also of the instrument settings and assumptions made using the instrument's internal software (Cannell, 2016: 44), and Hunt and Speakman (2015) suggest that the effect of surface geometry on sediment samples is usually minimal when using modern HHpXRF instruments. Prior to undertaking analysis, a series of standard reference soils were analysed. SRMs used were SOIL-7, TILL-4, and GBW-7411. These data were subject to simple statistical analysis in order to determine the relative error (RE) and relative standard deviation (RSD) measurements for each element. These tests are helpful in determining the accuracy and precision of the instrument. Full data for analyses of SRMs can be found in Appendix 1. In general, inaccuracies within the analyses were common yet fairly consistent for each element. That is, those elements with measurements under the certified values were measured consistently so, and vice versa. Using HHpXRF, especially with an in situ methodological framework, is a compromise between accuracy and flexibility. Indeed, in situ results are not suitable for inter-site comparisons. Rather, it is the intra-site variability that is interpreted. Figure 4.4 shows the correlation for Cu for certified and average determined values and illustrates the effectiveness of the instrument's internal calibration.

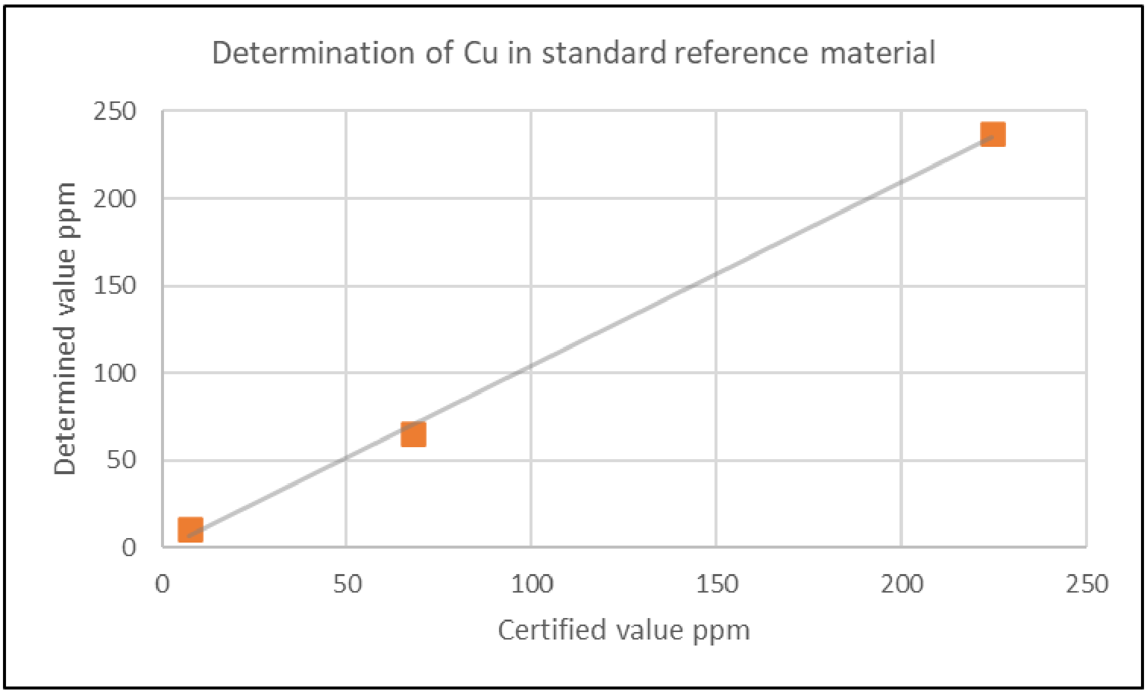

Figure 4.4: Correlation for Cu between measured values and for certified reference material values (SOIL-7= 11 ppm, GBW-7411= 65.4ppm, and TILL-4= 237 ppm).

Because of the accuracy of internal calibration methods, data underwent no further empirical calibration. This decision was also made due to the inherent inaccuracies in sampling strategy used for this project. The above figure demonstrates the ability for the instrument to accurately determine chemical concentrations in ideal circumstances. However, this does not necessarily translate to conducting in situ analysis of soils. This is due to many factors, including soil compaction, moisture and makeup, and the interference of air between sample and receiver. However, studies have shown that, for the majority of elements, HHpXRF is internally consistent and shows a high level of precision using these methods (e.g. Frahm and Doonan, 2013). Therefore, inaccuracies can be seen as common yet consistent. The aim of these methods was to look at chemical variation across a single site, with relative values being assessed between sample points. This means that understanding exact, empirical values was not necessary. Consequently, the results presented here should not be confused with the actual amount of any element within a sample. Rather, data should be considered as semi-quantitative, and presented values should not necessarily be used in order to draw comparisons with other studies. Using HH-pXRF for in situ soil analysis is a compromise between accuracy, flexibility, time-efficiency, and cost effectiveness. If the aim of a study is to obtain data with as close to true value as possible, more accurate instrumentation (such as ICP-MS) and field methods should be employed (Cannell, 2016).

4.5 Data handling and processing

4.5.1 Field methods

Subsequent to each working day, data was retrieved and underwent preliminary analysis. The exact methods employed for this in-field data handling were as follows:

- Chemical data was downloaded from the HHpXRF analyser using Thermo Niton NDT version 7.2.2.

- Raw data was archived, and a copy was exported into Excel workbooks on a trench by trench basis.
- Spatial data was retrieved from in-field recording devices, such as HH-GPS and the iDig software, and entered against chemical data for related sample points.
- Preliminary spatial plots for anthropogenically significant elements were produced for each context analysed during that period. These were used in order to inform excavation staff of the chemical variation within the contexts they were excavating.

4.5.2 Principal component analysis

Interrogating and disseminating large geochemical data sets is often complex, requiring many stages. Typical methods used are spatial pots of individual elements (e.g. Carey et al., 2014), cluster analysis (e.g. Dirix et al., 2013), and principal component analysis (PCA) (e.g. Mikolajczk & Milek, 2016), although studies often combine a number of techniques. PCA was selected for this study as a means of reducing the data set into dominant covariant clusters in order to extract what may be a product of soil processes and composition, and what may be archaeological. PCA simplifies complex data into components that influence the overall results by assigning each variable a value and assessing the degree to which this contributes toward underlying common trends within the data set. The following section summarises the method used for PCA of geochemical data from wide-area surveys of Dhaskalio and Kavos. All statistical analyses were conducted in IBM SPSS 25.

Elements were selected for PCA based on those which produced significant results (2 x LOD set to 2σ) and from published research could be considered as a result of anthropogenic activity (e.g. Entwistle et al., 1999; Oonk, 2009). Before proceeding to PCA, the data was standardised (z-score). PCA is sensitive to outliers and extreme variability which is reduced through standardisation.

A Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) was performed on the standardised data set in order to verify that PCA would produce valid results for interpretation. KMO indicates the proportion of variance that might be caused by underlying factors. Results between 0.6 and 1 are generally seen as a suggesting the variance within the data set is significant and suitable for PCA.

A Bartlett's Test of Sphericity was also performed on the standardised data. The Bartlett's test evaluates whether or not the correlation matrix is an identity matrix (1 on the diagonal and 0 on the off-diagonal) which would indicate that variables are unrelated, therefore unsuitable for PCA. Small values (< 0.05) of the significance level indicate that the correlation matrix is not an identity matrix, therefore PCA may be used on the data.

If the KMO and Bartlett's tests suggested that the data were suitable for further analysis, the standardised data was analysed using PCA. Parameters were set to extract all components with eigenvalues over 1, although scree plots were produced in case the number of components required reducing further and so are available in appendix 3.

In every PCA, the number of components is equal to the number of variables with components weighted in terms of their influence and correlation. However, the results of the initial PCA for the wide-area surveys of Dhaskalio and Kavos produced components which were still relatively complex, with the first component containing many dominant loadings and some far smaller components which contain many zero loadings. As such, a rotation strategy was implemented in order to further simplify the structure.

To determine which rotation strategy was to be implemented, it was first necessary to understand whether or not the components were correlated. Rotation methods in PCA are either orthogonal or oblique. Orthogonal rotation methods assume that the components in the analysis are uncorrelated, whereas oblique rotation methods assume that the components are correlated. To determine if the components are correlated, a simple bivariate correlation analysis was performed on the component scores. Components were uncorrelated; therefore, an orthogonal (varimax) rotation was chosen.

Subsequent to completing the varimax rotated PCA, each principal component was plotted spatially in QGIS. This was done to determine if the correlations identified were spatially significant and is the basis for interpretation in chapter 5.

4.5.3 Spatial projection of single elements

Principal component analysis was used in order to reduce the large data sets from the wide-area surveys so as to determine which elements at the site may have been enhanced through anthropogenic activity. However, PCA requires a large sample size, and even large context surveys often did not produce adequate data. Therefore, spatial analysis of soil chemistry for individual contexts focussed on the analysis of single elements which display structured variability and have been shown to be indicative of anthropogenic activity through statistical analysis of wider surveys of the site. The method for spatial interpretation from excavated contexts was as follows:

- Excavation records from iDig and matrices provided by the Keros-Naxos Seaways Project were used in order to isolate archaeologically important contexts from the overall dataset.
    - Contexts of interest included surfaces and areas of deliberate deposition.
- Where available, information pertaining to the phasing and relationships between contexts was used to create phased plans for extended areas of individual trenches.
- Prior to spatial interpretation, values presented as < LOD were given arbitrary, low values. In most cases the value of 6.666 was used as this figure was easily recognised as a false value.
    - This allowed for the spatial projections for every sample point, as QGIS does not recognise non-numerical formatting.
- Element values for these phased plans were graduated by size and superimposed on context imagery using QGIS 3.0.1. This allowed for the spatial patterning of element concentrations to be visualised.

4.6 Chapter Summary

This chapter has outlined in detail the methods used for obtaining high-resolution geochemical data from both surface surveys of the wider Dhaskalio-Kavos landscape, as well as from individual contexts of excavation. These data were subsequently used for the spatial interpretation of chemical concentrations across various areas of the site. Data produced from the wide-area surveys underwent principal component analysis in order to reduce the data set into dominant covariant clusters in order to extract what may be a product of soil processes and composition, and what may be archaeological. Those elements which showed the greatest utility for understanding anthropogenic activity formed the basis for single elemental spatial analysis of phased surface plans from within trenches at Dhaskalio. The next chapter details the key results from these analyses, and offers interpretation to the spatial distribution of key chemical concentrations.

CHAPTER 5: Results and Interpretation

5.1 Introduction

One of the main aims of this project is to understand the character and spatial organisation of activities associated with the EBA cult centre at Dhaskalio-Kavos. To achieve this, wide-area geochemical surveys were conducted at the site of Kavos on the Keros coastline, as well at the settlement of Dhaskalio. In addition, routine chemical analysis of archaeologically significant layers from excavations at Dhaskalio was also undertaken. The following chapter presents important results from these analyses, as well as an interpretation of the chemical variance and spatial patterning associated with each survey and context analysis. The first section deals with results from the wide-area surveys of Kavos and Dhaskalio. This is followed by results from the geochemical analysis of excavated contexts on a trench by trench basis.

Aside from results from PCA, all analyses are reported as elemental *parts per million* (ppm) and associated with spatial coordinates. For both prospection and context analyses, results are plotted as spatially distributed raw data, that is with no interpolation or other statistical treatment. Spatial plots for results from the PCA analyses of the wide-area prospection surveys use 'factor scores' generated for each sample point during the output of PCA results in SPSS. Factor scores are derived by combining observed variables in a linear manner, taking into account the amount of shared variance between the variable and the factor, as well as the unmeasured variance (Gorsuch, 1983; DiStefano et al, 2009). The resulting scores are standardised and can be thought of as similar to Z-scores, ranging from roughly -3.0 to +3.0, although the exact value can vary (DiStefano et al, 2009). Factor scores for the prospection surveys can be found in appendix 3 alongside the relevant survey data. Results from prospection surveys have been superimposed and georeferenced onto aerial photographs, while context analyses are superimposed on trench imagery provided by the Keros-Naxos Seaways Project.

5.2 Kavos Survey

The survey of Kavos on Keros included the areas associated with the *Special Deposit North, Special Deposit South,* the *Middle Area*, and the *Kavos Promontory.* It was conducted at a resolution of 5m with a total of 649 sample points.

5.2.1 Principal Component Analysis of Kavos

Table 5.2 displays the rotated component matrix from the PCA of data from the surface survey of Kavos. All elements with a correlation coefficient over ±0.5, which therefore accounts for over ±50% of the elemental variance, are highlighted. Greater significance is placed on higher values, which is indicated by the intensity of fill shade. Elements included in the PCA analysis are those which have been proven to produce interpretable results pertaining to anthropogenic activity. Table 5.1 offers an overview of current understanding of archaeological sites and features, and associated element enrichments in their soils.

Archaeological site/feature	**Elements**	**References**
Burials/graves	P,Cu,Mn,Ca	Cook and Heizer,1965; Keeley,1981; Bethell and Smith,1989
Hearths	P,K,Mg	Barba et al.,1996; Oonk, et al.,2009; Knudson et al.,2010
Middens	P,K	Chaya,1996; Fernandez et al.,2002; Wells et al.,2000; Parnell et al.,2001
(Farm)houses	P,Ca,Mg,Fe,K,Th,Rb,Cs,Pb, Zn,Sr,Ba	Chaya,1996; Manzanilla,1996; Fernandez et al.,2002; Entwistle et al.,2000;Wells et al.,2000; Parnell et al.,2001; Wilson et al.,2008,2009
Mining, metal smelting and production sites	Cu,Pb,Mn	Jenkins,1989; Maskall & Thornton,1998; Hong et al.,1994; Cannell,2016
General archaeological sites	B,Cu,Mg,Mn,Ni,P,Se, Zn,K,Ba,Ca,Na	Cook and Heizer,1965; Bethel and Smith,1989; Middleton & Price,1996; Entwistle et al.,1998

Table 5.1: *List of archaeological sites and features, and associated element enrichments in their soils.*

In order to verify that PCA on the data set from the Kavos survey would produce valid results, suitable for interpretation, a Kaiser-Meyer-Olkin measure of sampling adequacy was performed. The test showed a value of .692 which suggests that the variance within the data set is not random chance, but significant and suitable for PCA. Three principal components had eigenvalues greater than one and were selected for analysis based on the Guttman-Kaiser criteria. Varimax rotation was selected in order to emphasise important variables whilst limiting the influence of components with medium or low influence. Unrotated component matrices for PCA results can be found in appendix 2, and raw data from the wide area survey of Kavos, as well as Z-scores and factor scores from the PCA are given in appendix 3. These three principal components account for 62.585% of the total variance of the geochemical record for the site.

Kavos Survey Rotated Component Matrix			
	Component		
	1	**2**	**3**
Zscore(Sr)	0.313	-0.393	0.149
Zscore(Pb)	0.249	0.867	-0.008
Zscore(As)	0.419	-0.153	0.076
Zscore(Zn)	0.747	0.227	0.183
Zscore(Cu)	0.179	0.846	0.134
Zscore(Fe)	0.940	0.195	0.018
Zscore(Mn)	0.925	0.046	0.006
Zscore(Ti)	0.870	0.176	-0.233
Zscore(Ca)	0.056	-0.253	0.736
Zscore(K)	-0.125	-0.021	-0.844
Zscore(S)	-0.070	0.181	0.433
Influence	**31.307**	**16.951**	**14.327**

Table 5.2: *Results for varimax rotated principal component analysis on selected elements from samples from Kavos. Data were standardised using Z-score prior to PCA.*

The first principal component (PC1) accounts for 31.3% of the explained variance with high positive correlation coefficients (>.75) for Zn, Fe, Mn, and Ti. The second principal component (PC2) accounts for 17% of the explained variance and is dominated by heavy metal elements, with high positive correlation coefficients for Pb and Cu. The third principal component (PC3) accounts for 14.3% of the total explained variance, and shows a high positive correlation coefficient for Ca, and a high negative correlation coefficient for K.

Principal component 1

Figure 5.1 displays the spatial projection of PC1 from the Kavos survey. The first principal component extracted from the Kavos survey data can likely be interpreted as the influence from the soil and underlying geology due to the high positive correlation coefficient of Fe, Mn, and Ti. Whilst Fe and Mn have been shown be correlated with anthropogenic activity (see table 5.1), Mn, Fe are also abundant in many soil types (Oonk et al., 2009b; Sposito, 1989). Furthermore, Ti has been used in published geochemical investigations as a suitable proxy for geological influences (Cannell, 2016: 107). This is because Ti is essentially a direct product of minerogenic erosion and it is neither biologically important, nor prone to leaching (Kylander et al., 2011: 114). The spatial distribution of datum points which are highly correlated with PC1 also suggests natural, rather than anthropogenic processes. Indeed, there is no discernible spatial patterning for this principal component. Rather, the distribution remains fairly uniform across the entire site. Therefore, PC1 can be fairly confidently described as geological or pedological in origin. This is unsurprising, as HHpXRF analyses sample makeup in their entirety, rather than individual features. Therefore, it can be expected that natural features of soil matrices tend to have the greatest impact on results.

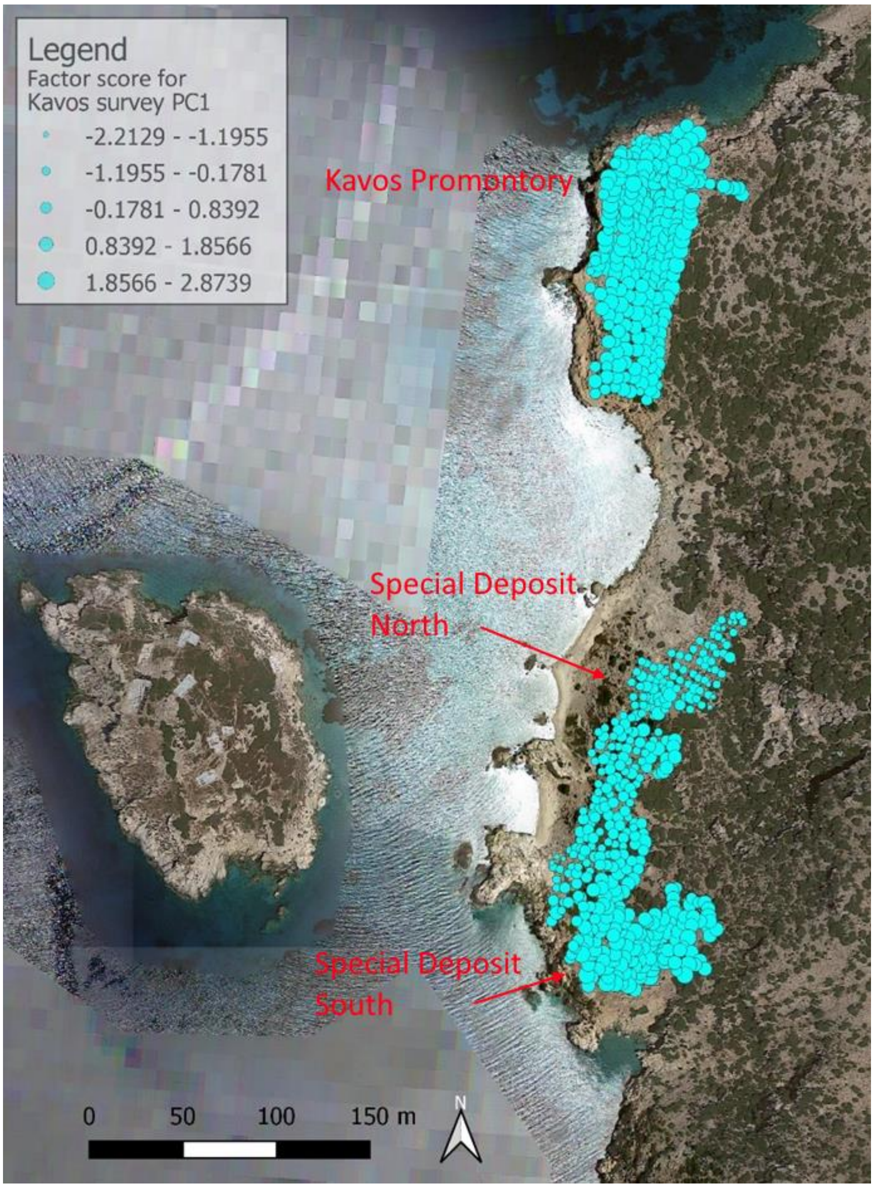

Figure 5.1: Spatial projection of PC1 from the Kavos survey data (image source: author/Google Satellite 2021).

Zinc also displays a high positive correlation coefficient with PC1, and has been shown to be present in soils through natural processes (Mikołajczyk and Milek, 2013: 580; Sposito, 1989: 10-12) and, indeed, is easily absorbed by mineral and organic components, and so can often accumulate in soil horizons close to the surface (Kabata-Pendias and Pendias, 1984: 99). However, Zn is also useful for archaeological site prospection and interpretation as it is considered an indicator for general anthropogenic activity (Oonk et al., 2009b). The influence of an element within a principal component is not a measure of elemental concentration, rather the relative impact the element has on covariance.

Furthermore, even the high positive correlation coefficient for Zn (.796) does not account for the entirety of Zn spatial variance. Zn concentrations range from below the instruments limit of detection (< LOD) to 87.98 ppm with a mean of 34.39 and a standard deviation (σ) of 17.37 (RSD 50.5%) across 113 points of analysis. By plotting the results for Zn spatially and emphasising data which fall above 1σ (51.76 ppm), which can therefore be considered as elevated, the spatial distribution of anomalous concentration can be examined (**figure 5.2**).

Anomalous concentrations of Zn are structured within the area of the Special Deposit South and the Kavos Promontory, leaving a clear divide between these areas and the remaining landscape of Kavos. Since the spatial structure is only inclusive of elevated concentrations of Zn, it is likely that this chemistry represents evidence of past human activity and, therefore, the spatial distribution of these Zn concentrations can be seen as indicating regions of varying intensity of activity. These regions, along with the Special Deposit North, represent the main areas of EBA activity at the site. However, the Special Deposit North was subject to extensive looting (Renfrew, 2007) which has resulted in widespread disturbance of EBA deposits. It is possible that this disturbance has led to poor retention of anthropogenic signatures in the soil. This would explain the absence of anomalous concentrations of Zn in the area.

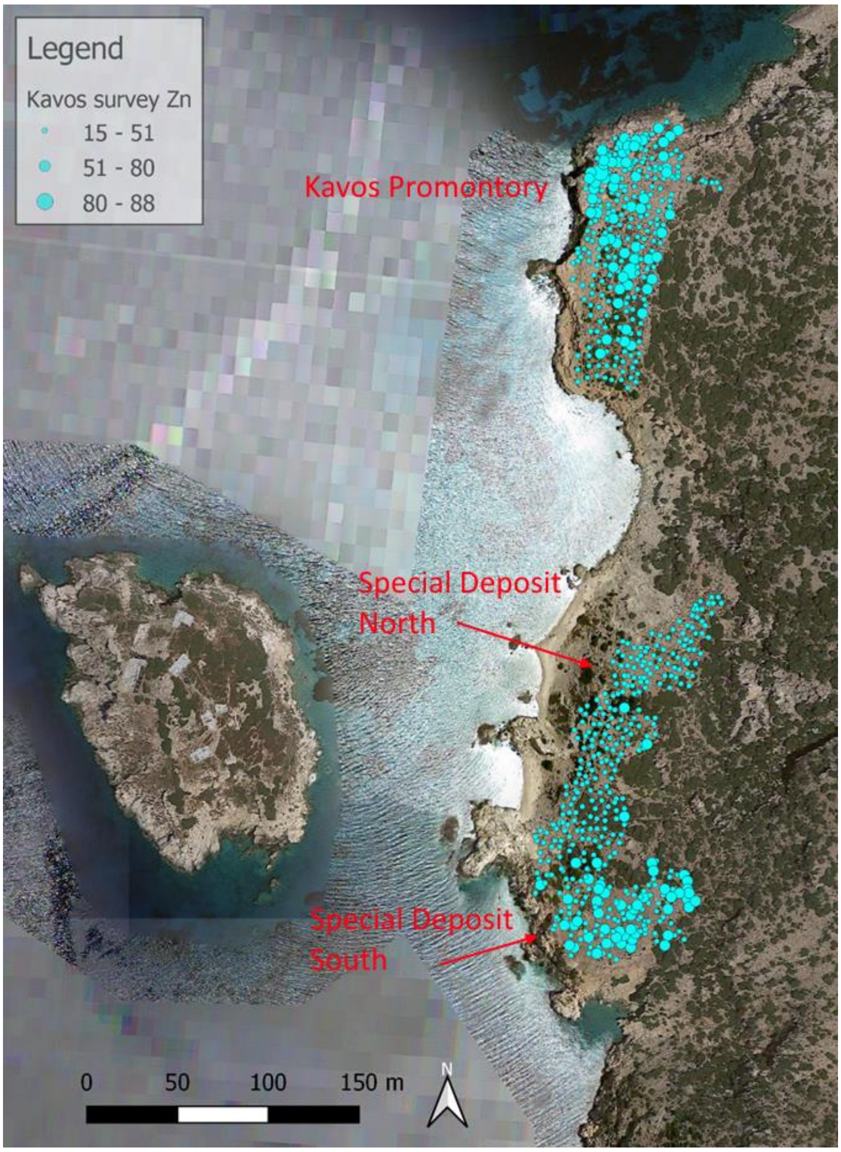

Figure 5.2: Spatial plot of anomalous Zn values on Kavos. Note that the value of 10 ppm is a proxy for < LOD in order to aid spatial projection (image source: author/Google Satellite 2021).

Principal component 2

Figure 5.3 displays the spatial projection of PC2 from the Kavos survey. The second principal component extracted from the Kavos survey data is dominated by high positive correlation coefficients of Cu and Pb. Whilst the influence of an element within a principal component is not a measure of elemental concentration, both Cu and Pb were measured in high concentrations (max. Cu=171.23 ppm, max. Pb=392.01 ppm) variously across the site. The fact that Cu and Pb are relatively equal in influence within PC2 is an indication that these two elements function in tandem to create their own principal component which explains >85% of the spatial variance for both elements.

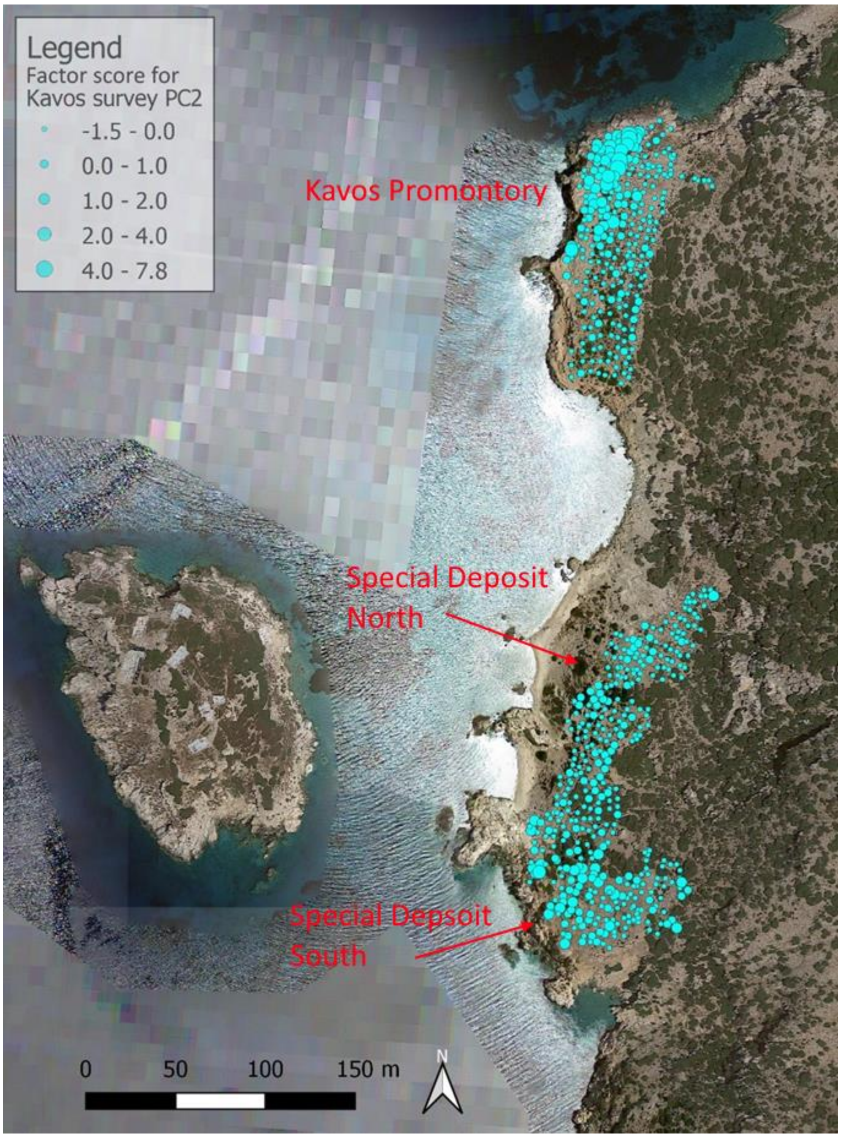

Figure 5.3: Spatial projection of PC2 from the Kavos survey data (image source: author/Google Satellite 2021).

The activity most likely explained by this principal component is metalworking. There is also great variability in the spatial distribution of PC2, with areas displaying high correlation being organised towards the Kavos Promontory and the area around the Special Deposit South. The Kavos Promontory is a known EBA smelting site (Brodie and Georgakopoulou, 2015) and so these results are expected. However, there has been no evidence of metalworking found through excavations at the Special Deposit South. Examining the spatial plots for Cu (**figure 5.4**) and Pb (**figure 5.5**) once these elements have been isolated, gives an indication of relative concentrations of Cu and Pb across the site. Values for Cu range from below the level of detection to 171.23 ppm, and Pb values range from < LOD to 392.01 ppm. It is clear from these analyses that the highest concentrations of both Cu and Pb are located towards the northern edge of the Kavos Promontory, suggesting an intensification of metalworking activity in this area. This is consistent with evidence from previous investigations into metalworking on the site (Brodie and Georgakopoulou, 2015).

There is clear structure to elevated Cu concentrations around the area associated with the Special Deposit South, with further structured areas to the north and in the region associated with the northern Special Deposit North. The middle Kavos area largely produced soil Cu levels below levels of detection, yet there is evidence of structure to the NW and a linear anomaly to the east. Excluding the Kavos Promontory, Cu values range from below the detectable level to 85 ppm, and Pb values range from below the detectable level to a maximum of 107 ppm. Given the difference between these concentrations relative to the Kavos Promontory, it is unlikely that the areas around the Special Deposits were utilised for metalworking. Instead, these structure concentrations may be explained as contemporaneous pollutants, either through airborne contamination, or as a result of frequent use of these areas by people who had been actively involved with metallurgical activities.

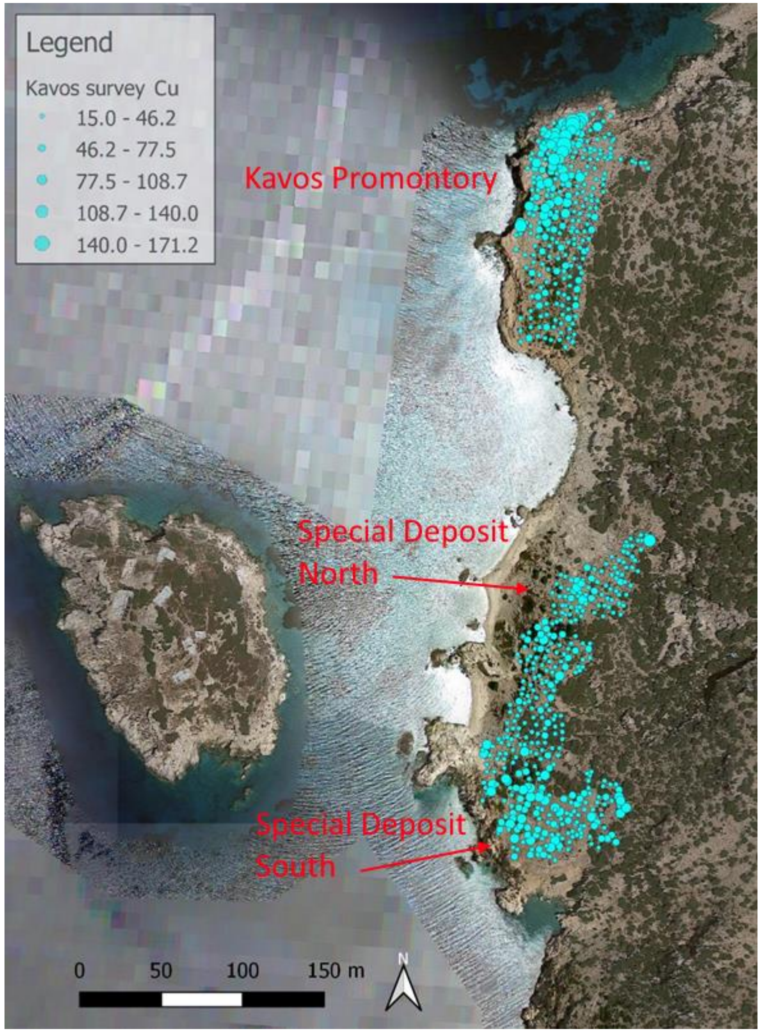

Figure 5.4: *Spatial plot of anomalous Cu values on Kavos. All are presented in ppm. Note that 15 ppm is a proxy for order to aid spatial projection .*

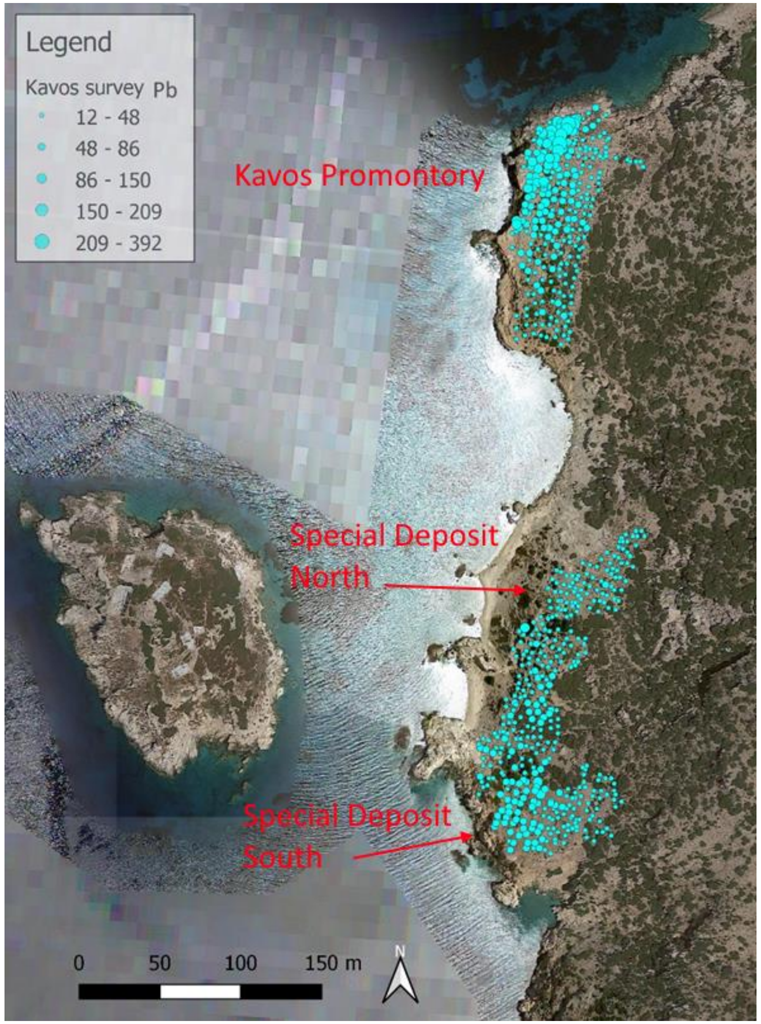

Figure 5.5: *Spatial plot of anomalous Pb values on Kavos. All values values are presented in ppm. Note that 12 ppm is a proxy for < LOD in < LOD in order to aid spatial projection* **.**

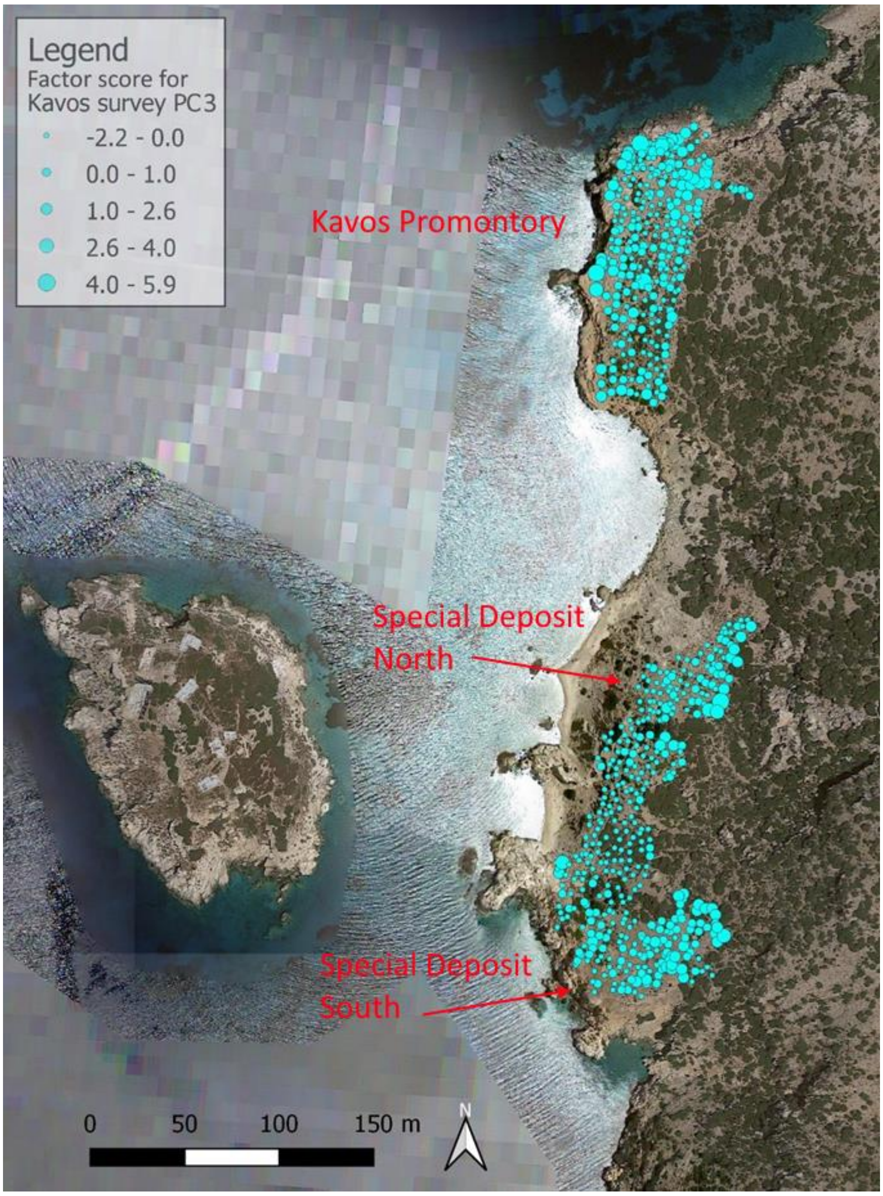

Figure 5.6: Spatial projection of PC3 from the Kavos survey data (image source: author/Google Satellite 2021).

Principal component 3

Figure 5.6 displays the spatial projection of PC3 from the Kavos survey. The final principal component analysed from the wide-area surface survey of Kavos (PC3) shows a high positive correlation coefficient for Ca, and a high negative correlation coefficient for K. Whilst both these elements have been shown to be useful for interpreting anthropogenic activity in archaeological geochemistry (Oonk et al., 2009b) the negative correlation between the two, which is the defining factor of the principal component, is likely to be natural. Calcium rich soils have been linked with the leaching of potassium, especially in sandy soils (Jalali and Rowell, 2003). Furthermore, the spatial distribution of this factor indicates that the sample points with the highest correlation are located in areas of soil which sit on marble bedrock, a crystalline calcium carbonate rock (Dixon and Kinnaird, 2013: 26). This could explain the depletion of K in the area, and also suggests that the accumulation of Ca is a natural phenomenon.

5.2.2 Kavos Survey Summary

The wide-area geochemical survey of Kavos has revealed evidence for past human activity. Through principal component analysis, evidence for metalworking at the Kavos Promontory, and possible use of the Special Deposits by those involved, was isolated from the data (PC2). The structure of enhanced Cu and Pb concentrations offers insight into the spatial organisation of those activities, with a clear intensity of practice towards the northernmost extent of the Promontory. The remaining principal components (PC1 and PC3) are likely evidence of natural soil processes. However, anomalous concentrations of Zn offer some evidence for intensity of past human action which, again, indicates that the Kavos Promontory was central to activities taking place in the Dhaskalio-Kavos landscape.

5.3 Dhaskalio Survey

The wide-area surface survey of Dhaskalio was performed prior to excavation at the site. The survey was conducted at a resolution of ~8m for a total of 215 points of analysis. The following section highlights key results from the principal component analysis of those data, as well as single elements deemed important for understanding the spatial organisation of EBA craft practice.

5.3.1 Principal Component Analysis of Dhaskalio

Table 5.3 displays the rotated component matrix from the PCA of data from the wide-area surface survey of Dhaskalio. As with the PCA analysis of data from the Kavos survey, all values over ±0.5 are highlighted. Greater significance is placed on higher values, which is indicated by the intensity of fill shade. Elements included in the PCA analysis are those with proven archaeological interest and which produced a great amount of data in concentrations above the limit of detection (LOD).

The data was initially tested for its suitability for further statistical interrogation using the Kaiser-Meyer-Olkin measure of sampling adequacy. The test showed a score of .650 indicating that the data were suitable for further analysis, and all components with an eigenvalue greater that one were extracted using varimax rotation, which was chosen in order to highlight the most influential factors. In total, four principal components were extracted for further scrutiny.

Dhaskalio Survey Rotated Component Matrix				
	Component			
	1	**2**	**3**	**4**
Zscore(Sr)	-0.077	-0.021	0.001	0.838
Zscore(Pb)	0.240	-0.202	0.602	-0.024
Zscore(As)	0.020	0.724	-0.142	0.146
Zscore(Zn)	0.114	0.685	0.237	-0.307
Zscore(Cu)	-0.121	0.221	0.808	0.039
Zscore(Fe)	0.880	0.133	0.073	-0.172
Zscore(Mn)	0.802	-0.068	-0.089	-0.267
Zscore(Ti)	0.854	0.289	0.054	-0.064
Zscore(Ca)	-0.629	0.249	-0.364	0.057
Zscore(K)	0.762	-0.100	0.017	0.440
Zscore(S)	-0.536	-0.056	-0.070	-0.300
Influence	**31.832**	**11.497**	**11.333**	**11.019**

Table 25.3: Results for varimax rotated principal component analysis on selected elements from samples from Dhaskalio. Data were standardised using Z-score prior to PCA.

The first principal component (PC1) accounts for 31.8% of the explained variance with high positive correlation coefficients (>.75) for Fe, Mn, Ti, and K, with moderate negative correlation coefficients for Ca and S. The second principal component (PC2) accounts for 11.5% of the explained variance with moderate positive correlation coefficients for As and Zn. The third principal component (PC3) accounts for 11.3% of the total explained variance and shows moderate positive correlation coefficient for Pb and Cu. The final principal component extracted (PC4) explains 11% of the total variance with a high positive correlation coefficient for Sr.

Principal component 1

Figure 5.7 displays the spatial projection of PC1 from the Dhaskalio survey. As with the data from the wide-area survey of Kavos, the first principal component can be explained through natural soil processes. Fe, Mn, Ti, and K are abundant and stable in many soils (Gilkes and McKenzie, 1988; Oonk, 2019b; Sposito, 1989). The spatial distribution of correlated data for PC1 displays a bias towards the eastern, northern, and western slopes of Dhaskalio, with relatively low correlation in the central, summit region. The summit of Dhaskalio was the main focus of excavations between 2006 and 2008 (see chapter 2). Therefore, this spatial patterning may be explained through disturbance to those areas, and replacement of naturally formed soils with modern backfill. The moderate negative correlation coefficients for Ca and S may be seen as a result of absorption by plants, as both Ca and S are required in relatively large amounts by plant life (Maathuis, 2009). The spatial distribution of these results also indicates that results with the highest correlation are organised within areas which would have been associated with the highest density of vegetation during the initial stages of the first field season (i.e. those areas which were not previously subjected to archaeological excavation).

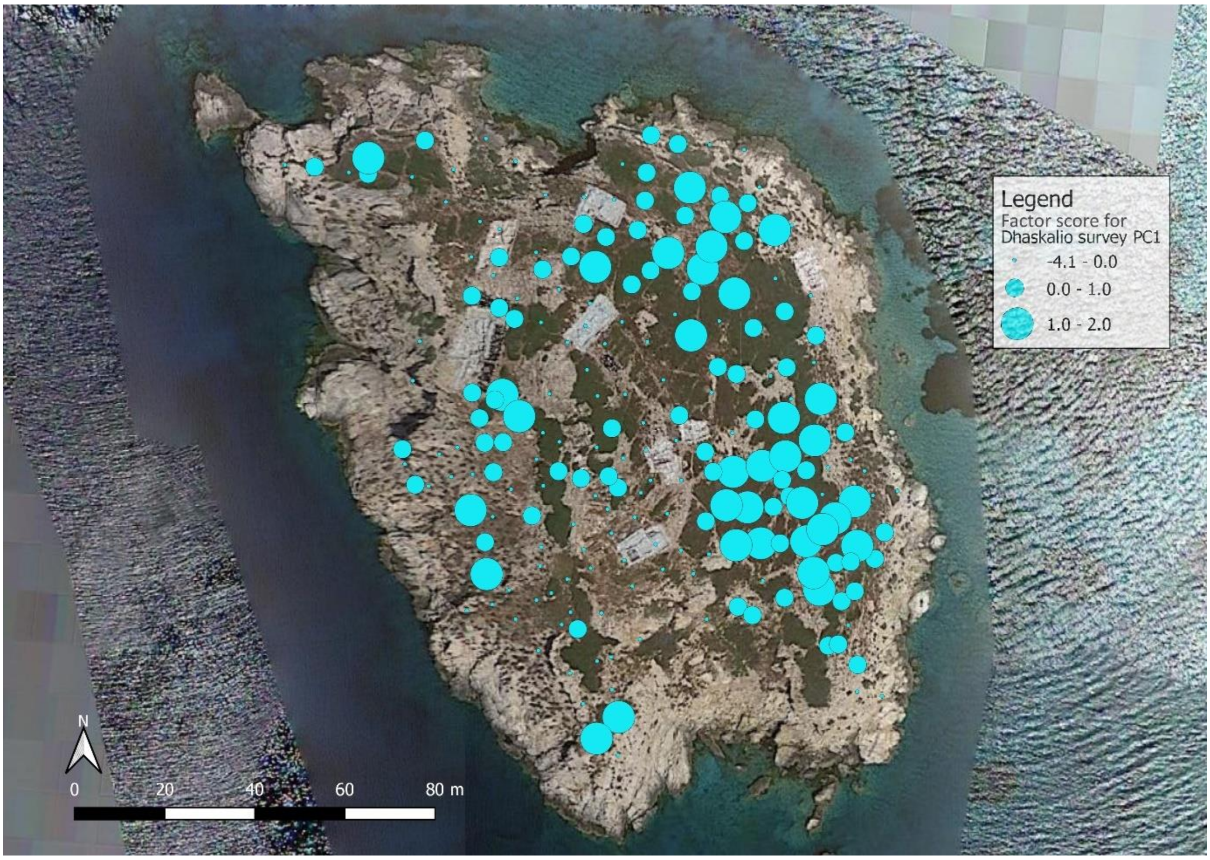

Figure 5.7: Spatial projection of PC1 from the Dhaskalio survey data (image source: author/Google Satellite 2021).

Principal component 2

Figure 5.8 displays the spatial projection of PC2 from the Dhaskalio survey. The second principal component from the Dhaskalio survey data is dominated by As and Zn, which both display moderate positive correlation coefficients. Although Zn is easily absorbed by mineral and organic components, and so is often present in soils through natural processes (Mikołajczyk and Milek, 2013: 580; Sposito, 1989: 10-12), background As concentrations in topsoils are generally low (Kabata-Pendias and Pendias, 1984: 171-2). Furthermore, As, and especially Zn may be enhanced through past human activity such as occupation areas, human waste, or more generally (Middleton and Price, 1996: Oonk et al., 2009b). However, As was only analysed above the limits of detection for the instrument on 16 samples from a total of 215 points of analysis. These readings ranged from 13.3 ppm to 26.1 ppm with a mean value of 2.9 ppm and RSD of 17.7% across 213 points of analysis. These low concentrations and relative lack of variability may make the statistical significance of As in this principal component misleading. The spatial distribution of PC2 shows some structure to the north and west of the site which, if anthropogenic in origin, may indicate areas of enhanced activity. However, areas with the highest correlation appear sporadically across the site. For these reasons, it is difficult to conclude whether PC2 is an indication of natural or anthropogenic processes.

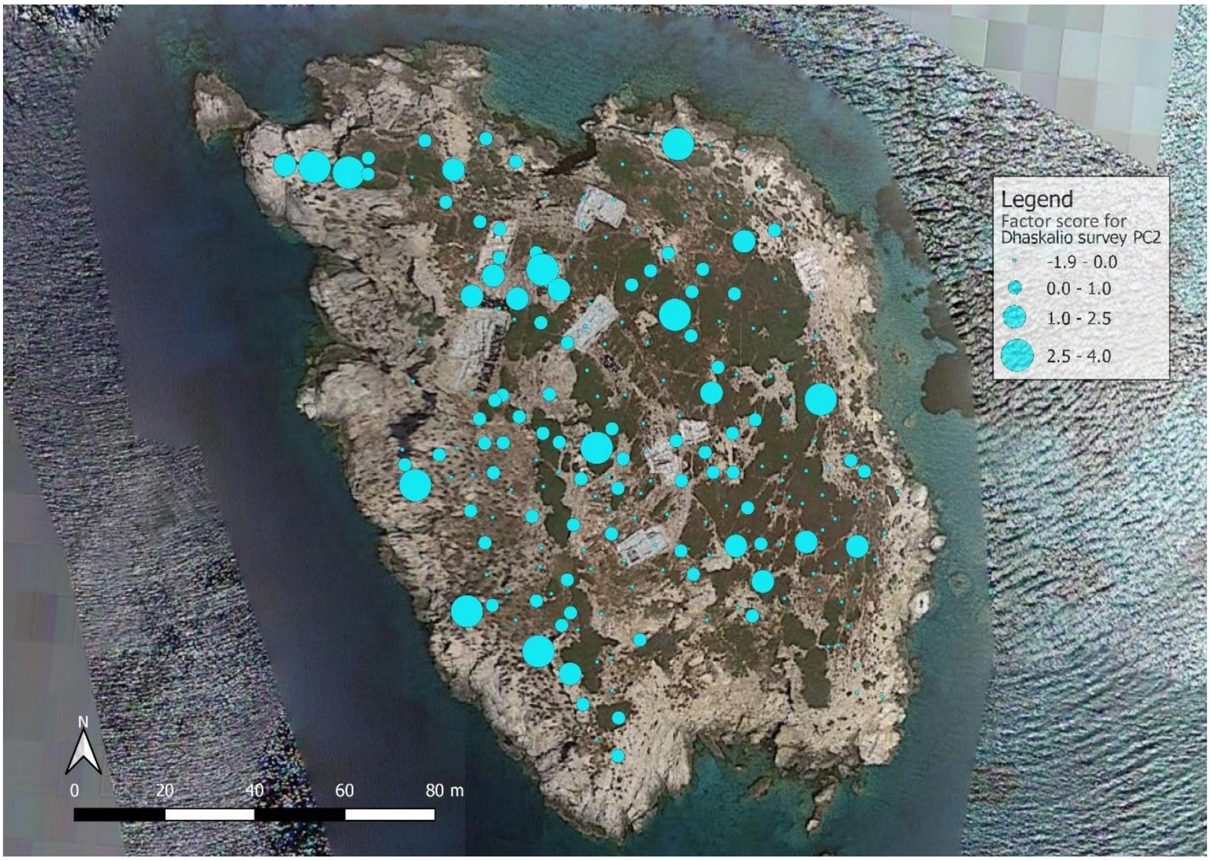

Figure 5.8: Spatial projection of PC2 from the Dhaskalio survey data (image source: author/Google Satellite 2021).

Principal component 3

Figure 5.9 displays the spatial projection of PC3 from the Dhaskalio survey. The third principal component shows a high positive correlation coefficient for copper (Cu) and a moderate positive correlation coefficient for lead (Pb). Trace amounts of Cu and Pb may be observed naturally in soils (Kabata-Pendias and Pendias, 1984). However, as with the data from the wide-area survey of Kavos, the high correlation of Cu and Pb, which have come together to create their own principal component, is a strong indication of its relation to human activity. Again, the most obvious activity that PC2 can relate to is metallurgical practice, specifically copper and lead working. Further, since there is no evidence for activity of this kind on the site since the 3rd millennium BCE (Renfrew, 2007; 2013), this certainly relates to EBA craft practice.

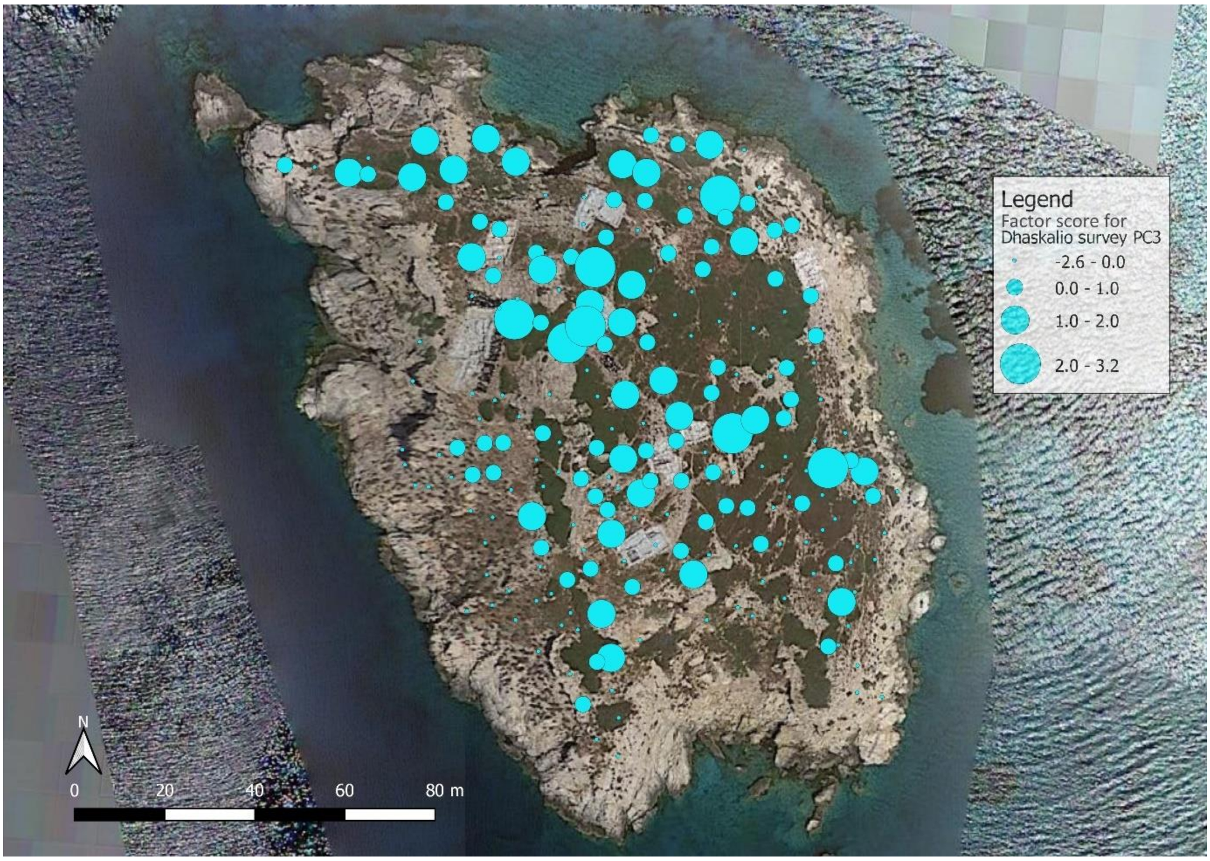

Figure 5.9: Spatial projection of PC3 from the Dhaskalio survey data (image source: author/Google Satellite 2021).

The spatial distribution of PC3 indicates that chemical residues from metalworking are widespread at Dhaskalio. However, there is clear structure to the spatial distribution, with areas of intensity to the north, east, and central region of the islet. PC3 demonstrates a higher correlation coefficient for copper than for lead. This may indicate that, to a certain degree, different metallurgical processes were taking place in different areas of the settlement. Isolating each element for further spatial analysis may aid this interpretation. To that end, figures 5.10 and 5.11 show the spatial distribution of Cu and Pb concentrations at Dhaskalio.

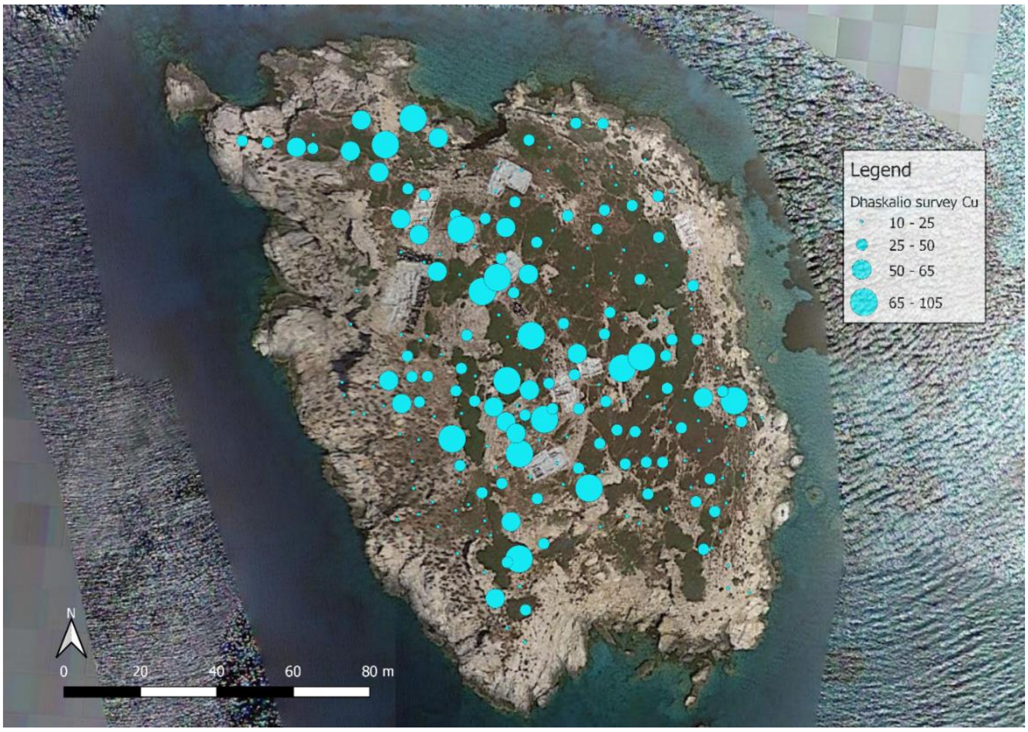

Figure 5.10: Spatial plot of soil Cu levels across Dhaskalio. All values are displayed in ppm. Note that the value of 10 ppm is a proxy for < LOD in order to aid spatial projection (image source: author/Google Satellite 2021).

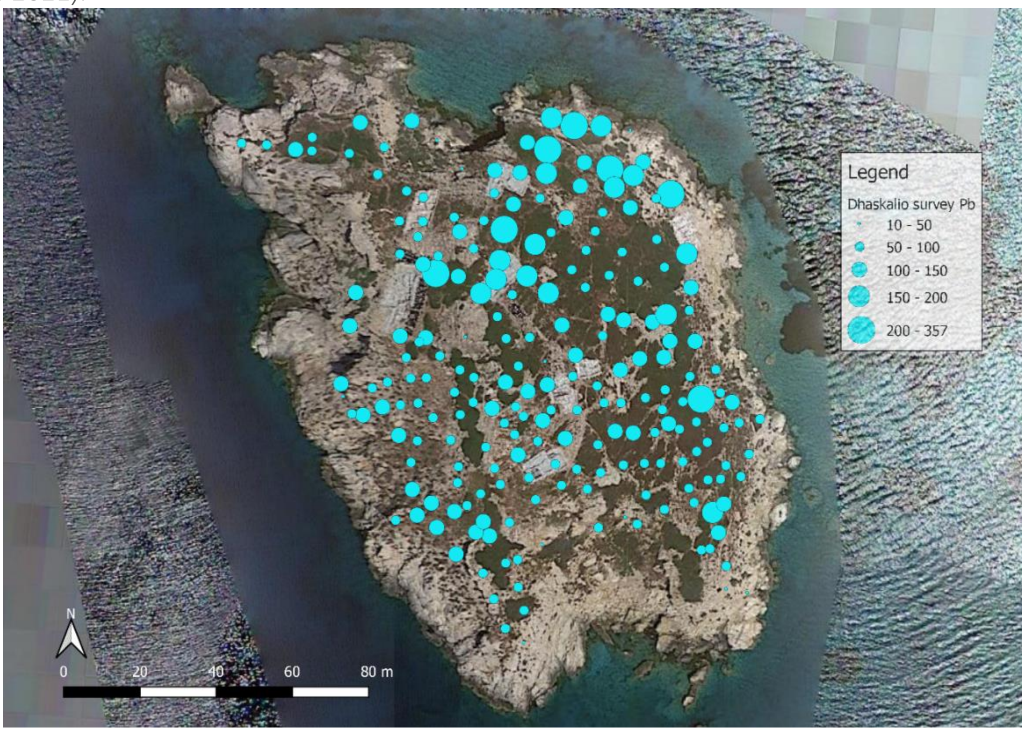

Figure 5.11: Spatial plot of soil Pb levels across Dhaskalio. All values are displayed in ppm. Note that the value of 10 ppm is a proxy for < LOD in order to aid spatial projection (image source: author/Google Satellite 2021).

The values for Cu range from below the level of detection for the instrument (~25 ppm) to 105 ppm, and concentrations of Pb range from below levels of detection (~15 ppm) to 357 ppm. The highest concentrations of Cu are structured to the central, northern, and eastern regions of Dhaskalio. However, the highest Pb readings are structured largely to the northern extent of the island. Pb was measured in high concentration across the islet, whilst the spatial distribution of very high Cu values is more restricted. This could indicate that lead working was a widespread activity on Dhaskalio, whilst copper metallurgy held a more specific focus.

Principal component 4

Figure 5.12 displays the spatial projection of PC4 from the Dhaskalio survey. The fourth principal component shows a high positive correlation coefficient for Sr but no other element correlates to a value of ±0.5. Therefore, Sr is the dominating factor in the variance of PC4. However, there is perhaps cause to include K as a significant influencing factor. This is because K displays a positive correlation coefficient of .44 which is only marginally lower than the arbitrary cut-off of ±0.5 used for this study. Archaeologically, Sr and K are both understood as being indicative of 'domestic' types of activity. Indeed, whilst both elements may represent many broadly domestic practices, K has been found to be associated with middens and hearths (Parnell et al., 2001; Wells et al., 2000) whilst Sr has been used for identifying food preparation (Milek and Roberts, 2013; Wilson et al., 2008). Therefore, it is likely that the fourth principal component from the Dhaskalio survey is related to domestic use of space at the settlement.

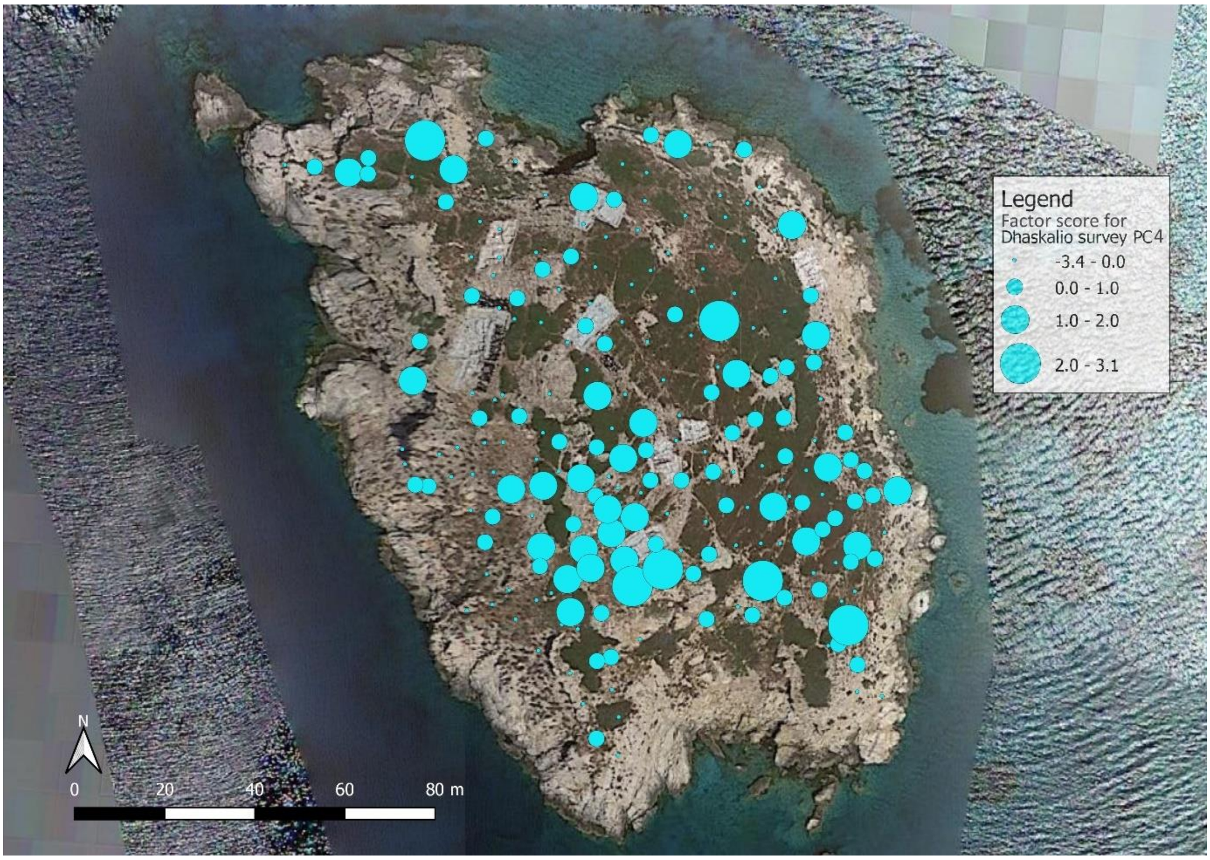

Figure 5.12: Spatial projection of PC4 from the Dhaskalio survey data (image source: author/Google Satellite 2021).

Analysing the spatial distribution of data which correlate with PC4, clear structure can be observed. Most notably, there appears a distinct spatial structuring to the south-central region of the settlement, and to the south-east of the islet. Smaller structured anomalies can be seen to the north and eastern regions of the site. It is unclear if all of these structured anomalies represent the same process taking place in different areas of the settlement, or if each region of high correlation is indicative of a distinct process. However, given the proven archaeological associations for Sr and K, the spatial distribution of PC4 suggests that broadly domestic activities were relatively localised, yet widespread.

4.3.2 Dhaskalio Survey Summary

The wide-area surface survey of Dhaskalio has revealed evidence for past craft practice, as well as domestic activities. Through principal component analysis, activities of archaeological interest were separated from natural processes in data set. This allowed for distinct areas of activity to be identified.

It is clear that metallurgical activities were taking place at the settlement. This entailed widespread lead working and more strictly organised copper metallurgy. In addition, the data suggest that some areas of the settlement were utilised for more domestic purposes. The spatial structure of PC4 (domestic) displays differing spatial organisation to PC3 (metallurgy). This suggests a degree of partitioning of activities at the site, with metalworking largely taking place to the north and north-east of the settlement, whilst domestic spaces were organised to the south and south-east.

4.4 Dhaskalio Trenches

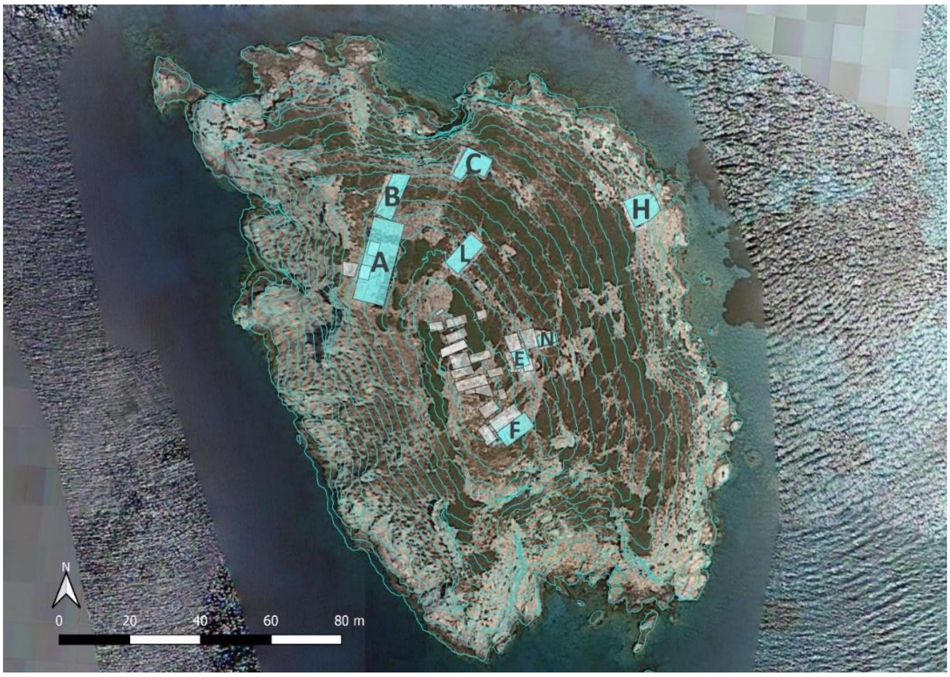

Figure 5.13: Satellite image depicting the location of Trenches on Dhaskalio (image source: author/ Google Satellite 2021).

During the latest excavations at Dhaskalio (2016-18) a total of eight main trenches were opened (Trenches A, B, C, E, F, H, L, and N, see figure 5.13). During the course of the three field seasons, 553 single contexts were subject to geochemical survey for a total of 4905 individual points of analysis. However, the majority of contexts analysed are associated with phases of collapse which likely took place subsequent to the abandonment of Dhaskalio, and it is beyond the scope of this thesis to summarise in detail every context which was analysed for soil chemistry. Instead, the following section will highlight results from areas understood as floors or surfaces, or features highlighted as potential activity areas (geochemical data from all analysed contexts can be found in Appendix 2). Where available, information pertaining to the phasing and relationships between contexts has been used in order to create phased plans for extended areas of individual trenches which have been used wide-area spatial analysis. However, the Cambridge Keros-Naxos Seaways Project is ongoing, and study seasons have been limited due to unforeseeable setbacks (such as the 2020 COVID-19 outbreak). Therefore, phasing for the majority of trenches was unavailable, or only available in preliminary form at the time of submission. Where finalised relationships between contexts was unavailable, individual contexts of interest will be presented. However, PCA requires a large sample size, and even large context surveys often did not produce adequate data. Therefore, spatial analysis of soil chemistry for individual contexts will focus on elements which display structured variability and have been shown to be indicative of anthropogenic activity through statistical analysis of wider surveys of the site. However, it should be understood that analysing soils and sediments using HHpXRF instruments provide several issues, especially if analysis is undertaken in situ. For example, sample heterogeneity and sample geometry, that is, the size and compaction of grains and the smoothness of the surface analysed, can impact the overall precision and accuracy of the instrument (Cannell, 2016: 44). When using laboratory methods, with homogenised samples and a stand for stabilising the instrument, the sources of error are largely limited to the internal mechanism of the instrument and the choice of analytical timings. However, this is not the case when the instrument is handheld and used in the field. Whilst precautions have been made to standardise the methods used for in situ analysis, and the internal calibrations used for the instrument's 'Soil mode' assumes the sample is not ideal, but porous with an uneven surface geometry, human error is unavoidable. Minor variations in stability whilst wielding a 5kg instrument may marginally alter the sample point, or otherwise slightly change the contact between the analyser and the sample over the course of analysis. In addition, the moisture content of samples will likely vary across a site and change throughout the period of investigation due to a wealth of natural and man-made variations, which are not always quantifiable (Cannell, 2016: 45). These potential errors have not been quantified here. Therefore, the data presented here may be regarded as semi-quantitative. However, the effect of surface geometry on sediment samples has been shown to be minimal, especially with heavy metals (Davis et al., 2011; Hunt & Speakman, 2015). Understanding the spatial organisation of metallurgical practice is an essential aim of this project. Therefore, in most cases, the elements reported for contexts will be Cu and Pb which will highlight metalworking spaces, and Zn for understanding more general domestic activity, which will offer insight into spatial changes to practice by also highlighting areas without evidence of metalworking.

Furthermore, a major issue in archaeological geochemistry is that the connection between the level of any elemental enhancement or depletion remains undefined (Oonk et al, 2009). Therefore, contextual observation, where the variability within a site is analysed and interpreted, is crucial in determining the validity of interpretation. This is indeed true for the results presented here. Enhancements of Pb, Cu, and Zn have been assessed and interpreted based upon observations made by the investigator with regards to what constitutes a real level of enhancement, alongside basic descriptive statistics drawn from the overall data. Whilst initial observation is useful in the field for immediate dissemination to excavators and other specialists, determining the average concentrations of anthropogenic elements across the site allows for the establishment of a site-specific baseline. Whilst site-specific knowledge and experience was still used in the interpretation of the results presented below, descriptive statistics from the overall data set will be offered where relevant. These statistics for Pb, Zn, and Cu from all analyses on Dhaskalio can be seen in table 5.3. Due to the fact that areas which have been exploited for past metallurgical practices often have concentrations of heavy metals, such as Cu or Pb, far above any normal geological background (Slater, 2016: 84), the chemical signatures of metallurgical practices were able to be identified beyond ambiguity. It should be noted here the process of dealing with censored data when calculating these basic statistics. Censored data are common in geochemical survey where an element is present but below the limit of detection (i.e. a nonzero value which cannot be measured but is known to be below some threshold) yet it is still desirable to include such data in statistical analysis (Baxter, 2003: 121). Strategies for dealing with censored data are numerous, but almost always rely on attributing a value greater than zero but less than the minimum measured value to these data (Hornung & Reed, 1990). In the case of this study, and arbitrary value of 9.999 was used consistently in place of censored data in order to determine these descriptive statistics. Because this value was used consistently across contexts, comparisons may still be drawn between values across the site. However, because of the partially random nature of assigning nonzero values to these data, and as has been iterated previously within this study, results presented here are not suitable for inter-site comparisons (Cannell, 2016: 45). Rather, it is the intra-site variability that is interpreted.

	Pb	**Zn**	**Cu**
Count	4904	4904	4904
Max	11222.08	74.39	100695.2
Min	< LOD	< LOD	< LOD
Mean	211.247	30.01353	225.7613
Stdev	571.4868	8.355094	2606.024
RSD	270.5302	27.83776	1154.327

Table 5.4: Descriptive statistics for Pb, Zn, and Cu from analysis of excavated contexts on Dhaskalio.

4.4.1 Trench A

Trench A represents the largest trench to be opened at Dhaskalio between 2016 and 2018. It measures 24 x 9m and is located on the north-western edge of the settlement, immediately to the west of the central summit area (**figure 5.14**). Throughout the three field seasons, a significant complex of building structures set against passageways and stairways was uncovered. Consequently, the archaeology of Trench A is remarkably complex. Due to this complexity, the stratigraphic phasing and spatial relationships between individual contexts remains (at the time of writing) in a preliminary stage. Consequently, any attempt to piece together an overall plan of soil chemistry for multiple stratigraphically related contexts which encompasses the entirety of the trench is likely to be subject to change. However, from preliminary phasing data, it is understood that Trench A had a single phase of occupation in the EBA during Dhaskalio phases A and B. Consequently, all surfaces of occupation which were analysed for soil chemistry can be assigned to this period of use on the settlement. Therefore, spatial projections of soil chemistry for multiple contexts will be reported in order to evaluate relative chemical concentrations across multiple surfaces. However, it should be understood that individual spaces across the trench may not have been occupied concurrently. Otherwise, soil chemistry for distinct archaeological contexts which have been highlighted as potential activity spaces or characterised as floors or surfaces will be reported individually, and any information as to their chronological phasing will be highlighted.

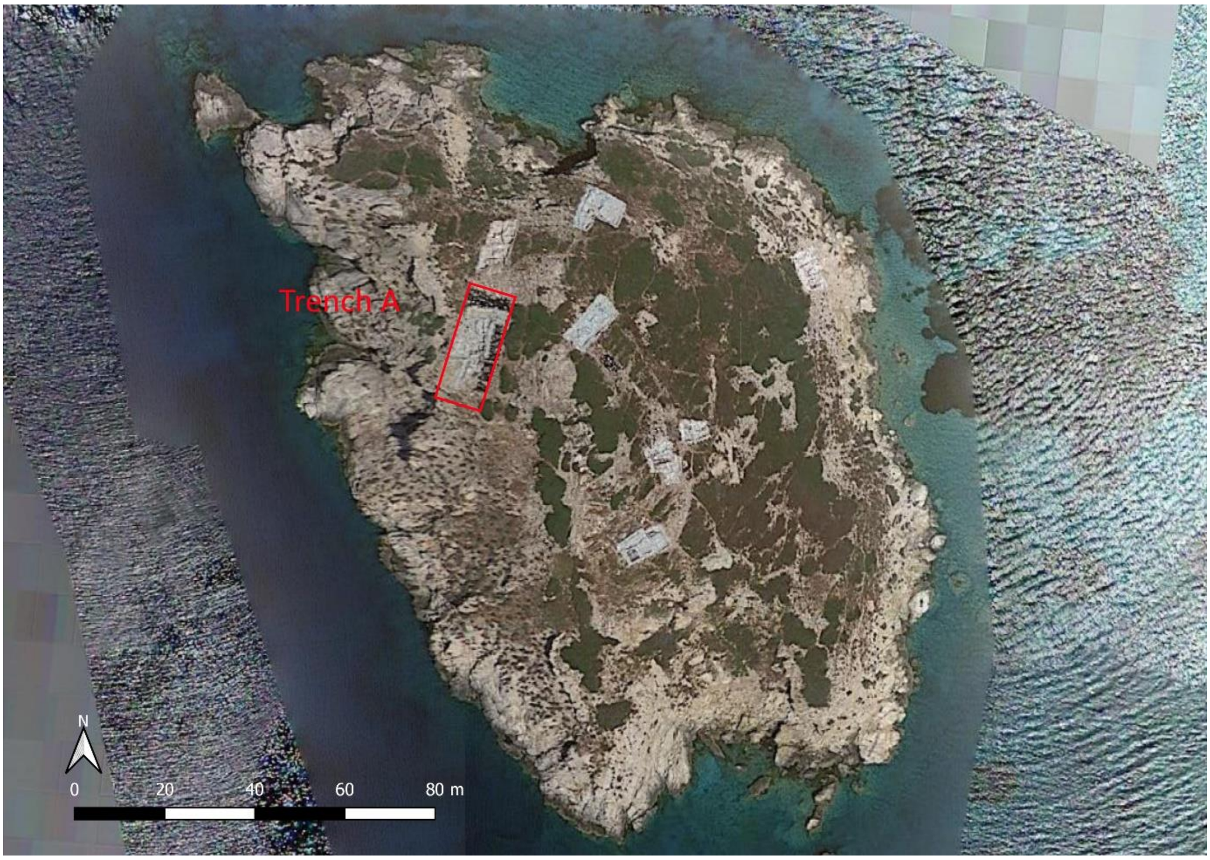

Figure 5.14: *Satellite image depicting the location of Trench A on Dhaskalio (image source: author/ Google Satellite 2021).*

Trench A: hearths

During the final stages of excavation at Trench A, two possible hearths were uncovered from below floor layers in the south-central region of the trench which likely date to Dhaskalio Phase A. These features contained deposits which were subject to chemical analysis. Because these features represent singular deposits, and not spaces of activity, spatial analysis is not necessary. However, figure 5.15 and 5.16 displays the spatial projection of these two features in order to demonstrate their relative locations, as well as highlight differences in terms of Cu (figure 5.15) and Pb (figure 5.16) concentrations.

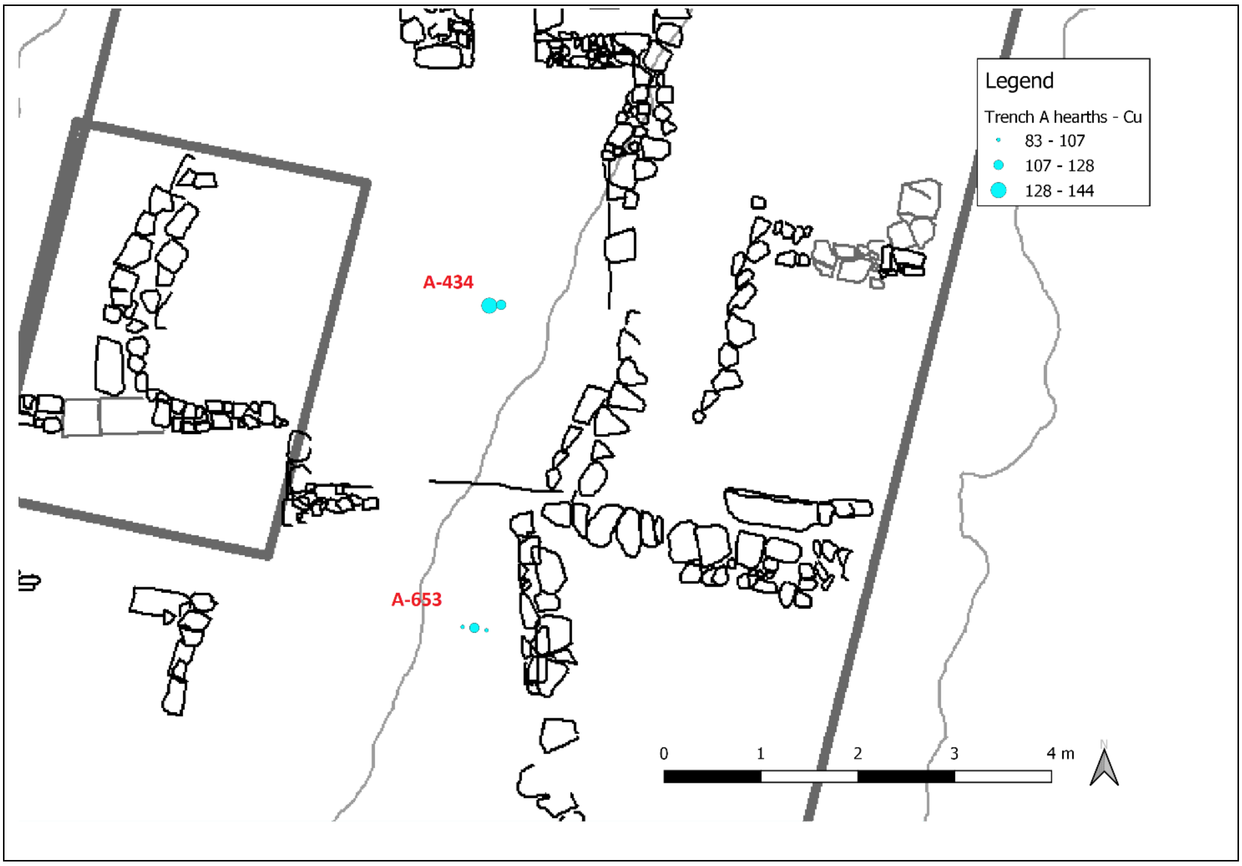

Figure 5.15: *Spatial projection of Cu values for hearth features (A-653 and A-434) from trench A. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).*

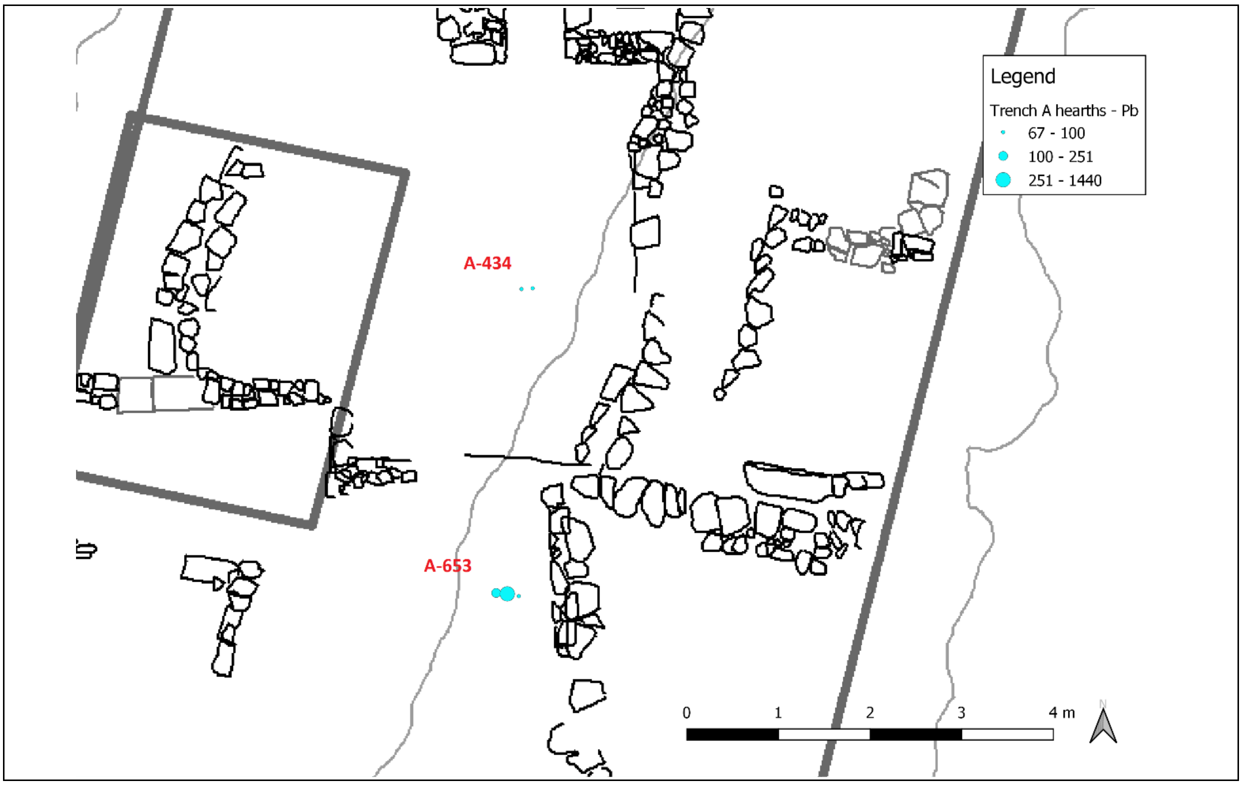

Figure 5.16: Spatial projection of Pb values for hearth features (A-653 and A-434) from trench A. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).

Context A-653 represents the feature to the south of the trench, whilst context A-434 is located in the central space. Context A-653 shows a maximum Cu value of 109.27 ppm, a minimum of 82.74 ppm and a mean value of 93.87 ppm across 3 samples, whilst context A-434 shows a maximum Cu value of 143.59 ppm, a minimum of 110.34 ppm and a mean value of 126.97 ppm across 2 samples. These Cu values are high for the specific area of the site (mean average of 70.3 ppm for Trench A) and are comparable to concentrations measured from the survey of the Kavos Promontory. However, analyses were taken from the surface (topsoil) during the wide-area survey of Kavos, and not directly from an archaeologically defined feature. Concentrations may be expected to be greater from precise deposits associated with repeated episodes of copperworking, as compared to when analysis is performed on layers above the feature. Furthermore, various areas of metallurgical activity were excavated from trenches across Dhaskalio which, when analysed for soil chemistry, showed far greater concentrations of Cu (see Trench H, L, and N), and the mean concentration of Cu analysed across all Dhaskalio contexts is 146.37 ppm. Therefore, in terms of soil chemistry, it appears unlikely that the features which these deposits are related to were used for copperworking, although their true function remains inconclusive.

Lead concentrations from A-653 are very high, with a mean value of 566.86 ppm and a maximum value of 1439.88 ppm. Conversely, A-434 shows relatively low concentrations of Pb, with a mean value of 74.66 ppm, and maximum value of just 82.44 ppm. The values associated with A-653 are highly elevated above the site average (211 ppm across all trenches) which suggests that the hearth feature associated with this deposit was directly used for lead metallurgy. The Cu concentrations were lower here than from A-434, which may suggest that the hearths were used for the working of different metals if, indeed, A-434 does represent a metallurgical installation.

Trench A: surfaces of occupation and use

During the three field seasons (2016 to 2018), and especially during the final season of excavation, a number of features which have been defined as 'surfaces' were uncovered and subject to soil chemical analysis. In addition, significant stone stairways and passageways were excavated. These features consisted of large stones embedded in compacted soil. The surrounding soil enabled high-resolution soil chemical analysis to be undertaken in order to characterise the walkways between occupational spaces. Through combining the geochemical analyses of these contexts into a single large-scale plan, the relative elemental concentrations within and between these spaces can be better evaluated. It is important to reiterate, however, that although all contexts discussed here relate to the Dhaskalio Phase A-B occupation, not all areas may be contemporaneous, and relationships between surfaces may be subject to future change. However, for the purpose of characterising the spatial organisation activities at Trench A, this large-scale analysis will allow for a better understanding of the possible overall function and use of space across the area, as well as highlight areas of intense activity.

Figure 5.17 shows the location of analysed contexts from Trench A which have been defined as either surfaces of activity (shaded green), or architectural features associated with movement between spaces, such as stairways or passageways (shaded orange). This large-scale analysis includes data from 180 sample points across 10 contexts.

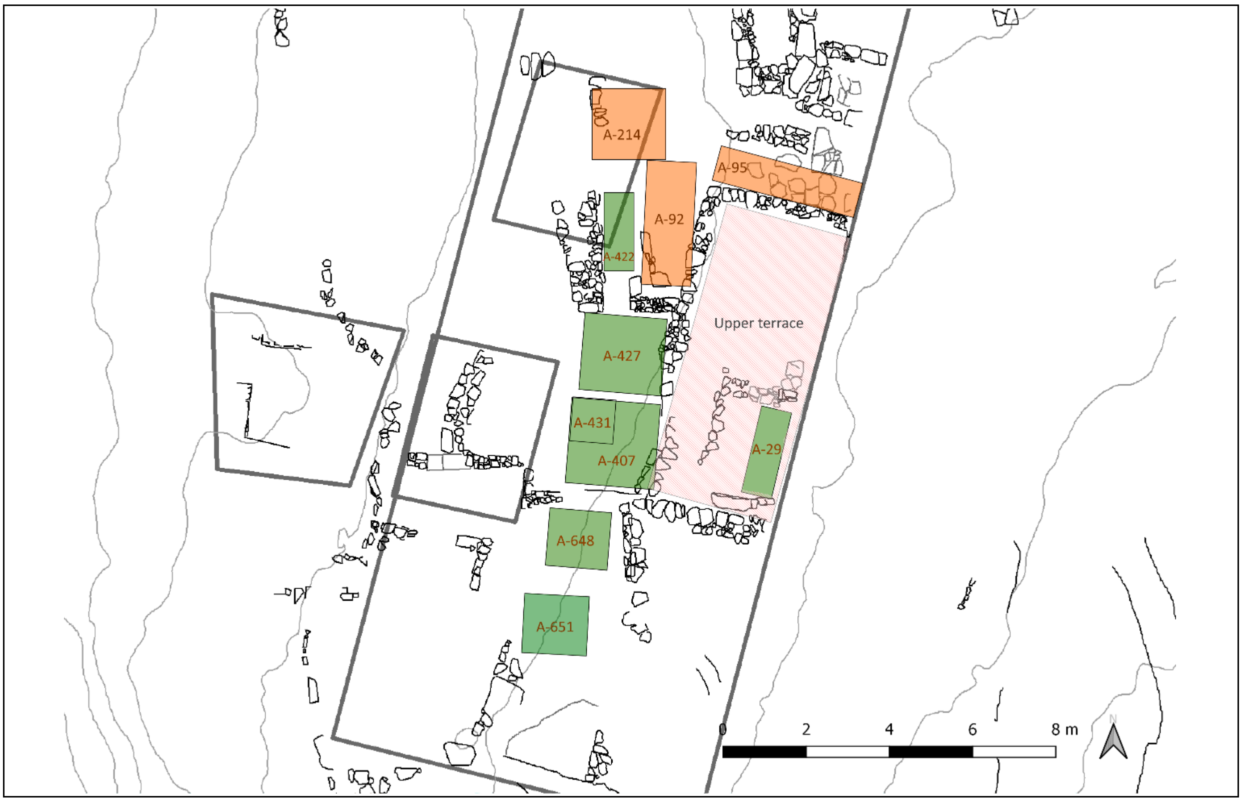

Figure 5.17: Image detailing the location of contexts associated with occupation activity in Trench A. Green represents surface features and orange shows stairways and/ or passageways (image source: author/Keros-Naxos Seaways Project 2018).

The spaces defined as floors/surfaces or other forms of activity space encompass a large region of Trench A, although the main focus of activity is the central region and towards the eastern trench edge. This is due to the architectural reality in the area, where rooms are located both on a lower terrace (A-427, A-407/403, A-648, and A651), and upper terrace (A-29), whilst stairs (A-92 and A-95), and passageways (A-422 and A-214) facilitate movement between the terraces and the central summit region of the site. This variation between room spaces (located on both upper and lower terrace) and walkways offers the unique opportunity to characterise movement and organisation of activities across the trench. Due to the fact that the earliest features characterised in the trench, in terms of EBA chronology, are suspected metallurgical hearths, the first elements to be assessed will be lead (figure 5.18) and copper (figure 5.19). This will be followed by evaluating the spatial distribution of zinc (figure 5.20) in order to assess more general human activity.

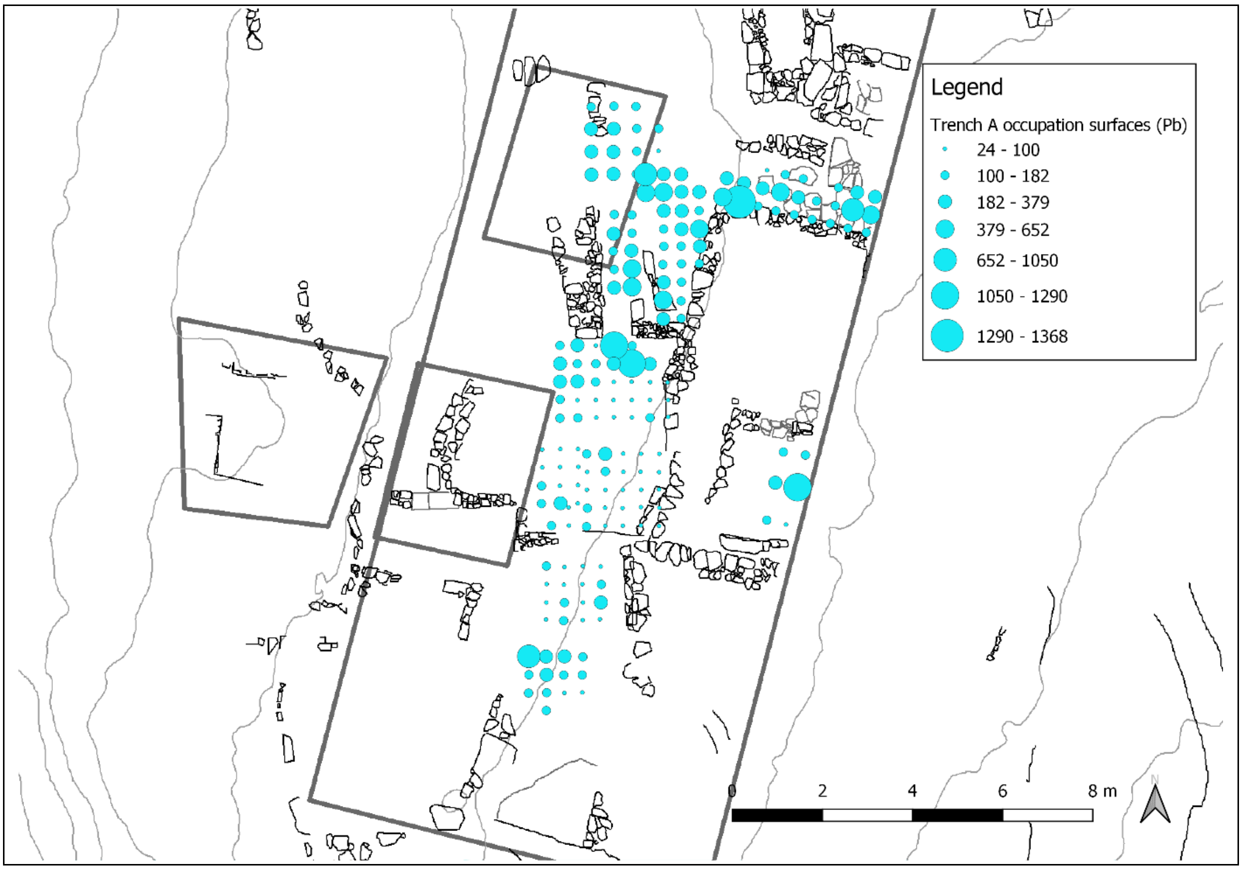

Figure 5.18: Spatial distribution of Pb concentrations from occupational surfaces in Trench A. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).

Lead concentrations across the occupational spaces are very high, with a maximum concentration of 10367.8 ppm. However, the lowest concentration analysed was 23.52 ppm, giving a mean value of 186.14 ppm and a standard deviation of 201.04 (CV=1.08) across 180 samples. This shows that there is great variation in terms of Pb concentration across the trench. The highest Pb values from within the room spaces on the lower terrace are organised within the north-east corner of context A-427, with another sizeable anomaly towards the north-west of context A-651. The highest concentrations of Pb in these areas are 1278.9 ppm from A-427, and 949.4 ppm for context A-651. These values are very high indeed and are likely indicative of more than just general domestic use of space. The structure to these anomalies also suggests that these high concentrations are not as a result of an error in the analysis. Rather than random high 'spikes' of Pb, the values rise towards the anomaly. The structure to these high concentrations indicates that Pb has accumulated through human action, and most likely indicate that metallurgical practices involving lead were taking place in these spaces. The melting point of lead is 327.5 °C and does not necessarily require the same infrastructure (dedicated hearths, bellows/blowpipes etc.) as casting copper (Dungworth, 2015). Therefore, very little evidence beyond these chemical residues may be available for further characterising these spaces as lead workshops, or the exact process of metalworking which was taking place (e.g. casting, cold working). However, the Pb values in these areas are so highly elevated above the background chemistry that there is little doubt that some form of lead metallurgy was taking place in the area.

Interestingly, Pb is also highly elevated in all areas associated with connectivity within the space. Indeed, the both the passageway (A-422) and stairways (A-92 and A 95) are associated with some of the highest concentrations of Pb in the area. As discussed previously, these contexts are characterised as connective spaces, rather than habitable rooms. The stairways are narrow and constructed from stone slabs. Therefore, it is unlikely that these spaces were used directly for craft practices, such as leadworking. Instead, the high concentrations of Pb across these areas may be indicative of contamination through constant use by craftspeople, who were immediately involved in leadworking, moving from workshop to workshop, or accessing various parts of the settlement. This may also explain why there is less structure to these anomalies. Rather, Pb is highly concentrated throughout the thoroughfare. This is interesting, not only because it elucidates methods of anthropogenic chemical contamination which are often ignored, but also because it offers suggestion as to the intensity of leadworking in the area.

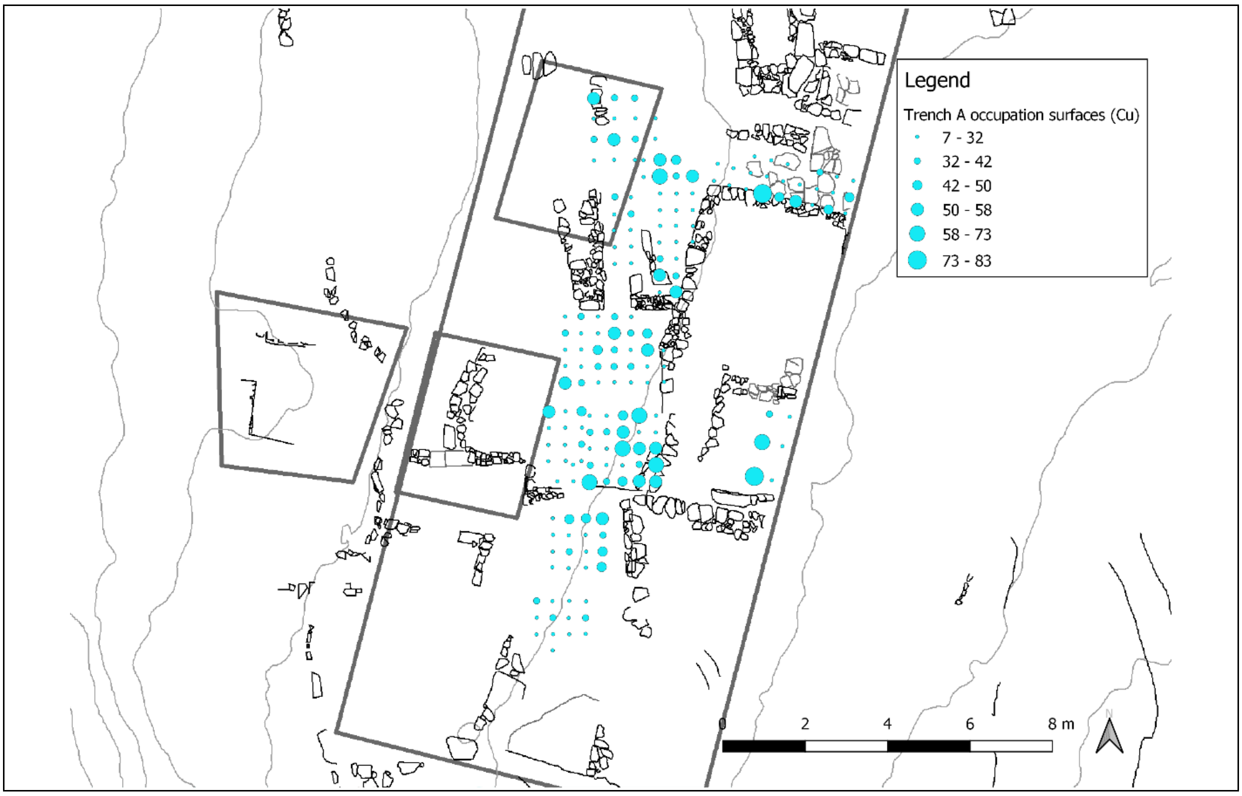

Figure 5.19: Spatial distribution of Cu concentrations from occupational surfaces in Trench A. All values are displayed in ppm. Note that the value of 6.7 is proxy for <LOD (image source: author/Keros-Naxos Seaways Project 2018).

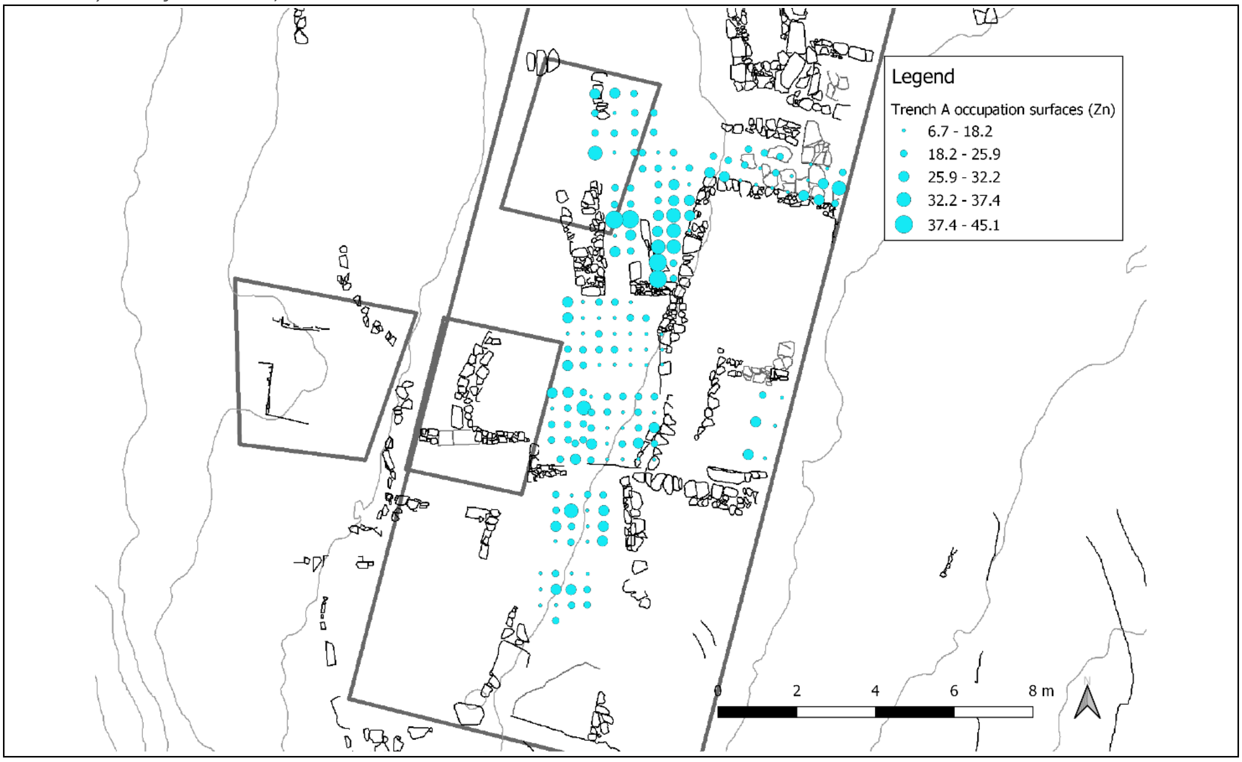

Figure 5.20: Spatial distribution of Zn concentrations from occupational surfaces in Trench A. All values are displayed in ppm. Note that the value of 6.7 is proxy for <LOD (image source: author/Keros-Naxos Seaways Project 2018).

Whilst the concentrations of Pb are very high across the areas of use from trench A, the same is untrue for copper (figure 5.19). Cu was measured from below the detection limit of the instrument to a maximum value of 88.15 ppm. These values indicate that copper working was likely not taking place in Trench A during this phase of EBA occupation. However, Cu is varied throughout the trench (RSD=93.12%), indicating that elevated concentrations may be considered indicative of more general past human activity. The highest values of Cu are largely structured within the central room of the lower terrace complex, with further structured anomalies within areas of the thoroughfare. This is mirrored with Zn (figure 5.20), also displays structure to elevated concentrations within the central region of the trench, and throughout the stairways and passageway. Like phosphorus, both Cu and Zn have been used archaeologically to characterise general past human activity (Bethel and Smith,1989; Cook and Heizer,1965; Oonk, 2009b). Consequently, it is difficult to assess the exact process which is likely to have led to their enrichment in these contexts. However, the spatial distribution of these elements throughout occupation layers in Trench A, likely indicates areas of intensity with regards to past activity.

Trench A: context A-401 – possible upper story use

During the course of the excavation of Trench A, an interesting deposit (A-401) was excavated from rooms within the lower terrace structure which immediately preceded a deposit roof/ceiling debris. Because of this stratigraphic relationship, this layer, dated through diagnostic 'Kastri Group' pottery to Dhaskalio Phase B, may be associated with the floor deposit of a second story in that area. Consequently, this offers a unique opportunity for examining how upper floors were utilised on Dhaskalio through soil chemistry. Figure 5.21 displays the spatial distribution of Pb concentrations across this possible upper-story floor deposit.

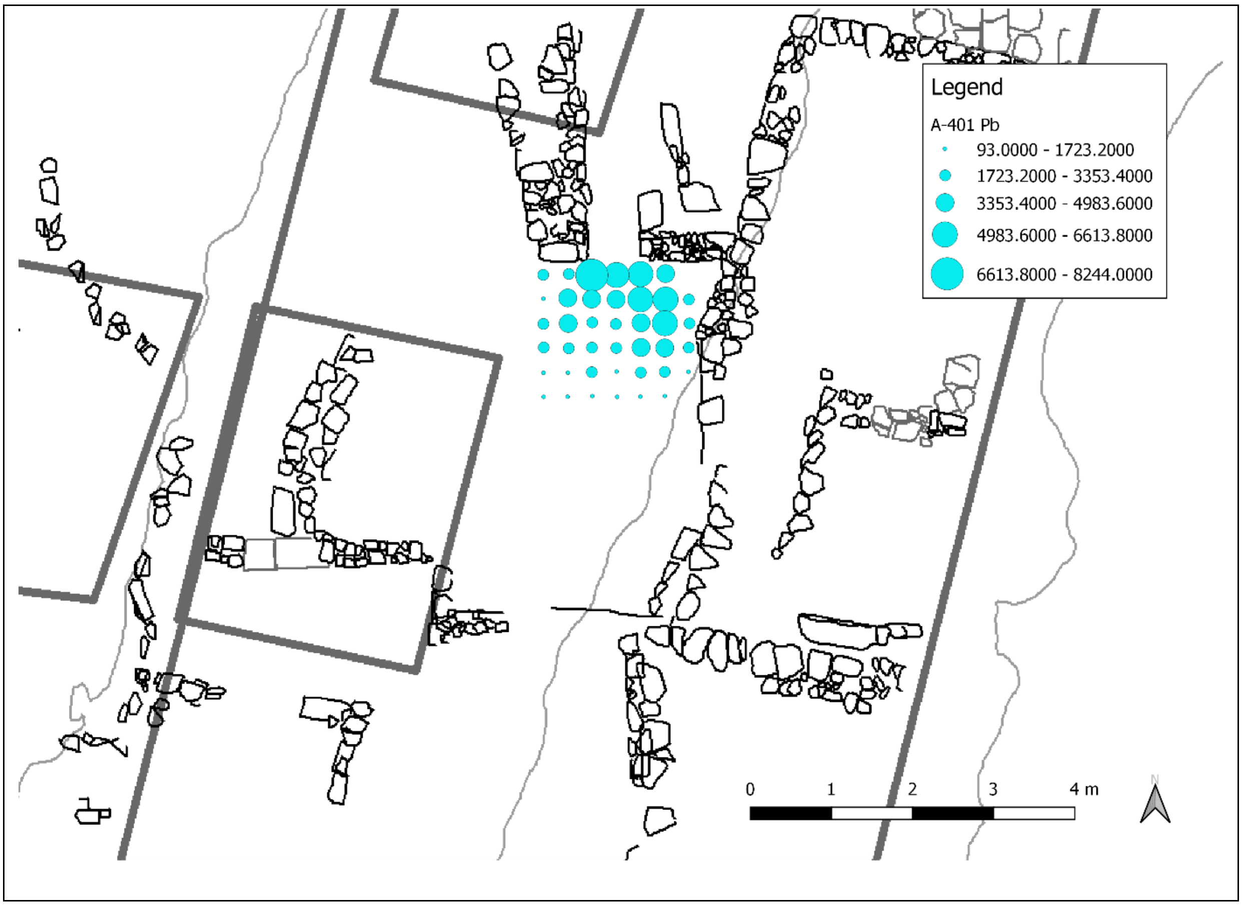

Figure 5.21: Spatial distribution of Pb concentrations from context A-401 in Trench A. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).

As seen with the previous surfaces analysed, Pb concentrations from A-401 are extremely elevated. However, the maximum concentration of Pb from A-401 (8244 ppm) is several times higher than those recorded from other contexts and is highly elevated across most of the feature (mean value = 1418.5 ppm across 40 samples). There is also clear spatial structure to these anomalous levels of Pb, suggesting that the highest concentrations are not as a result of random contamination, but represent evidence for past leadworking in this space. This would suggest that lead metallurgy was a persistent practice in the area, continuing from the Phase A hearths through to the Phase B 'Kastri' phase.

As with other contexts from Trench A, Cu (figure 5.22) and Zn (figure 5.23) were analysed in relatively low concentrations and may only be useful as indicators of 'general' human activity.

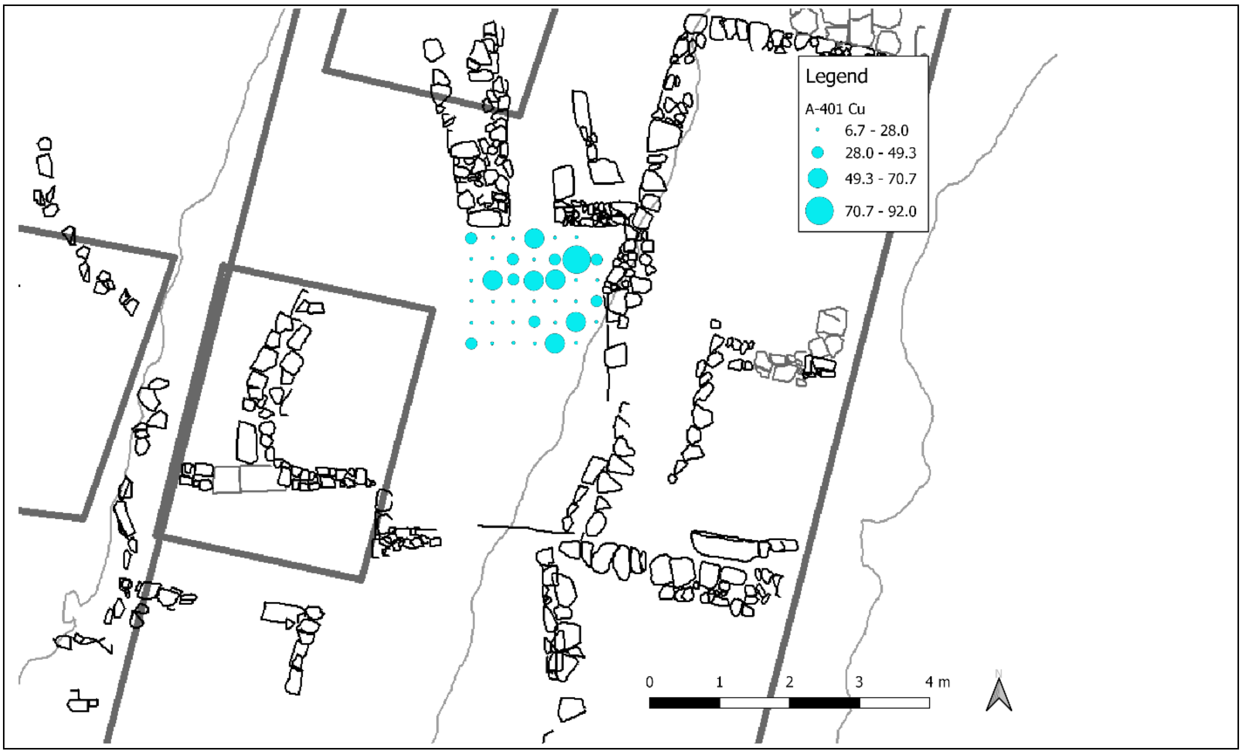

Figure 5.22: *Spatial distribution of Cu concentrations from context A-401 in Trench A. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).*

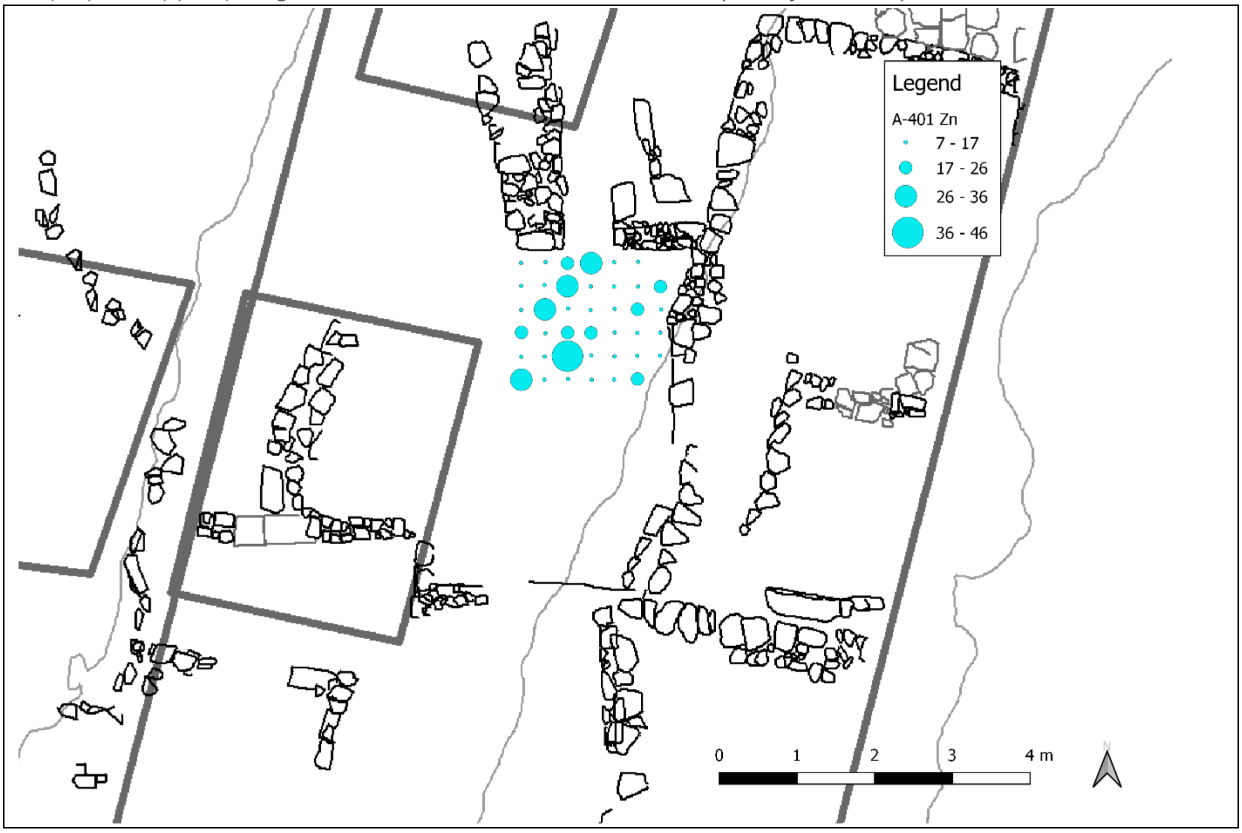

Figure 5.23: *Spatial distribution of Zn concentrations from context A-401 in Trench A. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).*

Trench A: summary

It is clear from the spatial analysis of chemical concentrations from occupation layers in Trench A that leadworking represents the salient activity taking place in that area of the settlement during the EBA. Evidence from the suspected Phase A hearth features, the later Phase B deposits, and the level of Pb accumulation in walkways, that this was a persistent practice for an extended period of time. However, there is little conclusive evidence for other metalworking, although the Cu concentrations from context A-434 are elevated enough to make this conclusion somewhat ambiguous.

4.4.2 Trench B

Trench B is located on the north-west extreme of Dhaskalio, directly north of Trench A (**figure 5.24**). The trench measures 5 x 12.5m to the west, extending to 14m on the eastern edge of the trench and includes a number of large north-facing terrace walls. Trench B was opened at the beginning of the 2017 field season and incorporated test trench SB which was excavated in the latter part of the 2016 season. Throughout the excavation of Trench B, major architectural features, including the remnants of a substantial stone stairway, terraces paved with large slabs, and a number of rooms were uncovered. The investigation of Trench B identified a single phase of occupation during Dhaskalio Phase B before the immediate area was abandoned. Many of the surface features associated with this period of EBA use are constructed stone and so were unavailable for soil analysis. However, the rooms located adjacent to the stairway and paved walkways were surfaced in soil. In addition, a small deposit to the south of the trench, and dated to the main phase of occupation, may be significant in terms of craft practice. Therefore, the following section will present the results from soil chemical analysis of occupational layers from Dhaskalio Trench B.

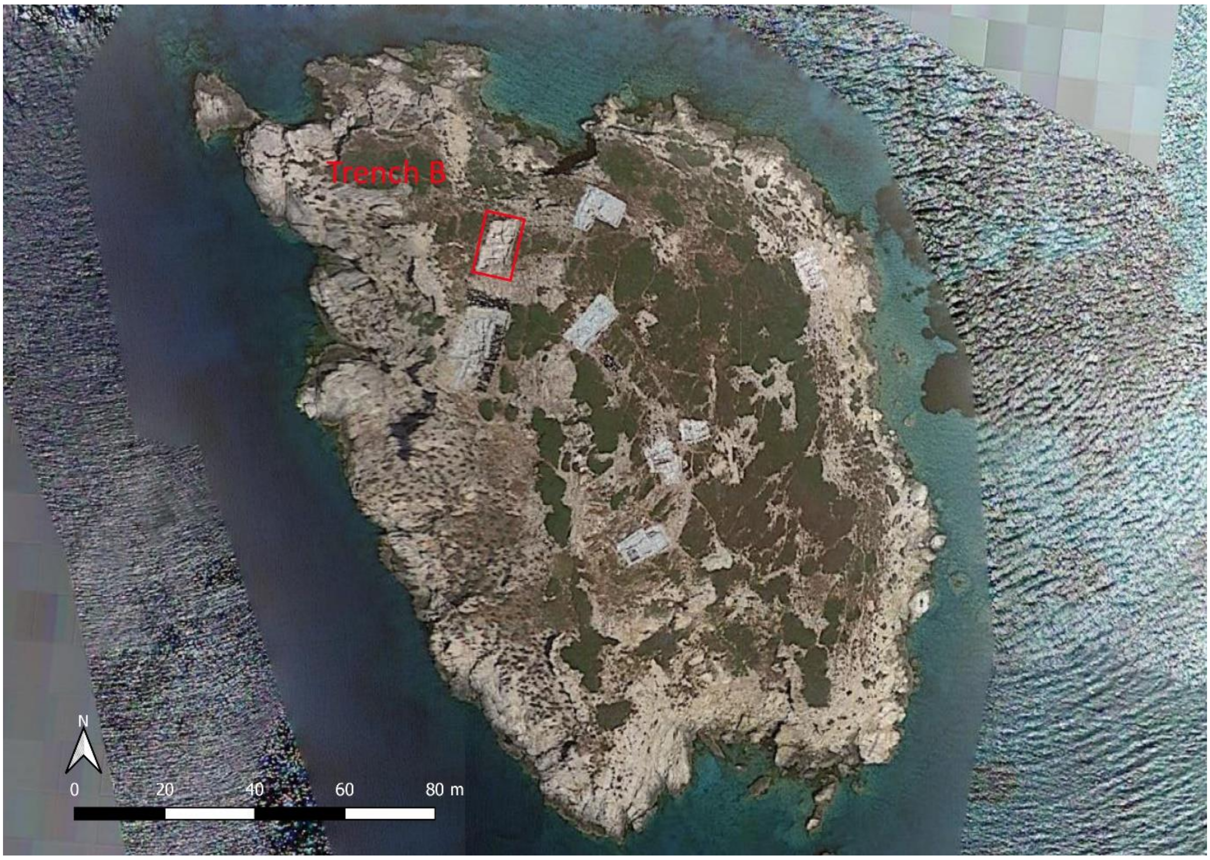

Figure 5.24: *Satellite image depicting the location of Trench B on Dhaskalio (image source: author/ Google Satellite 2021).*

Trench B: surfaces of occupation and use

Figure 5.25 displays the location of Trench B contexts identified as associated with the main phase of occupation of Trench B during Dhaskalio Phase B. A total of 61 samples across 4 contexts are included. Contexts attributed to this phase include: B-82, which represents a surface feature in room B09 to the north-east of the trench; context B-96, which is characterised as a surface layer at the base of the man staircase; context B-99, which constitutes the surface of room B03 which lies to the north-west of the trench adjacent to the large paved upper terrace above the staircase (Space B01); and feature B-112, an charcoal rich deposit in room B04 on the upper terrace to the north of the trench. As with the occupational layers from Trench A, elements chosen for spatial analysis are those which proved most informative for answering specific questions pertaining to the spatial organisation of craft practice at Dhaskalio (Pb, Cu) and which were shown through the wide-area surveys to be useful for identifying more general past use of space (Zn). Figures 5.26 to 5.28 display the spatial projections of Pb, Zn, and Cu respectively.

Figure 5.25: Image detailing the location of individual contexts associated with occupational activity in Trench B. Green represents features which are included in the spatial analysis of soil chemistry (image source: author/Keros-Naxos Seaways Project 2018).

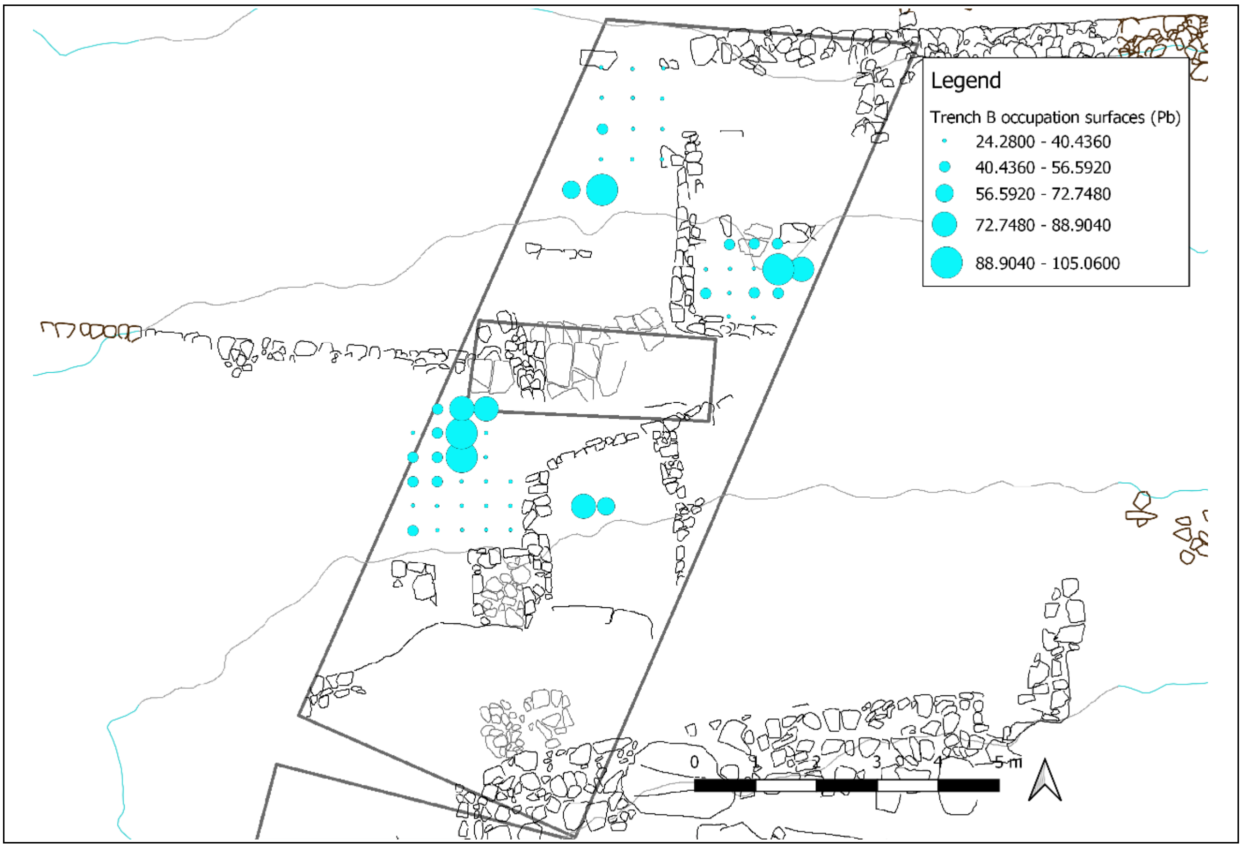

Figure 5.26: Spatial distribution of Pb concentrations from occupational contexts in Trench B. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).

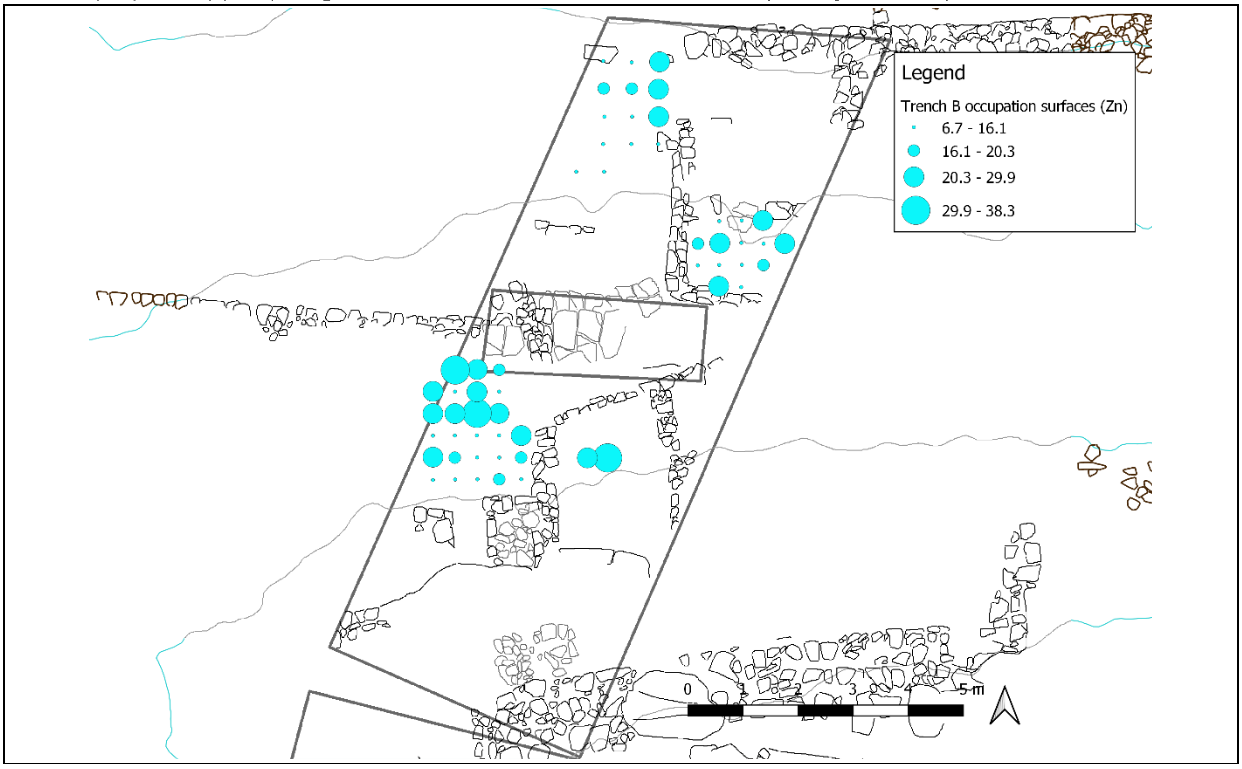

Figure 5.27: Spatial distribution of Zn concentrations from occupational contexts in Trench B. All values are displayed in ppm. Note that the value of 6.7ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).

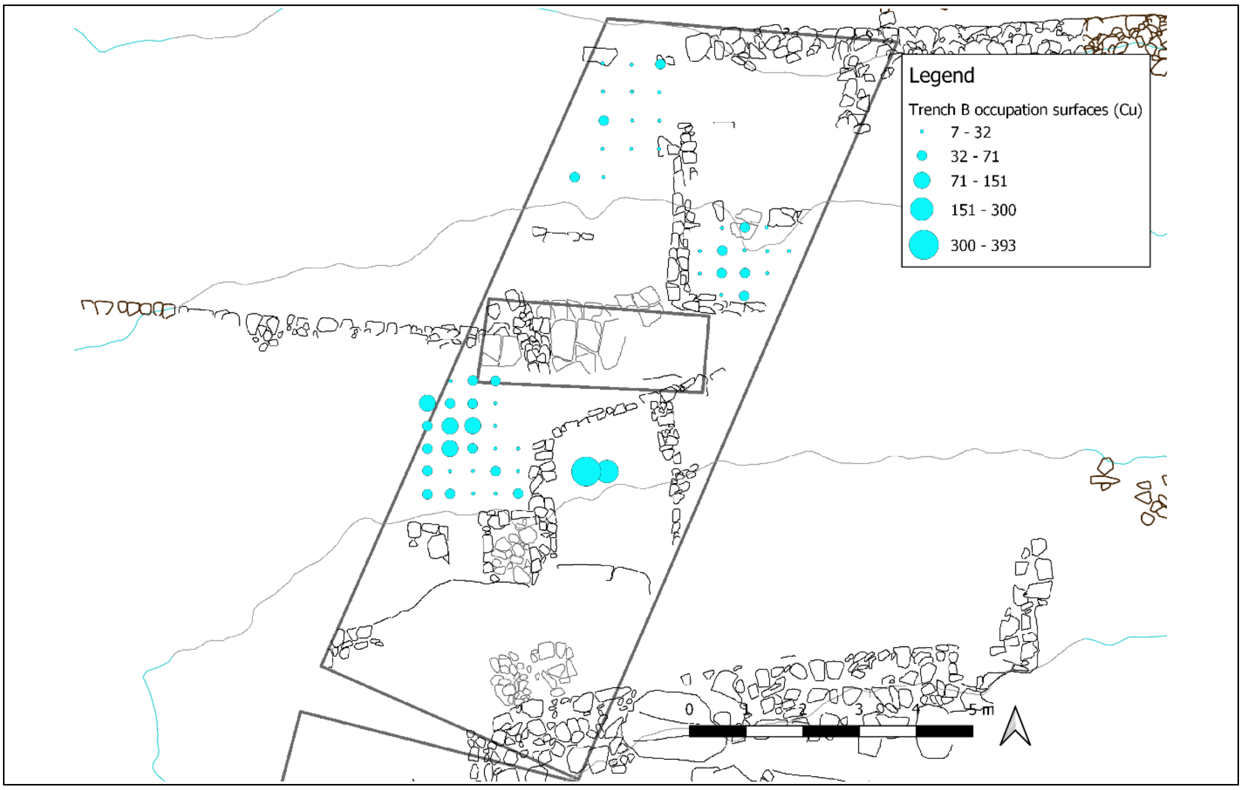

Figure 5.28: Spatial distribution of Cu concentrations from occupational contexts in Trench B. All values are displayed in ppm. Note that the value of 7 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).

Lead values range from below the limit of detection to a maximum value of 105 ppm and a mean value of 54.4 ppm across 61 samples. Unlike Trench A, Pb values are not highly elevated, and likely do not represent evidence for leadworking. However, there is observable spatial variation to in their levels. Increased concentrations of Pb are largely structured to the north of room B03 (B-99) within the access point to the paved terrace and stairway. There are also notable anomalous Pb concentrations to the south of B-96 (at the bottom of the stairway), and in room B09 (B-82). The evidence for lead metallurgy at Dhaskalio is significant, and it is likely that even areas not explicitly used for these activities would show evidence of Pb contamination through frequent use by people exposed to leadworking. Therefore, elevated concentrations of Pb which are not indicative of metalworking may be seen as a site-specific indicator of increased human activity.

The spatial distribution of Zn concentrations shows a similar pattern to Pb, with structured anomalies within the north of room B03, and to the north-east of context B-96. As with Pb, this spatial distribution of Zn concentrations is likely an indication of increased general activity.

Copper concentrations from occupational layers in Trench B range from below the limit of detection to a maximum value of 392.79 ppm. The highest concentrations of Cu were recorded from feature B-112, a charcoal rich deposit within a space on the upper terrace. Cu values from B-112 are significantly elevated (mean= 293.06 ppm across 2 points of analysis) which suggests that the deposit may contain material associated with copper metallurgy. Certainly, the elevated concentrations of Cu from B-112 are consistent with those recorded from hearth features with unambiguous connections to copper metallurgy from other areas of Dhaskalio. However, whether this feature represents the in situ contents of a metalworking hearth, or merely the redeposition of metallurgical debris is unclear through soil chemistry alone. B-122 was recorded by the excavator as belonging to a posthole, although this may be subject to change during ongoing post-excavation study.

Aside from the feature in room B04, Cu concentrations are structured towards the same general areas as seen with Pb and Zn, although not with the same concentrations associated with context B-112. These structured anomalies, again, likely reflect areas of intense general activity.

Trench B: summary

The excavation of Trench B uncovered a complex of major architectural features with rooms offset from paved terraces and a large stairway, and stratigraphic evidence suggests that these spaces were utilised for a single phase of occupation during Dhaskalio Phase B. Geochemical analysis of these occupational layers has offered insight into where human activity may have been most intensely focussed during this period, as well as aiding in the interpretation of an ambiguous depositional feature.

4.4.3 Trench C

Trench C is located on the northern extreme of Dhaskalio and measures 8 x 5.5m with a 3.5 x 3m extension to the SW of the trench (**figure 5.29**). Trench C was opened during the latter stages of the 2016 field season and excavation continued throughout the 2017 and 2018 seasons. The trench contains a number of architectural features, including large terrace walls, smaller building elements, and drainage systems. Information pertaining to precise stratigraphic relationships and phasing are not finalised at the point of writing, but a preliminary analysis suggests that the main architectural features were constructed during Dhaskalio Phase A, followed by an initial period of use in limited rooms. However, non-structural contexts for this initial phase of Trench C are limited, and the majority of the surface features were excavated as small, laminated layers within the threshold of the main access to the space. Consequently, soil chemical data for this phase is largely limited to a small number of analyses across contexts measuring <30cm. This is unhelpful for evaluating the organisation of activities during this period, which requires broader spatial analysis. Therefore, the focus for spatial characterisation of trench C will focus on latter phase of use in the area.

Figure 5.29: Satellite image depicting the location of Trench C on Dhaskalio (image source: author/ Google Satellite 2021).

The initial phase of construction and limited use was followed by a second period of construction and occupation during Dhaskalio Phase B, which is characterised by multiple resurfacing and use in the rooms to the west of the trench. A period of abandonment and reuse of space followed this main phase of occupation. The following section will report geochemical data for these phases of use. However, as with Trench A, stratigraphic relationships between reported contexts may be subject to change. Figure 5.30 shows the location of rooms and spaces for reference during the following discussion.

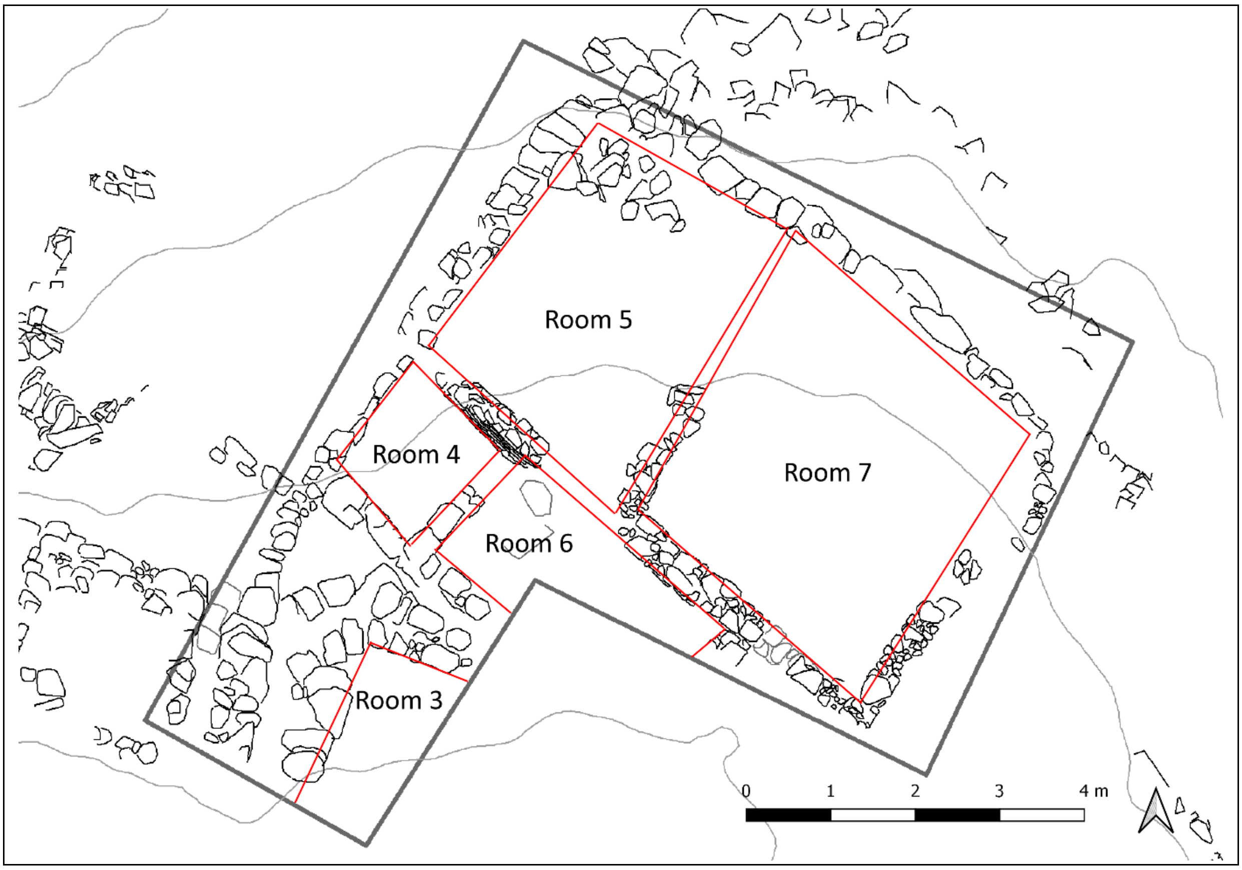

Figure 5.30: Image detailing the location of individual rooms associated with occupational activity in Trench C (image source: author/Keros-Naxos Seaways Project 2018).

Trench C: Occupation phase 2i

The second, main phase of use in Trench C is mainly limited to the rooms to the west of the trench (rooms 3, 4, and 5). This period of use likely dates to Dhaskalio Phase B or late-Phase A/B. This period saw several resurfacing events in the occupied rooms. This section will detail the spatial characteristics of soil chemistry for the earliest surface phases for this period (contexts C-100, C-139, and C-155 for a total of 38 samples). Note that C-100 is characterised as the 'makeup' of surface C-87. Soil chemical analysis was undertaken during the early stages of excavating C-87 and so was recorded as a sample for C-100.

Figures 5.31 to 5.33 display the spatial distribution of Cu, Zn and Pb respectively.

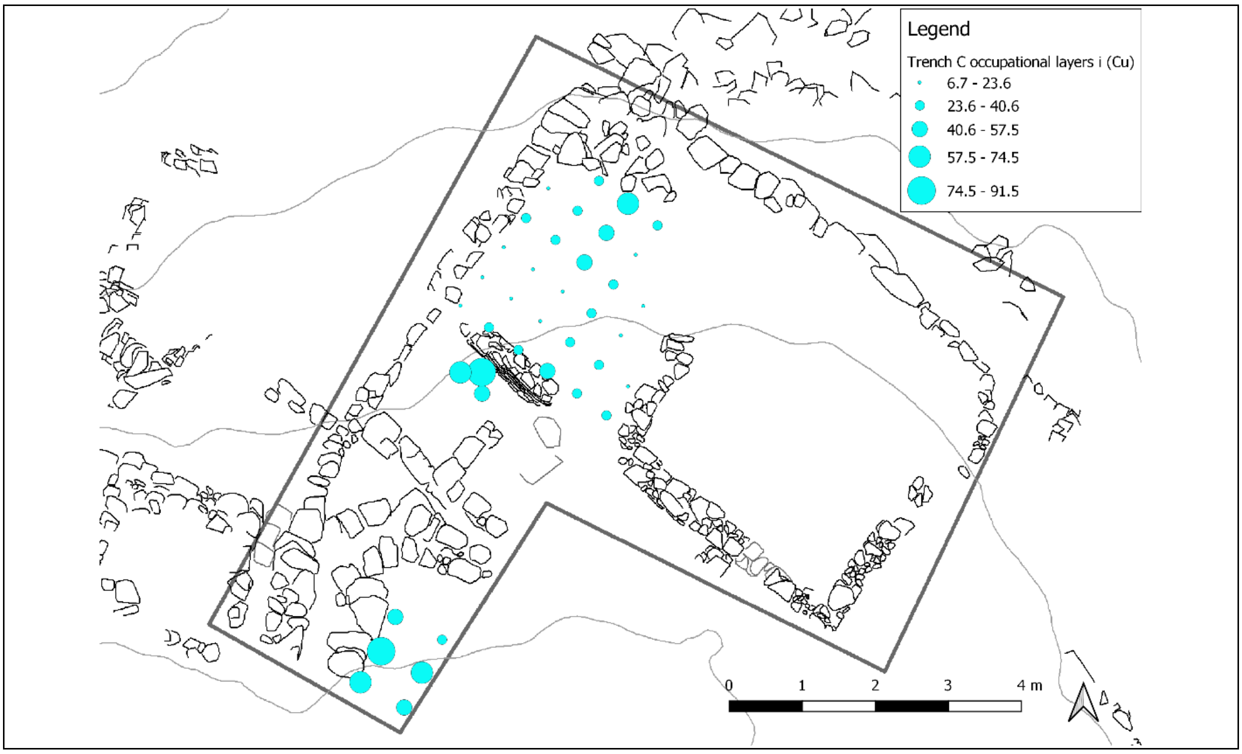

Figure 5.31: Spatial distribution of Cu concentrations from occupational phase 2(i) in Trench C. All values are displayed in ppm. Note that the value of 6.7 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).

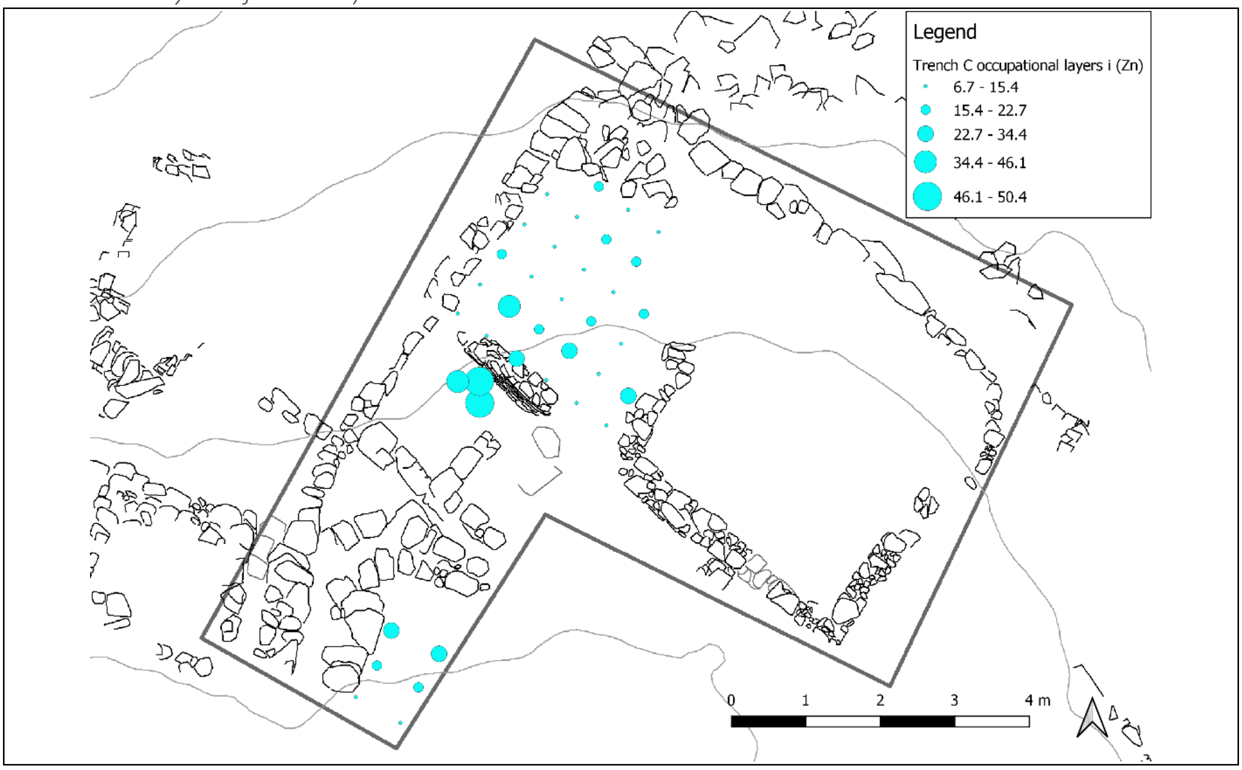

Figure 5.32: Spatial distribution of Zn concentrations from occupational phase 2(i) in Trench C. All values are displayed in ppm. Note that the value of 6.7 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).

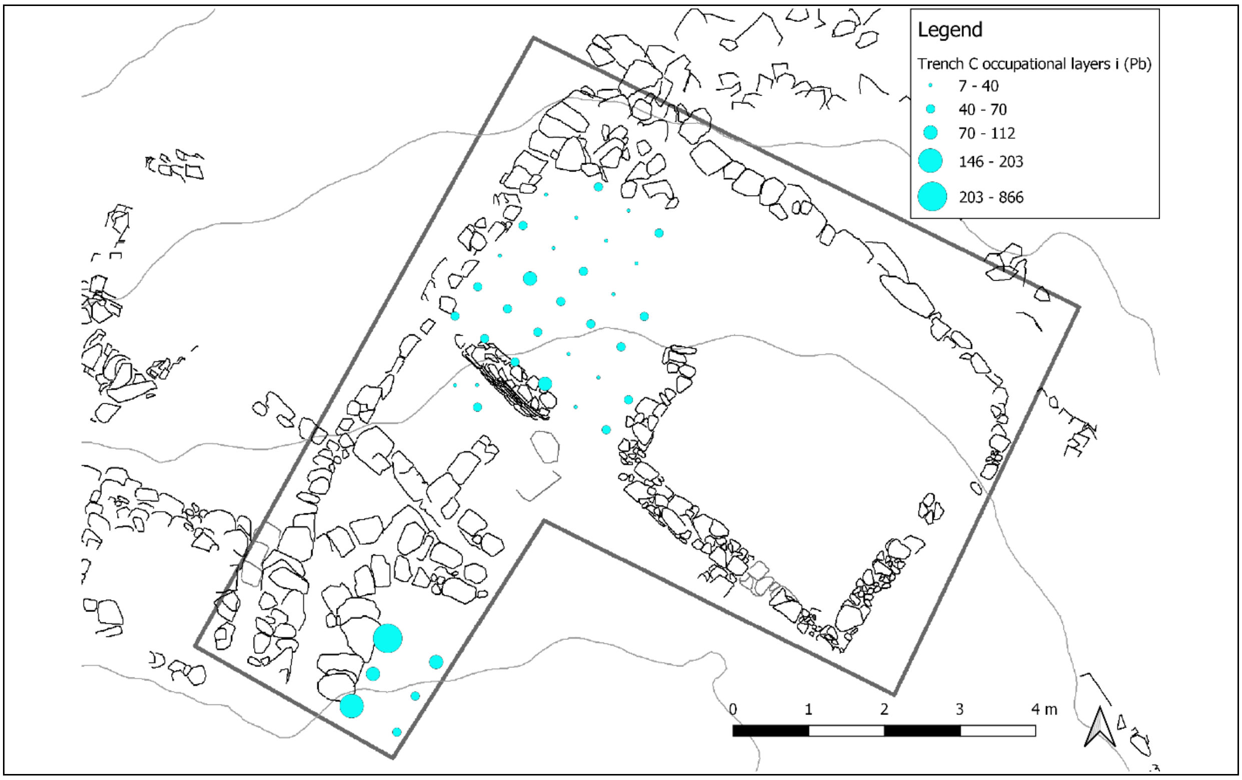

Figure 5.33: Spatial distribution of Pb concentrations from occupational phase 2(i) in Trench C. All values are displayed in ppm. Note that the value of 7 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).

Copper values from surfaces of this phase range from below the limit of detection to 91.5 ppm. These concentrations fall below the site average (146.4 ppm) and should not be considered indicative of the practice of metallurgy. Instead, areas of elevated concentrations should be regarded enhancement through a range of anthropogenic activities. The highest concentrations of Cu are structured to the north of room 4 (C-139), the north and south-east of room 5 (C-155), and within the excavated space of room 3 (C-100/87).

The spatial distribution of Zn displays a similar pattern to Cu, with elevated concentrations structured to the north of room 4, and south-east of room 5. Zn values range from below the limit of detection, to a maximum value of 50.4 ppm and, like Cu, should be considered as indicative of general human activity.

Lead concentrations are extremely varied, with values ranging from below the limits of detection, to a maximum value of 866.4 ppm. These upper values are very high and are structured favouring the excavated area of room 3 (C-100/87). No material evidence was uncovered from this context to suggest metallurgical practice was taking place in this room. However, room 3 extends beyond the trench edge and further excavation may reveal more information. Through chemical analysis alone, it is not possible to characterise the exact activity which was taking place in order to enhance soil Pb. A range of activities, such as metallurgical waste disposal, storage of lead working paraphernalia, or general contamination through intensive use by those associated with craft practice, are all possibilities.

Trench C: Occupation phase 2ii

This section will detail the spatial characteristics of soil chemistry for the second phase of surfaces for this period of occupation at Trench C. This includes contexts C-62 (room 3), C-131 (room 4), and C-137 (room 5) for a total of 48 sample points. Figures 5.34 to 5.36 display the spatial distribution of Cu, Zn and Pb respectively.

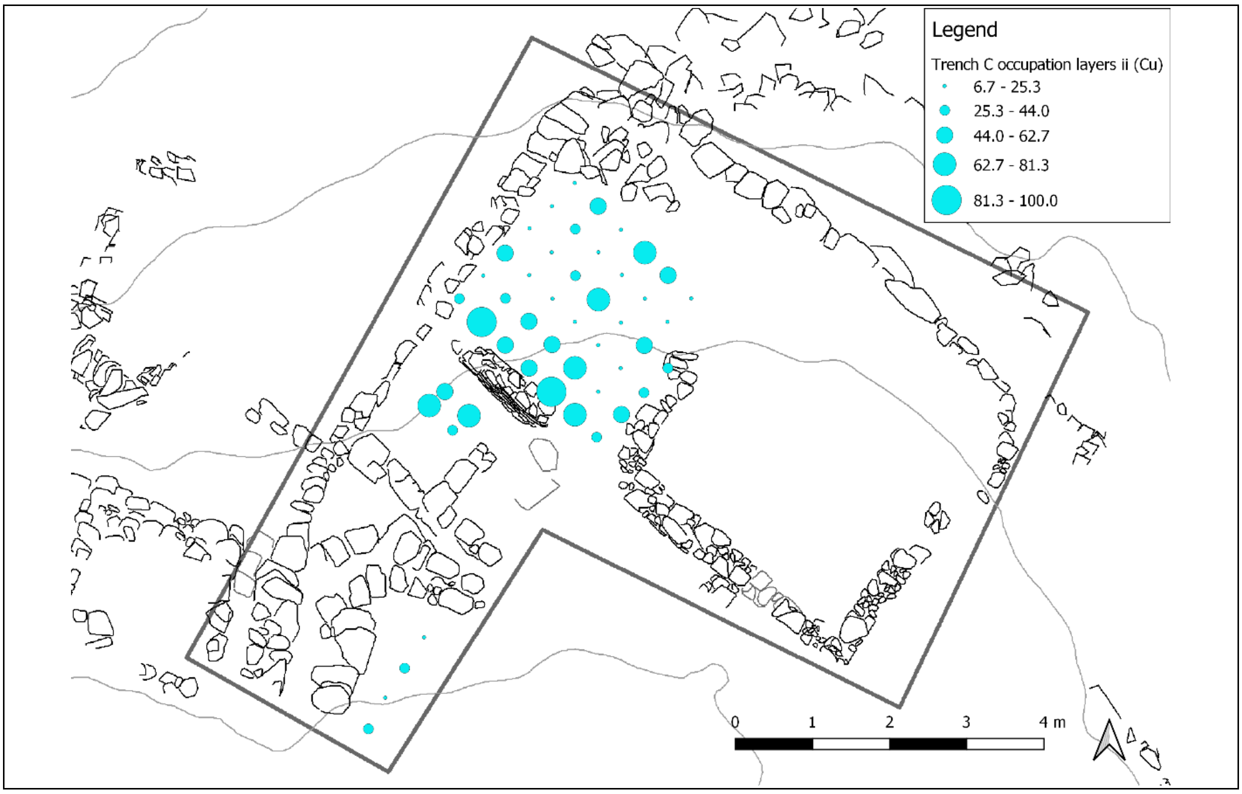

Figure 5.34: Spatial distribution of Cu concentrations from occupational phase 2(ii) in Trench C. All values are displayed in ppm. Note that the value of 6.7 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).

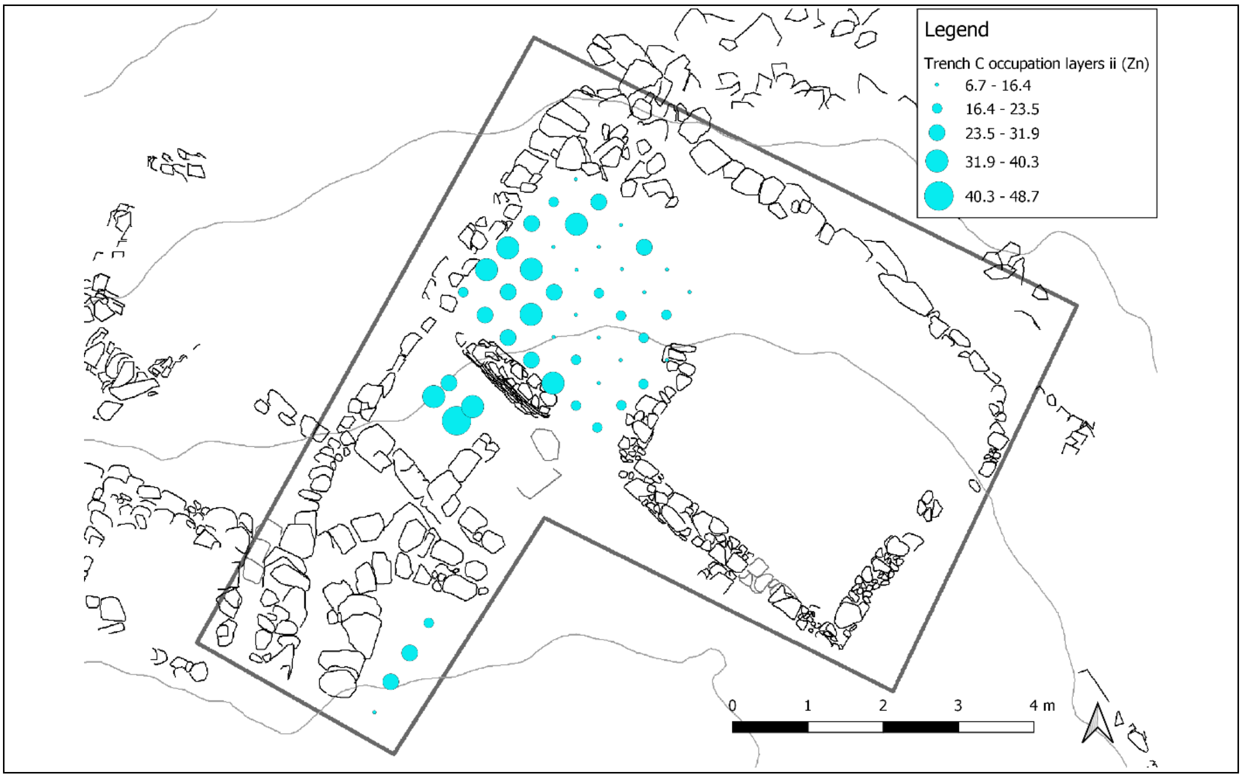

Figure 5.35: Spatial distribution of Zn concentrations from occupational phase 2(ii) in Trench C. All values are displayed in ppm. Note that the value of 6.7 ppm is proxy for < LOD (*image source: author/Keros-Naxos Seaways Project 2018*).

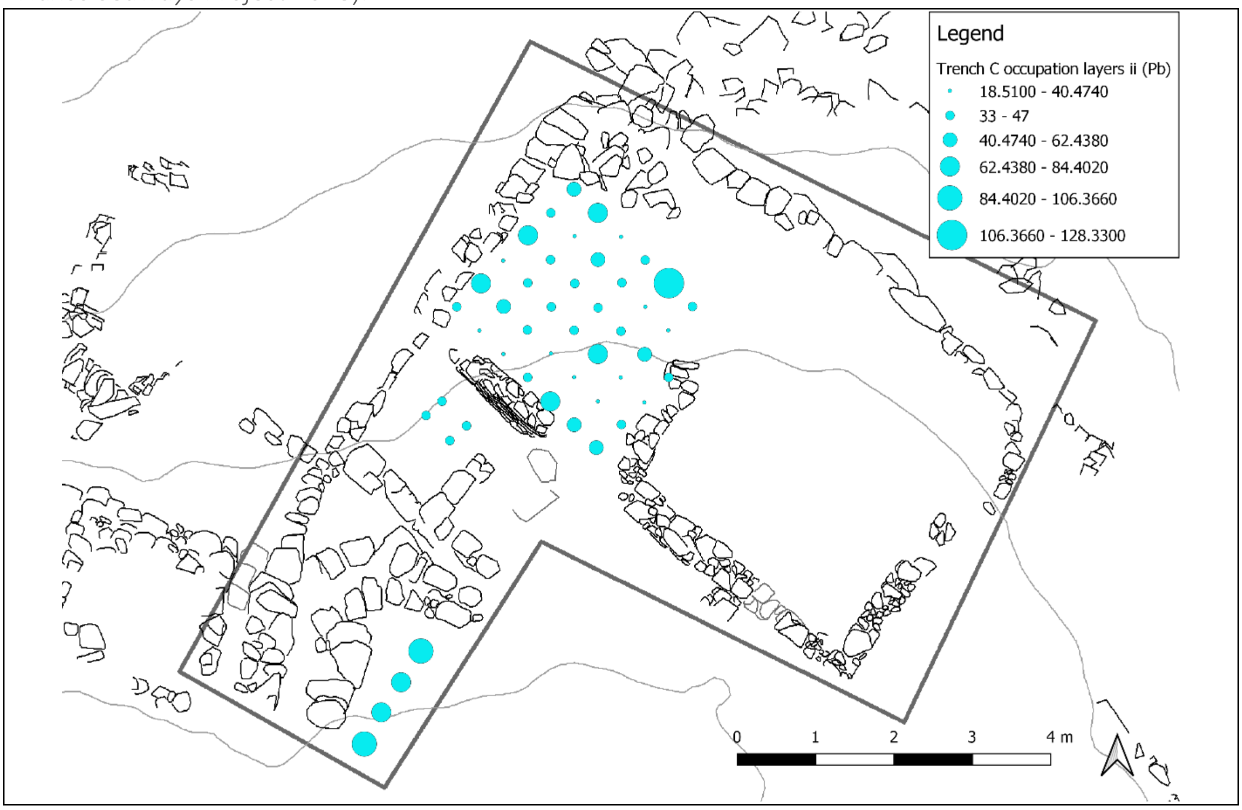

Figure 5.36: Spatial distribution of Pb concentrations from occupational phase 2(ii) in Trench C. All values are displayed in ppm (*image source: author/Keros-Naxos Seaways Project 2018*).

Copper values from the second phase of surfaces for this period range from below the limit of detection to 100 ppm. Again, these concentrations fall below the site average and are not indicative of metallurgical activity, but rather enhancement through a range of past human activities. The highest concentrations of Cu are structured within room 4 and the southern edge of room 5. Concentrations of Cu within the excavated space of room 3 are consistently low in comparison to rooms 4 and 5.

Zinc values range from below the limit of detection, to a maximum value of 48.7 ppm. Elevated concentrations are structured, again, within room 4, and the southern/south-eastern limits of room 5 and, like Cu, should be considered as indicative of increased anthropogenic activity.

Lead concentrations range from 18.5 ppm to a maximum value of 128.3 ppm. Soil Pb varies across the trench, with slight but noticeable structure to the north-west of room 5 and, again, within the excavated area of room 3. However, unlike the earlier phase of room 3 surfacing, Pb concentrations are not elevated to a level which can be considered as evidence for metallurgical activity on Dhaskalio.

Trench C: Occupation phase 2iii

The third phase of resurfacing from this period of occupation at Trench C includes contexts C-38 (room 3), C-120 (room 4), and a small surface feature within the threshold between rooms 5 and 6 (C-133). These three contexts include a total of 44 sample points. Figures 5.37 to 5.39 display the spatial distribution of Cu, Zn and Pb respectively.

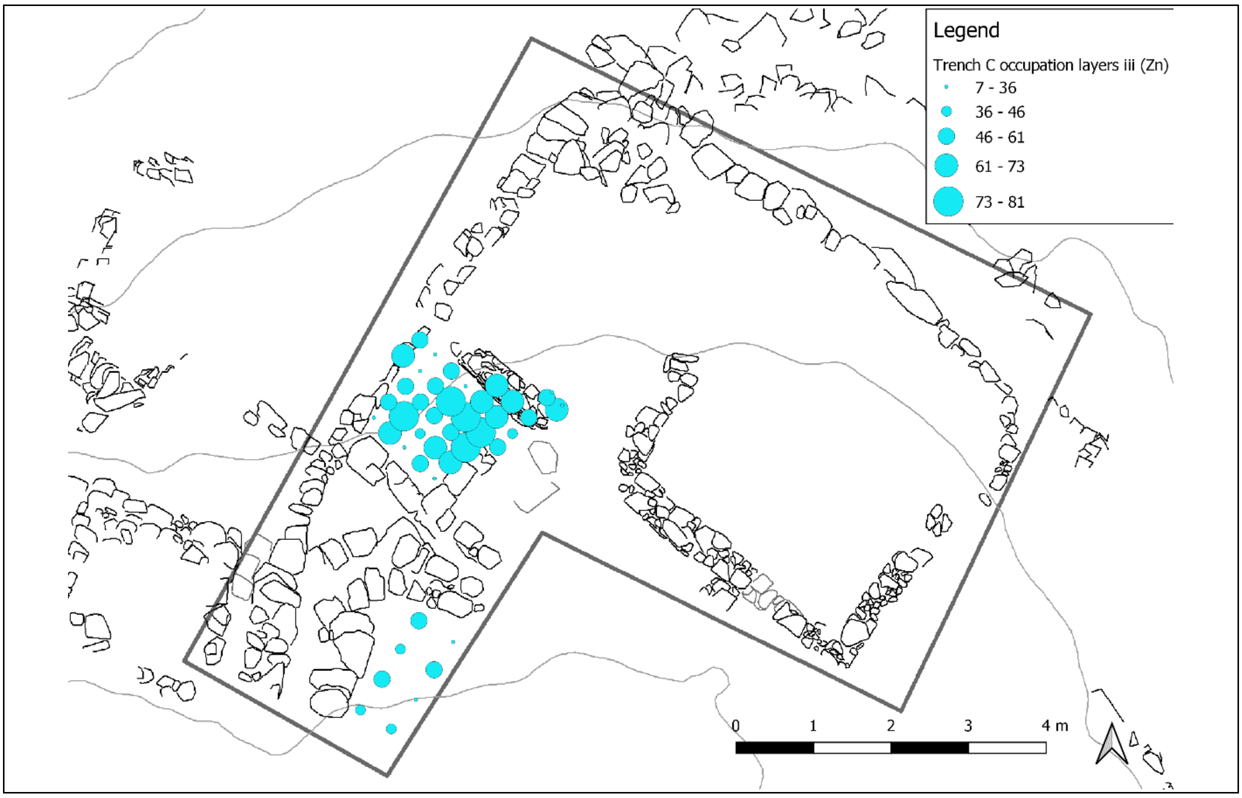

Figure 5.37: *Spatial distribution of Cu concentrations from occupational phase 2(iii) in Trench C. All values are displayed in ppm. Note that the value of 7 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).*

Figure 5.38: Spatial distribution of Zn concentrations from occupational phase 2(iii) in Trench C. All values are displayed in ppm. Note that the value of 7 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).

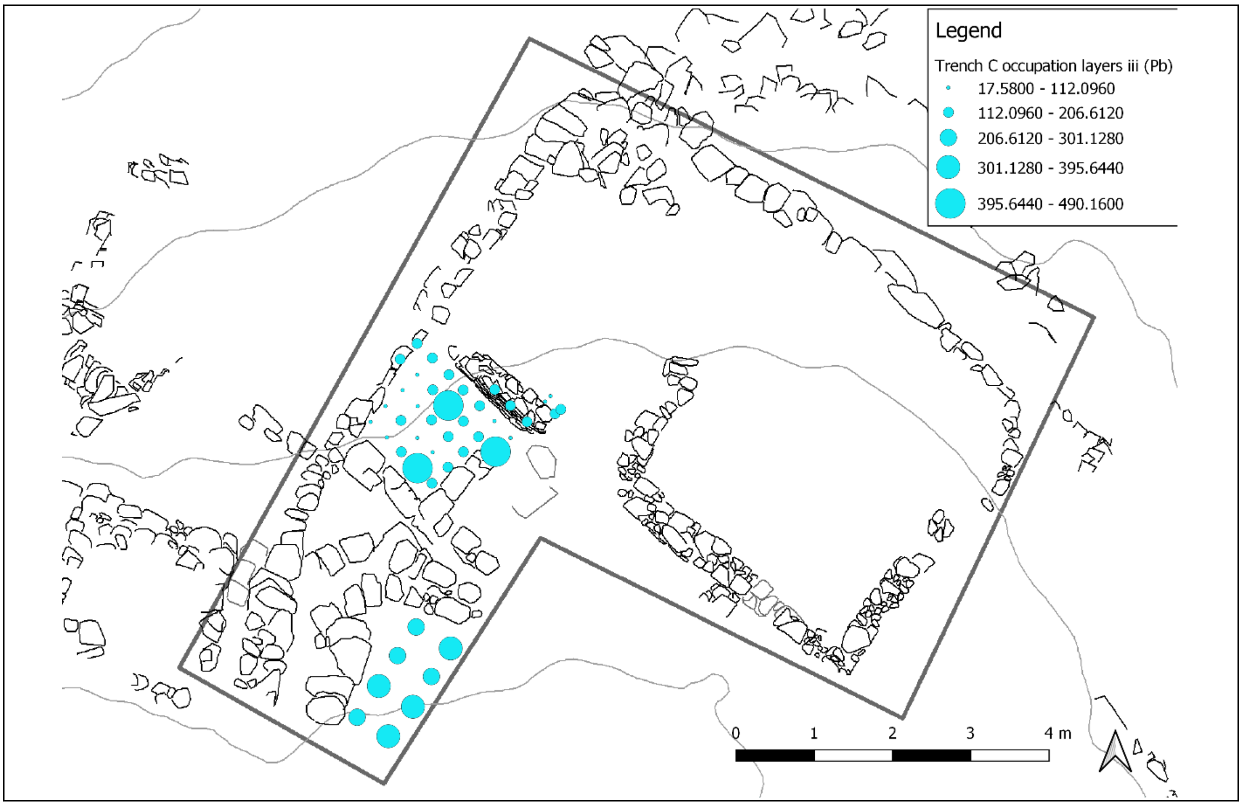

Figure 5.39: Spatial distribution of Pb concentrations from occupational phase 2(iii) in Trench C. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).

Copper values from this third phase of surfaces range from below the limit of detection to 81 ppm. The highest concentrations of Cu are structured to the north-east and central region of room 4 (C-120), as well as the region within the threshold of room 5 (C-133). These concentrations fall below the site average (146.4 ppm) and should not be considered indicative of metallurgical activity. However, areas of elevated concentrations show real structure and spatial variability, and consequently should be regarded enhancement through increased anthropogenic activity.

Zinc values range from below the limit of detection, to a maximum value of 68 ppm. The spatial distribution of zinc displays a similar pattern to Cu, with elevated concentrations structured to the north-east of room 4 which, together with the spatial distribution of Cu, suggests increased past human action in that area.

Lead concentrations are extremely varied, with values ranging from 17.6 ppm to a maximum value of 490.2 ppm. These upper values are very high and are structured favouring the excavated area of room

3 and, more sporadically, the eastern side of room 4. The highest Pb concentrations for this phase of surfaces may be considered as enhanced through lead working or contamination associated with such activities. As with the first phase of surfaces in room 3 no evidence of direct lead working was uncovered from this context. However, multiple pieces of worked stone, obsidian, and a small nondiagnostic piece of copper were recorded with this context. This mixed assemblage, largely of objects pertaining to craft practices, may suggest that this area was used as a workshop, although an area of industrial waste disposal is just as viable. Pb concentrations display little spatial variability within the excavated area of room 3, suggesting that whatever process led to its enhancement was not focused in a specific area. However, without data for the remainder of the room, no conclusions as to specific past human practice can be made through soil chemistry.

Trench C: occupation phase 3 - reuse phase

The final phase of occupation at Trench C can be characterised as a 'reuse' phase, since it appears after a period of abandonment and collapse of some structural features during the latter period of Dhaskalio Phase B. Only one surface (C-94), located in room 7, was excavated from this late phase of occupation. Therefore, the following spatial analysis includes two large spreads of depositional debris within the seemingly abandoned areas of rooms 4 (C-104) and 5 (C-83) for a total of 25 points of analysis. Figures 5.40 to 5.42 display the spatial distribution of Cu, Zn and Pb respectively.

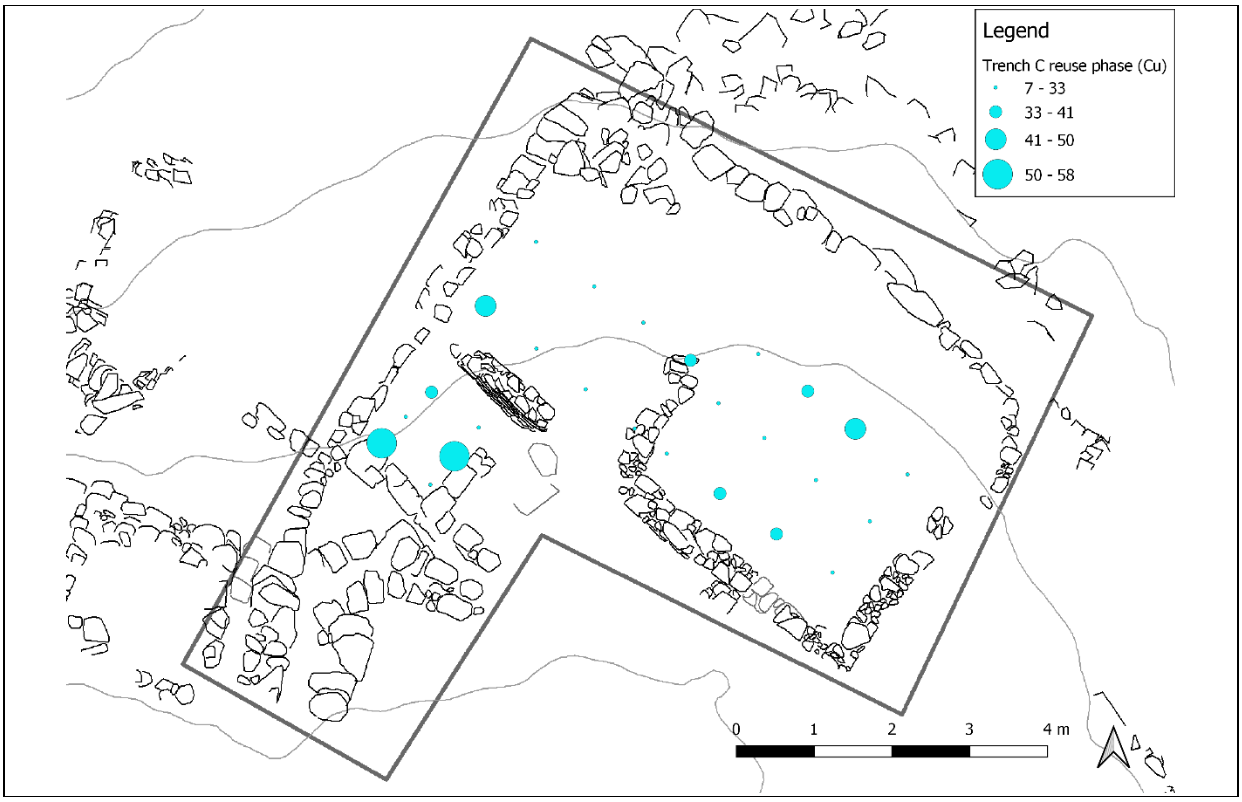

Figure 5.40: Spatial distribution of Cu concentrations from occupational 'reuse' phase in Trench C. All values are displayed in ppm. Note that the value of 7 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).

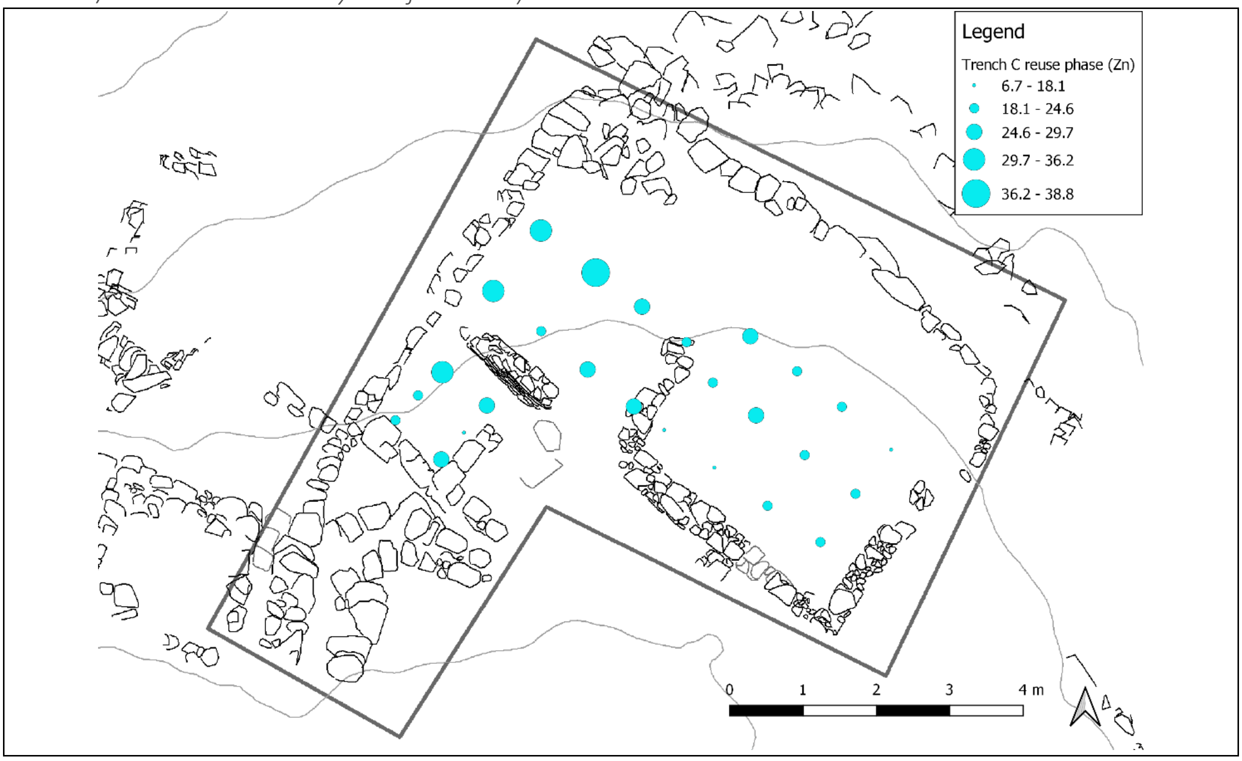

Figure 5.41: Spatial distribution of Zn concentrations from occupational 'reuse' phase in Trench C. All values are displayed in ppm. Note that the value of 6.7 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).

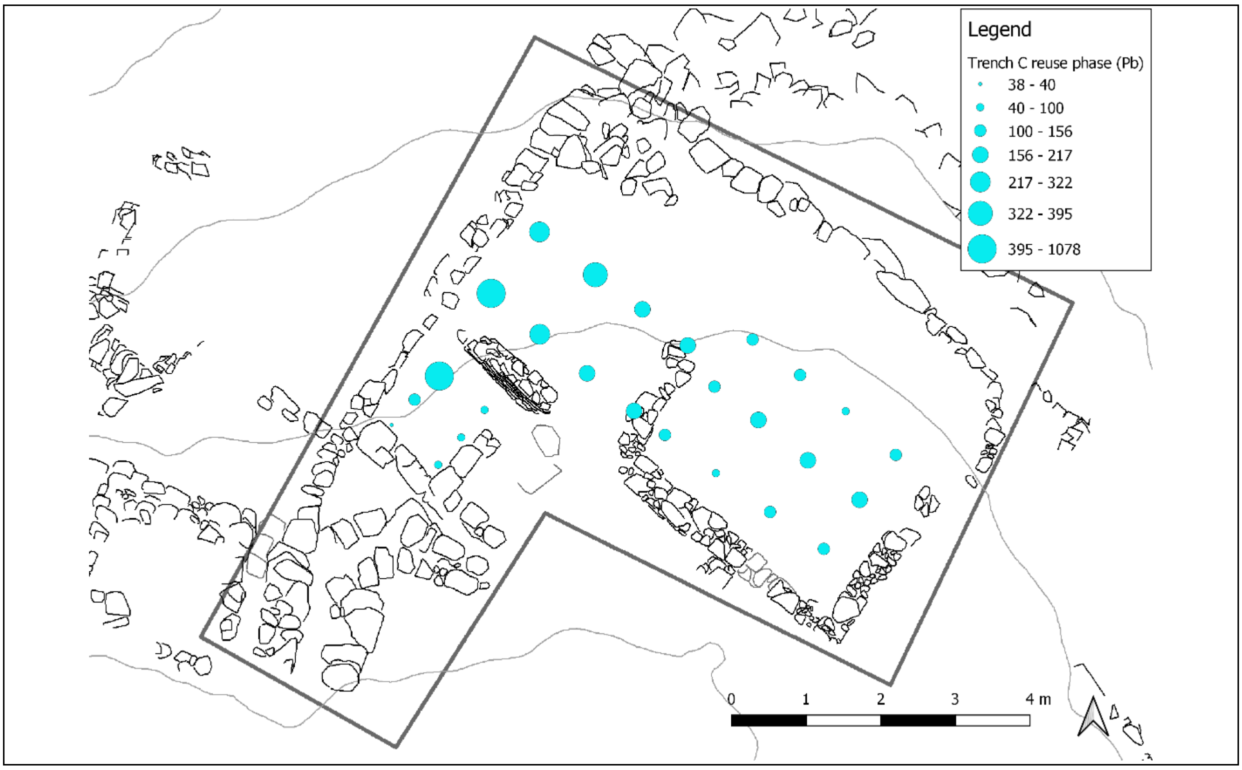

Figure 5.42: Spatial distribution of Pb concentrations from occupational 'reuse' phase in Trench C. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).

Copper values range from below the limit of detection to 58 ppm. There is very little structure to Cu concentrations, suggesting that enhancement was not achieved through routine human action. Instead, the spatial patterning suggests a more sporadic contamination process which may be associated with collapsing structure, or random, yet deliberate deposition of waste.

Zinc values range from below the limit of detection, to a maximum value of 38 ppm, ,which are low in comparison to previous phases of Trench C. The spatial distribution of zinc displays some structure towards the west of the trench but, largely, spatial variability is low. The relatively low concentrations of Zn, alongside the relative lack of spatial structure, suggests that human activity was not routine in this area. Both Zn and Cu are essential nutrients for living organisms (Kabata-Pendias and Pendias, 1984: 81: 104-5) and so can occur in archaeological soils as a result of occupational waste (Oonk et al., 2009b). This interpretation is consistent with the spatial patterning of Cu and Zn from this phase of Trench C occupation.

Lead concentrations range from 38.3 ppm to a maximum value of 1078.2 ppm. These upper values are very high. There is some observable structure, again favouring the western area of the trench, however, spatial variability is relatively low as compared to previous phases of occupation. This suggests that whatever process led to soil Pb enhancement was not limited in a specific space but remained consistent across the wider area. Therefore, these high concentrations of Pb are unlikely to have been caused by metallurgical practice, which would generally be evidenced by distinct special structure towards areas of increased practice.

Trench C: summary

The characterisation of two occupational phases at Trench C through geochemical analysis has demonstrated a potential change of use between the two periods. Initially, routine human action appears to have been the norm. This is suggested by the structured concentrations of anthropogenically significant elements within specific areas of the architectural spaces. This period of routine occupation was followed by a phase of abandonment and subsequent reuse. The spatial variability of Cu, Zn, and Pb are low during this period, suggesting that these chemical enhancements were not caused by repeated domestic or craft practice. Instead, this evidence is likely indicative of depositional practices or 'natural' processes related to abandonment and collapse of surrounding features.

4.4.4 Trench E

Trench E is located on the upper terrace of Dhaskalio, to east of the central summit area (**figure 5.43**). The trench measures 4 x 5m and was opened during the 2017 field season in order to explore several architectural features, including a significant passageway/stairway built into the upper terrace and leading to the central summit region of the settlement. Whilst this is an important archaeological feature for interpreting movement through the settlement, the stone-built structures dominating Trench E did not provide much opportunity for soil chemical analysis of Early Bronze Age layers. Whilst routine analysis was applied to the layers of collapse and soil build-up which preceded the EBA structures in the excavation sequence, the only notable area of Trench E to present a surface deposit built from soil measured >1m². Spatial characterisation of these surfaces in isolation would not add interpretive value to the results presented in this chapter. Therefore, until phasing and stratigraphic relationships have been finalised across the site, in which case contemporaneous surfaces from across all trenches may be analysed concurrently, data from Trench E will only be used for broader contextual discussion.

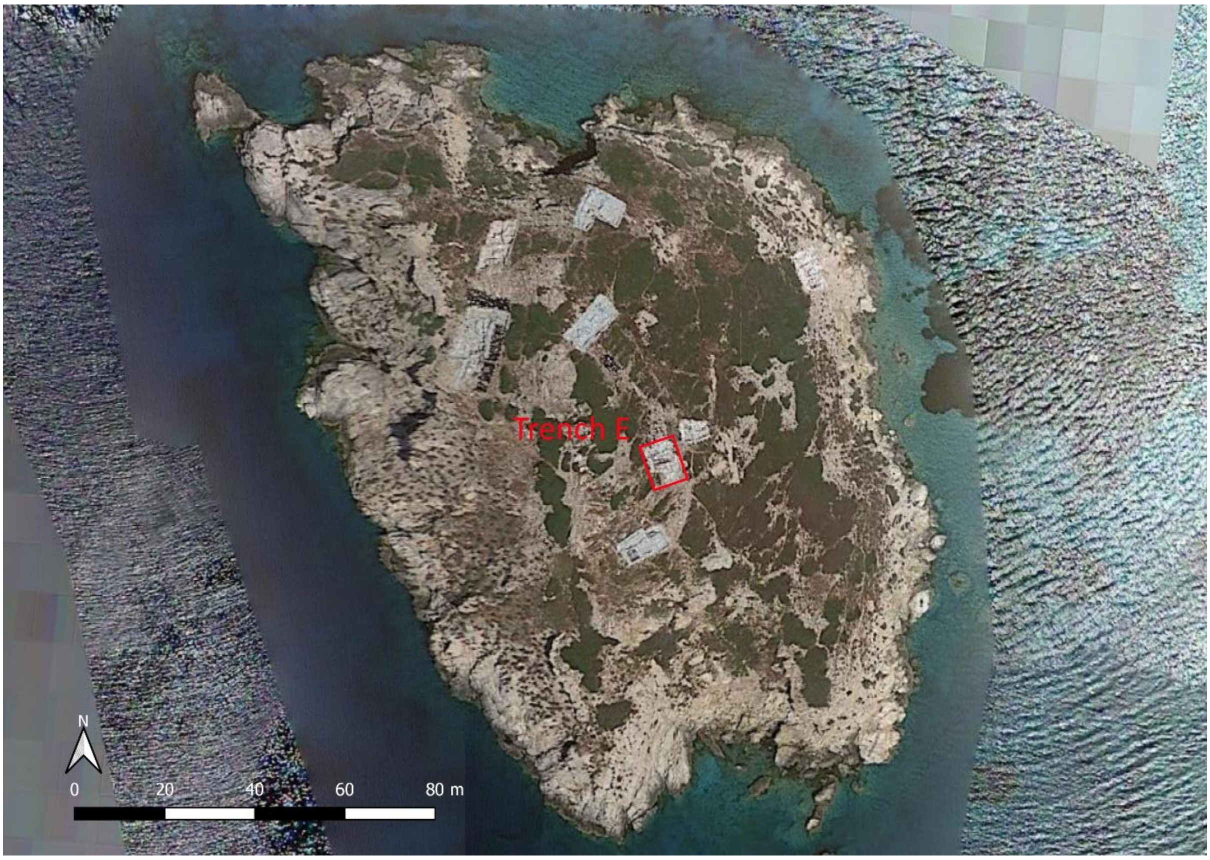

Figure 5.43: *Satellite image depicting the location of Trench E on Dhaskalio (image source: author/ Google Satellite 2021).*

4.4.5 Trench F

Trench F is located at the southern extent of the central summit area of Dhaskalio (**figure 5.44**) and was opened at the start of the 2016 field season, with excavation continuing throughout the 2017 season. The trench measures 10 x 5m and contains a number of architectural features including defined rooms and passageways. Precise stratigraphic relationships of surface features have yet to be finalised for Trench F (at the time of writing). However, preliminarily interpretation suggests that the terrace walls and rooms were constructed and occupied during Dhaskalio Phase C, although layers beneath the surface features associated with this phase may be earlier. The following section will report the spatial analysis of geochemical data from surfaces attributed to this main phase (Dhaskalio Phase C) of occupation.

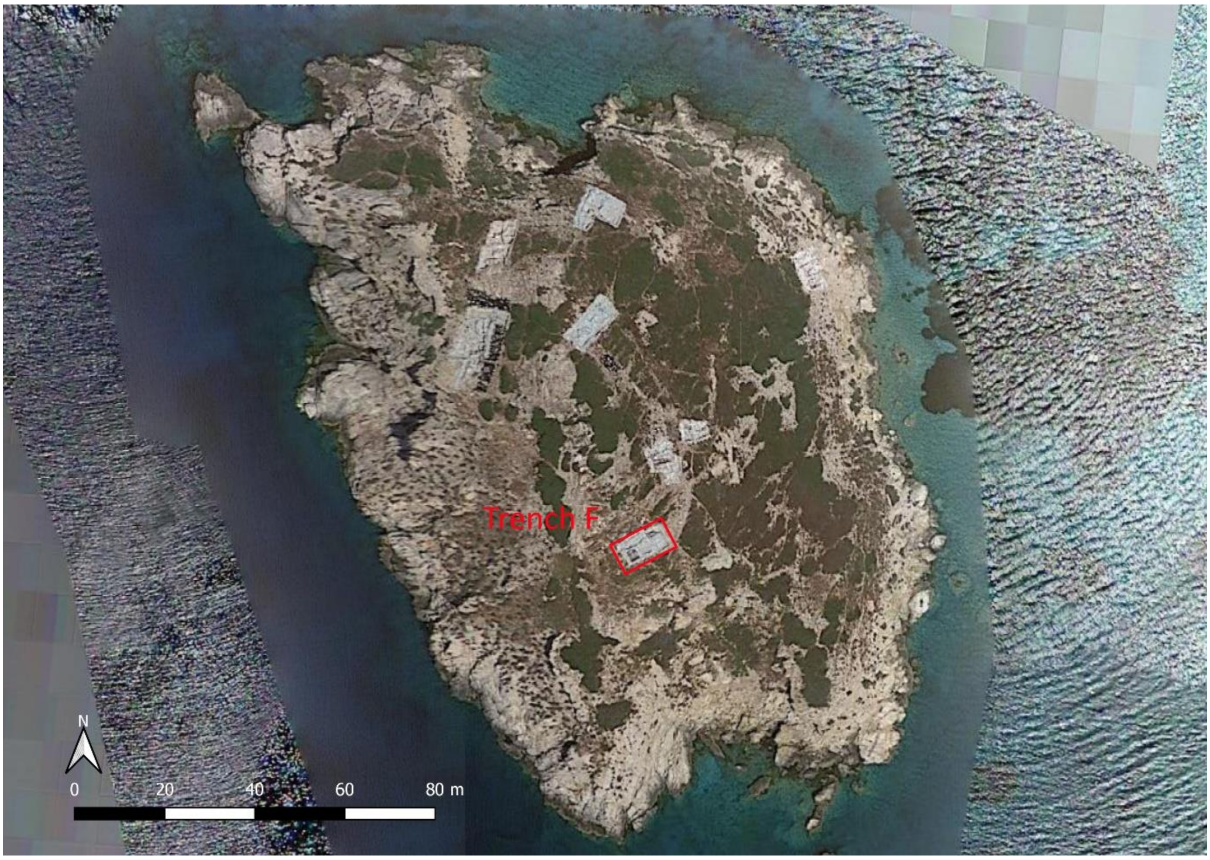

Figure 5.44: *Satellite image depicting the location of Trench F on Dhaskalio (image source: author/ Google Satellite 2021).*

Trench F: occupation phase

Figure 5.45 displays the location of Trench F contexts identified as surfaces associated with the main phase of occupation of during Dhaskalio Phase C. Three contexts are attributed to this phase, and include: F-10, which represents the surface of room 3 which sits immediately above the terrace wall;

context F-54, a Phase C surface form room 1; and F-56, which is located in the corridor between rooms. These three contexts include 50 points of analysis. Figures 5.46 to 5.48 display the spatial projections for Cu, Zn, and Pb values respectively.

Figure 5.45: Image detailing the location of individual contexts associated with occupational activity in Trench F. Green represents features which are included in the spatial analysis of soil chemistry (image source: author/Keros-Naxos Seaways Project 2018).

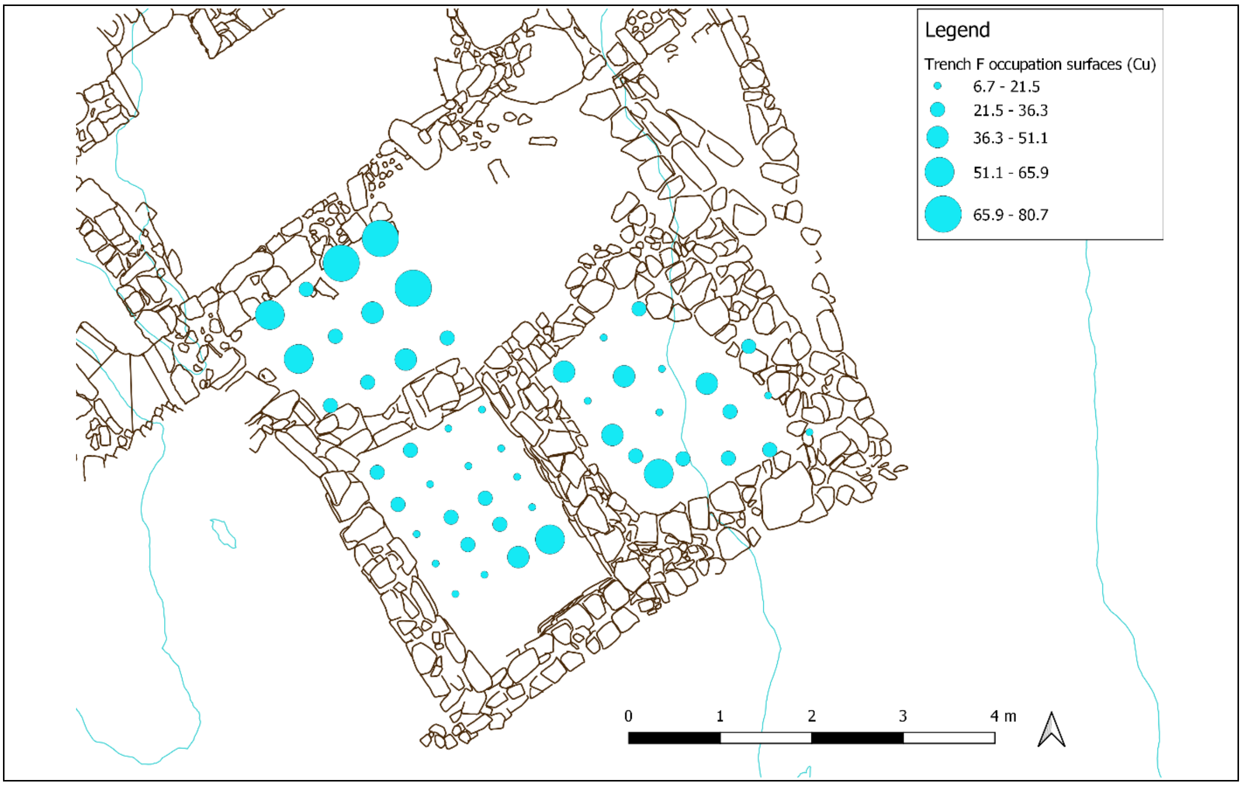

Figure 5.46: *Spatial distribution of Cu concentrations from occupational layers in Trench F. All values are displayed in ppm. Note that the value of 6.7 ppm is proxy for < LOD* (*image source: author/Keros-Naxos Seaways Project 2018*).

Figure 5.47: *Spatial distribution of Zn concentrations from occupational layers in Trench F. All values are displayed in ppm. Note that the value of 7 ppm is proxy for < LOD* (*image source: author/Keros-Naxos Seaways Project 2018*).

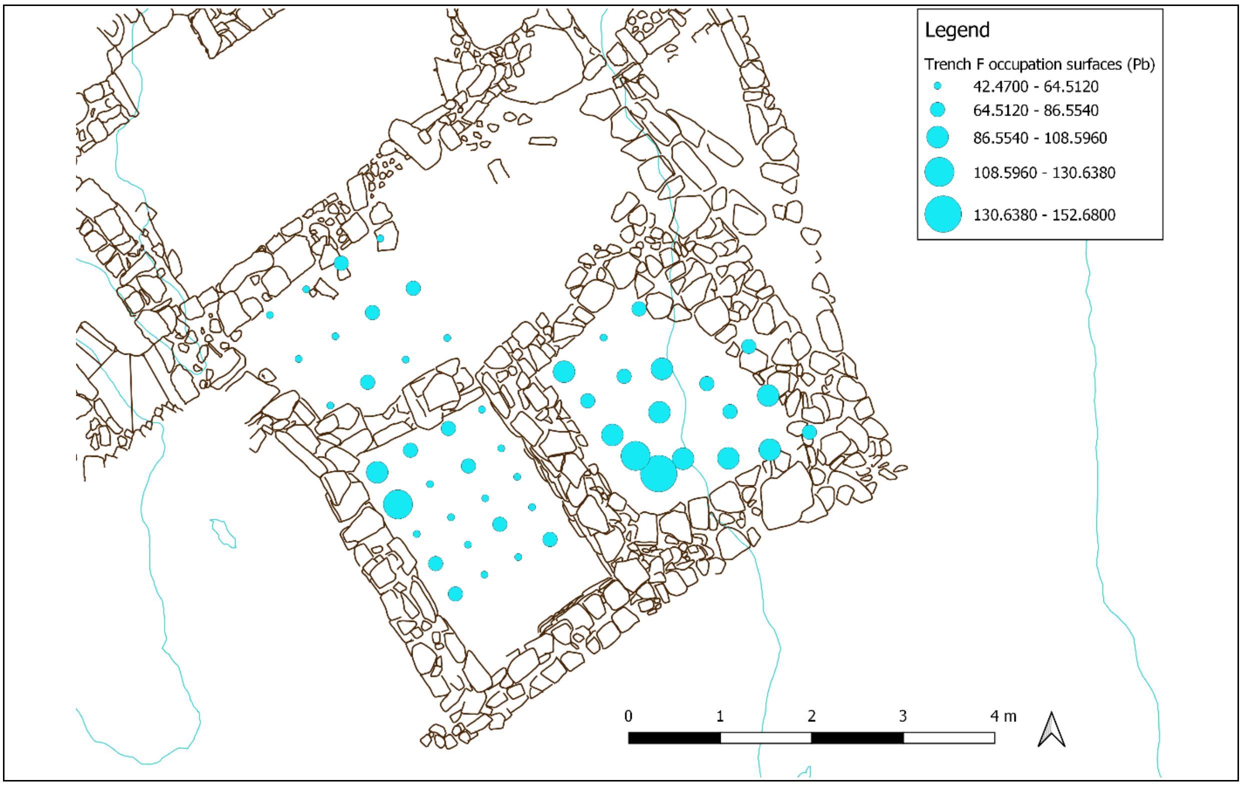

Figure 5.48: Spatial distribution of Pb concentrations from occupational layers in Trench F. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).

Copper concentrations range from below the limit of detection to a maximum value of 80.7 ppm across the 50 sample points. They vary across the trench (RSD=66.3%) with significant structure to the highest values. The highest concentrations of Cu are in the north-west of the trench, within the area associated with context F-62. Further structure can be seen to the south-west of F-10, and the east of F-54. Copper is present at levels which should be considered enhancement through a range of anthropogenic activities.

Zinc values range from below the limit of detection, to a maximum value of 42.6 ppm. As with Cu, the distirbution of Zn is varied across the context, with high concentrations structured favouring the east of context F10 (room 1). Further structure can be seen to the west of F-56, which represents the entrance to the Trench F building complex from the central summit region of the site. As with Cu, Zn concentrations are present at levels which might be considered indicative of a broad range of human practices.

Lead concentrations range from 42.5 ppm to a maximum value of 152.7 ppm. They are elevated across the trench (mean=73.6 ppm across 50 samples), yet significant structure to the highest values are observed to the south-west of room 1 (F-10), and the north-west of room 3 (F-54). Whilst soil Pb levels are relatively high throughout the trench, they should not be considered as evidence for in situ metalworking. Instead, anomalous concentrations of Pb which are not indicative of metalworking may be seen as a site-specific indicator of increased human activity.

Trench F: summary

The building complex at Trench F was likely constructed and occupied during Dhaskalio Phase C, which represents the final phase of EBA use on the site. Geochemical data has provided evidence for increased human activity, especially in room 1 (F-10) and the corridor area (F-56). However, concentrations of Cu and Pb are not present at levels consistent with metalworking activities. Instead, alongside structured anomalies of Zn, these concentrations should be considered enhancement through a range of anthropogenic activities and increased use of space.

4.4.6 Trench H

Trench H is located on the eastern extreme of Dhaskalio with overlooks Kavos, Keros (**Figure 5.49**). The trench measures ~8 x 8m and contains a number of architectural features including defined rooms, a drainage system and, significantly, a stone stepped passageway. This passageway is postulated to be an access point which served to link Kavos to the site of Dhaskalio during the EBA. The stratigraphic sequence of Trench H has determined three phases of occupation spanning Dhaskalio Phases A and B. Within the initial phase, the main architectural space (rooms 1 and 2) witnessed several resurfacing events. The following section reports geochemical results for the main surface features from each phase of occupation. This will include three distinct spatial interpretations from occupation phase 1, one from occupation phase 2, and one from occupation phase 3. Figure 5.50

displays a plan of Trench H with rooms 1 and 2 labelled as reference for subsequent geochemical interpretation.

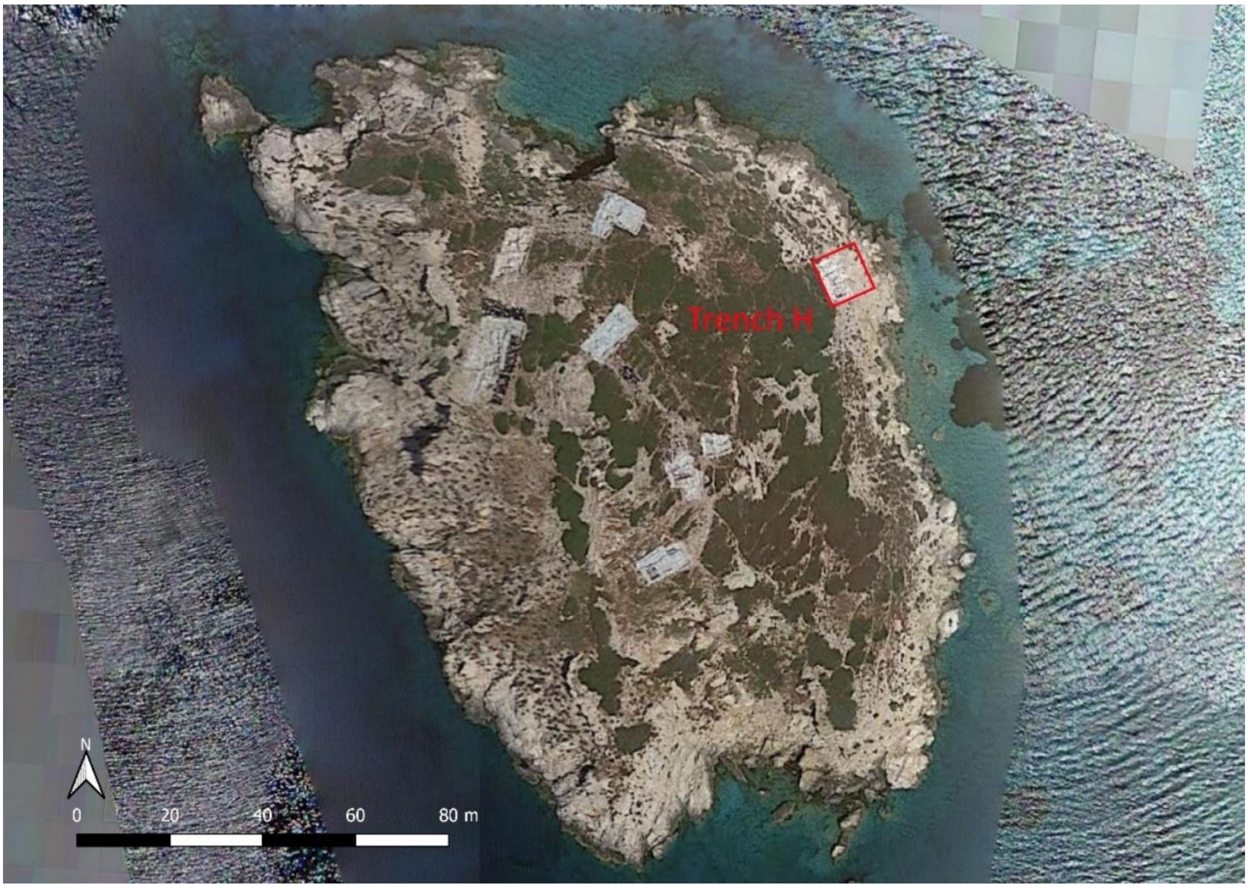

Figure 5.49: Satellite image depicting the location of Trench H on Dhaskalio (image source: author/ Google Satellite 2021).

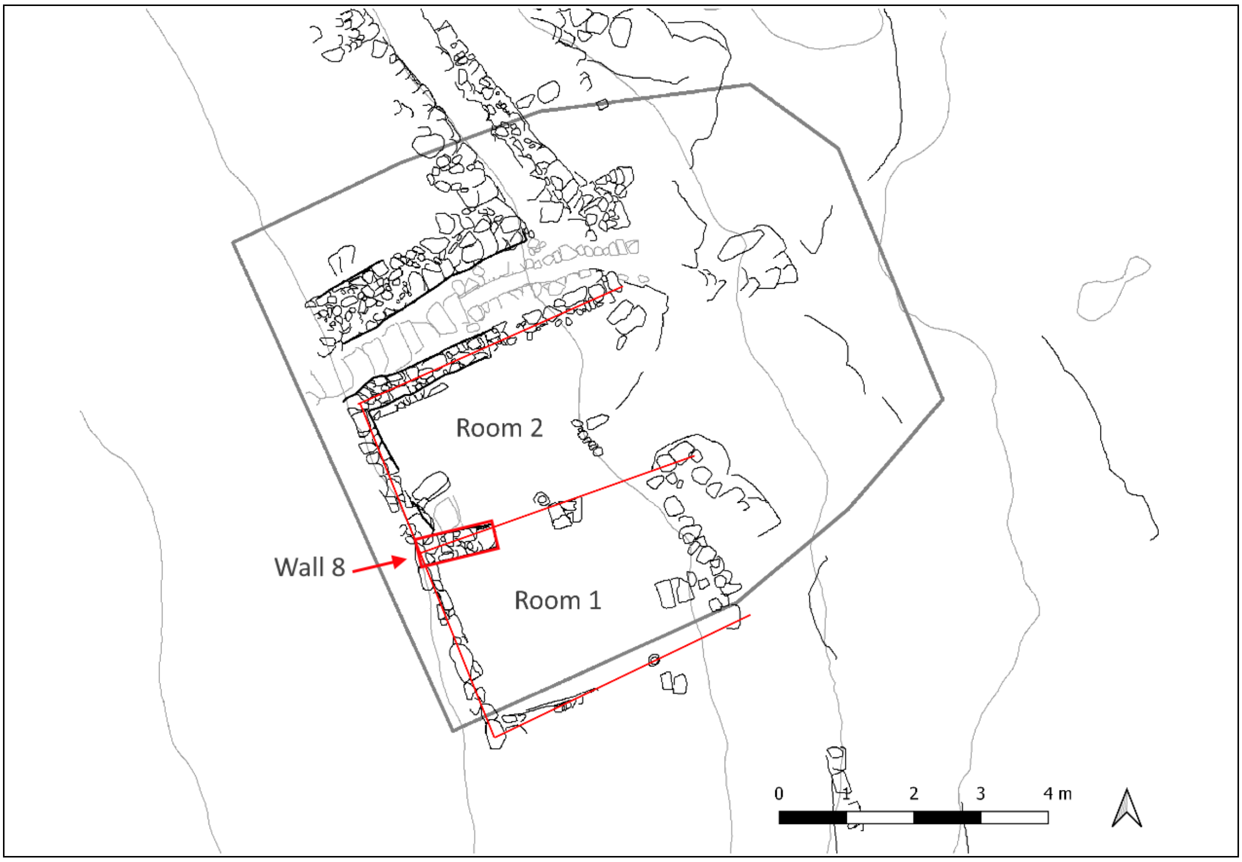

Figure 5.50: Image detailing the location of rooms 1 and 2, as well as wall 8 in Trench H (image source: author/Keros-Naxos Seaways Project 2018).

Trench H: occupation phase 1i

Evidence suggests that the area of Dhaskalio represented by Trench H was first constructed and occupied during Dhaskalio Phase A. During this initial phase, the wall separating rooms 1 and 2 (wall 8) was yet to be constructed. Therefore, whilst these areas will be referred to as 'room 1' and 'room 2' during the following analysis, this region can be considered as one coherent space during the initial phases of occupation. Figures 5.51 and 5.52 display the spatial variation of geochemical results for Cu and Pb from the first surfaces of Trench H occupation phase 1. Contexts include H-153 (room 2), H-103 (north/centre of room 1), and H-166 (southern extent of room 1) for a total of 176 samples.

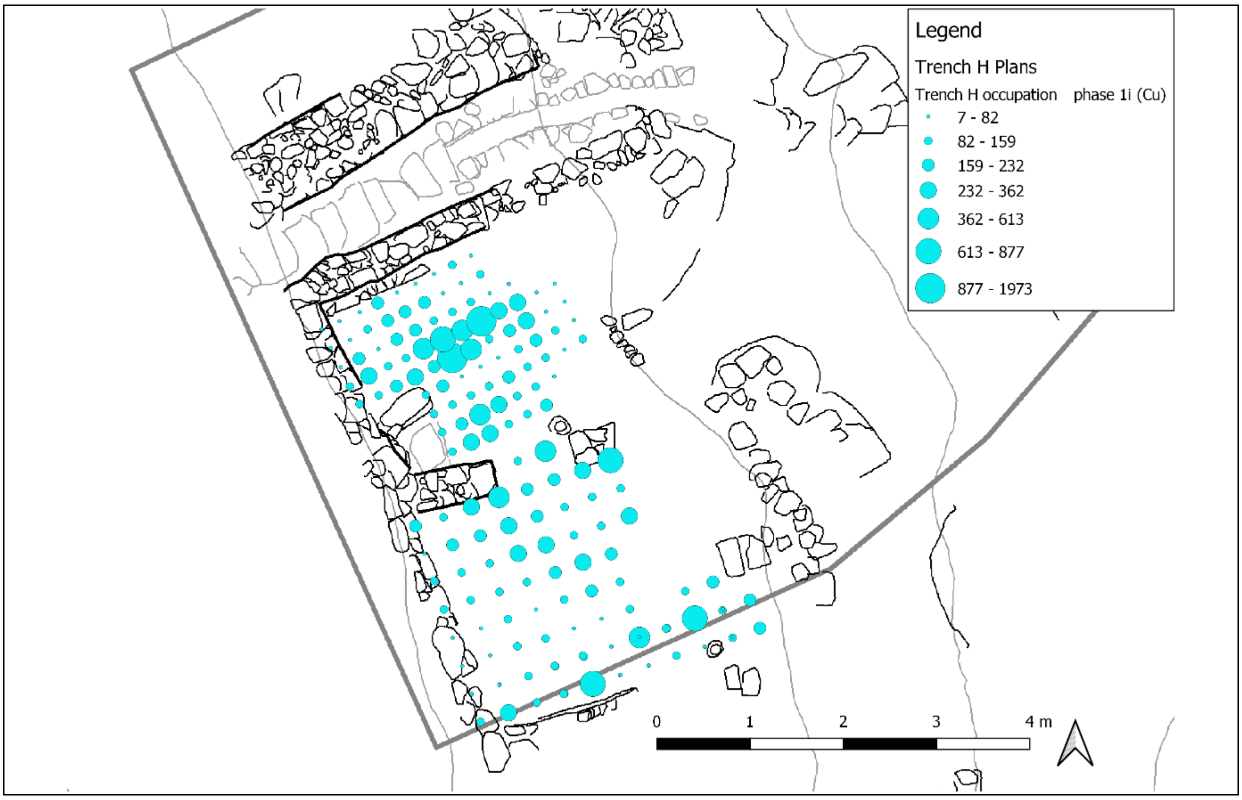

Figure 5.51: *Spatial distribution of Cu concentrations from occupation phase 1i in Trench H. All values are displayed in ppm. Note that the value of 7 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).*

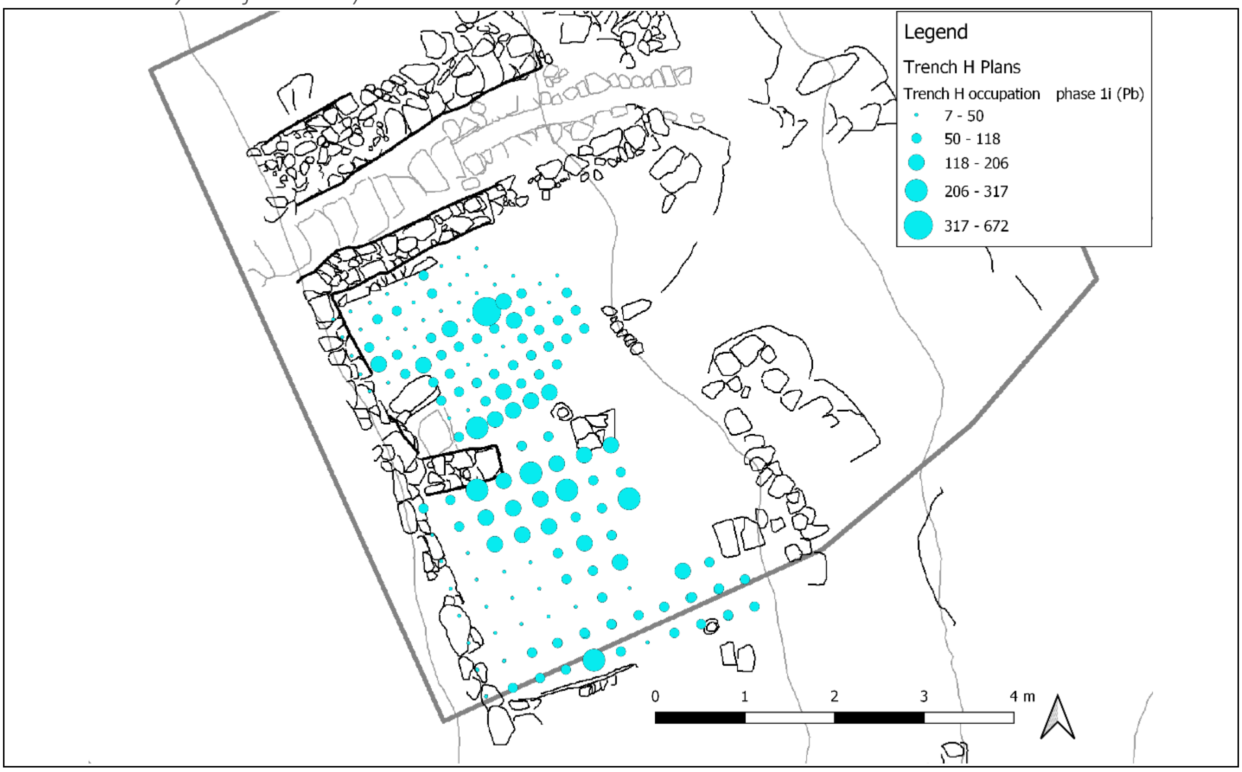

Figure 5.52: *Spatial distribution of Pb concentrations from occupation phase 1i in Trench H. All values are displayed in ppm. Note that the value of 7 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).*

Copper values for this initial phase of surfaces range from below the limits of detection to 1973.4 ppm. The variation of Cu concentration across the surveyed space is high, with a mean value of 165.3 ppm and standard deviation of 197.7 (RSD= 119.5%) across 176 analyses. There is also observable spatial structure to this variability, with the highest Cu concentrations centred in the area of room 2 (H-153) and the north of room 1 (H-103). These very high concentrations of Cu are indicative of metallurgical practice, and the observable structure is suggestive of where these activities were most intense. This would imply that the main focus of practice was within the area of room 2, whilst the less structured, yet significantly elevated levels observed in the southern area of room 1 might indicate where ancillary processes (equipment/material storage, cold working, cleaning crucibles etc) were taking place. The low values of Cu also display structure towards the north of room 2, indicating less intensive action in this area.

Lead concentrations are also highly elevated, yet varied, ranging from below the limits of detection to 671.8 ppm. The variability of Pb concentrations across the 176 points of analysis are significant (RSD= 93.9%), with observable structure favouring the same areas as Cu. This indicates that both Cu and Pb are likely associated with the same process of enrichment which, in this case, pertains to metallurgical activities. Concentrations of Pb are not as high as Cu and are significantly lower than values analysed in areas of Trench A (see above). This likely implies that copper metallurgy was the main focus of activities in Trench H during this period, with leadworking constituting a less intensive, or less frequent process.

Trench H: occupation phase 1ii

The second phase of surfaces (here – *occupation phase 1ii*) are also attributed to Dhaskalio Phase A and consist of 146 points of analysis across contexts H-147 (room 1) and H-85 (room 2). Figures 5.53 and 5.54 display the spatial projection of Cu and Pb values from geochemical survey of these contexts.

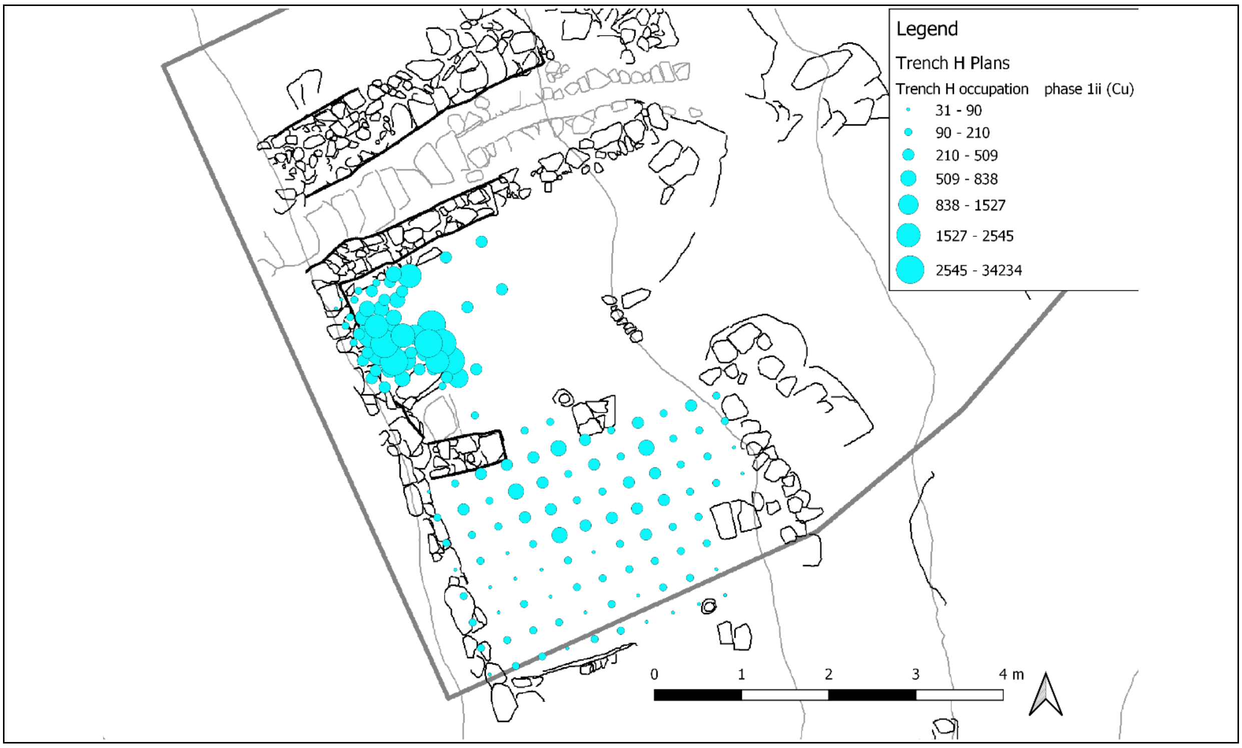

Figure 5.53: *Spatial distribution of Cu concentrations from occupation phase 1ii in Trench H. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).*

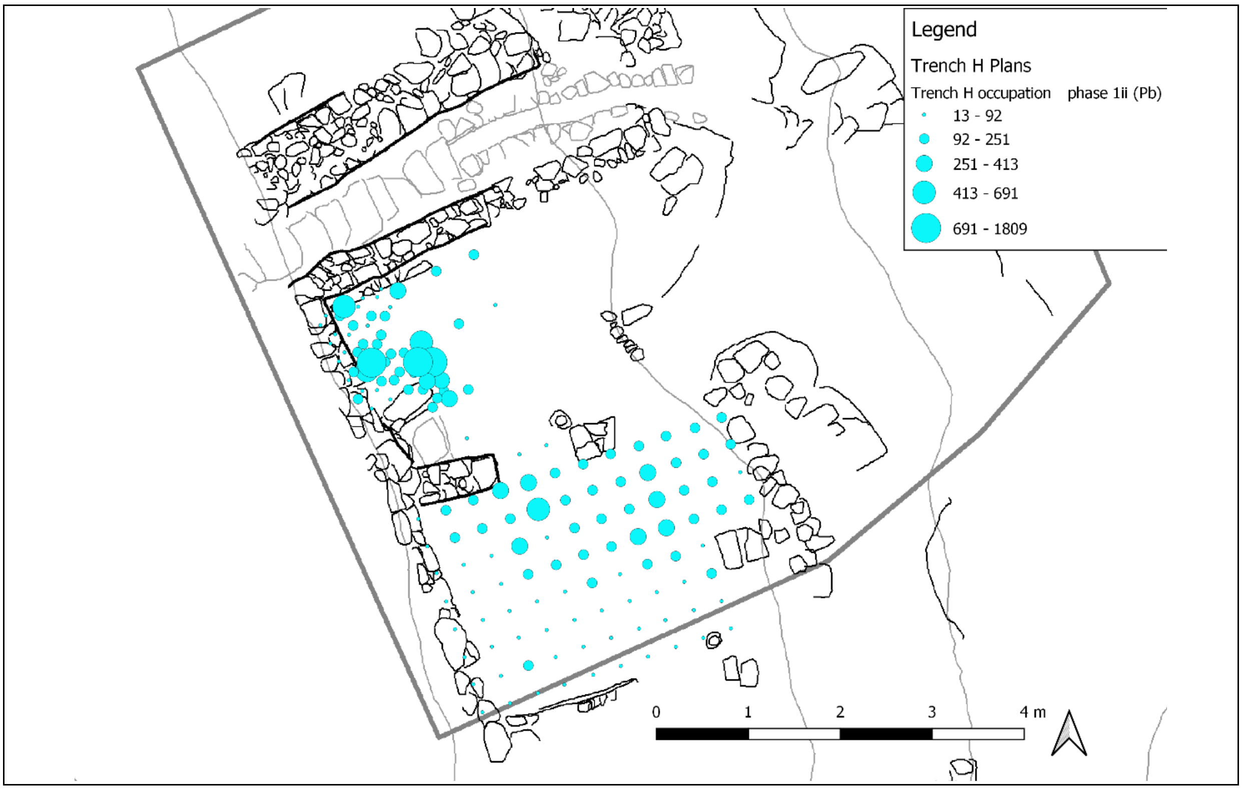

Figure 5.54: *Spatial distribution of Pb concentrations from occupation phase 1ii in Trench H. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).*

Copper values ranging from 31.1 ppm to a maximum value of 34234.1 ppm with a mean value of 795.4 ppm (146 samples). Cu is greatly varied in its concentration across the area which is illustrated by a relative standard deviation of 396.2%. This high variability may, in part, be attributed to the very high concentrations analysed from context H-85, where several sample points display values ranging between 2658.4 ppm and a maximum value of 34234.1 ppm. These values are extremely elevated and are structured favouring the south of room 2. As with the previous phase of surfaces from Trench H (*occupation phase 1i*), these concentrations are indicative of metallurgical practice, and the structured high values may be considered an indication of where past workflow was centred.

Lead concentrations are also highly elevated yet varied, ranging from 13.2 ppm to a maximum value of 1808.91 ppm with a mean value of 160.4 ppm and a standard deviation of 211.97 (RSD= 132.2%). The variability of Pb concentrations is significant, with high concentrations structured favouring the same areas as Cu. As with the previous surface phase, this mirroring of Cu indicates that both Cu and Pb are likely associated with the same process of enrichment. This certainly relates to metallurgical activities, although geochemistry alone may not offer information pertaining to the exact metallurgical process (i.e. smelting, casting, hot/cold working etc). However, the very high concentrations of both Cu and Pb suggest that these practices were likely intensive and persistent within the area during this phase of occupation.

Trench H: occupation phase 1iii

The final phase of surfaces identified for spatial analysis from the Dhaskalio Phase A occupation of Trench H includes 108 samples across the contexts H-28 in room 1, and H-115 in room 2. Figures 5.55 and 5.56 display the spatial variation of Cu and Pb values respectively.

Figure 5.55: *Spatial distribution of Cu concentrations from occupation phase 1iii in Trench H. All values are displayed in ppm. Note that the value of 7 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).*

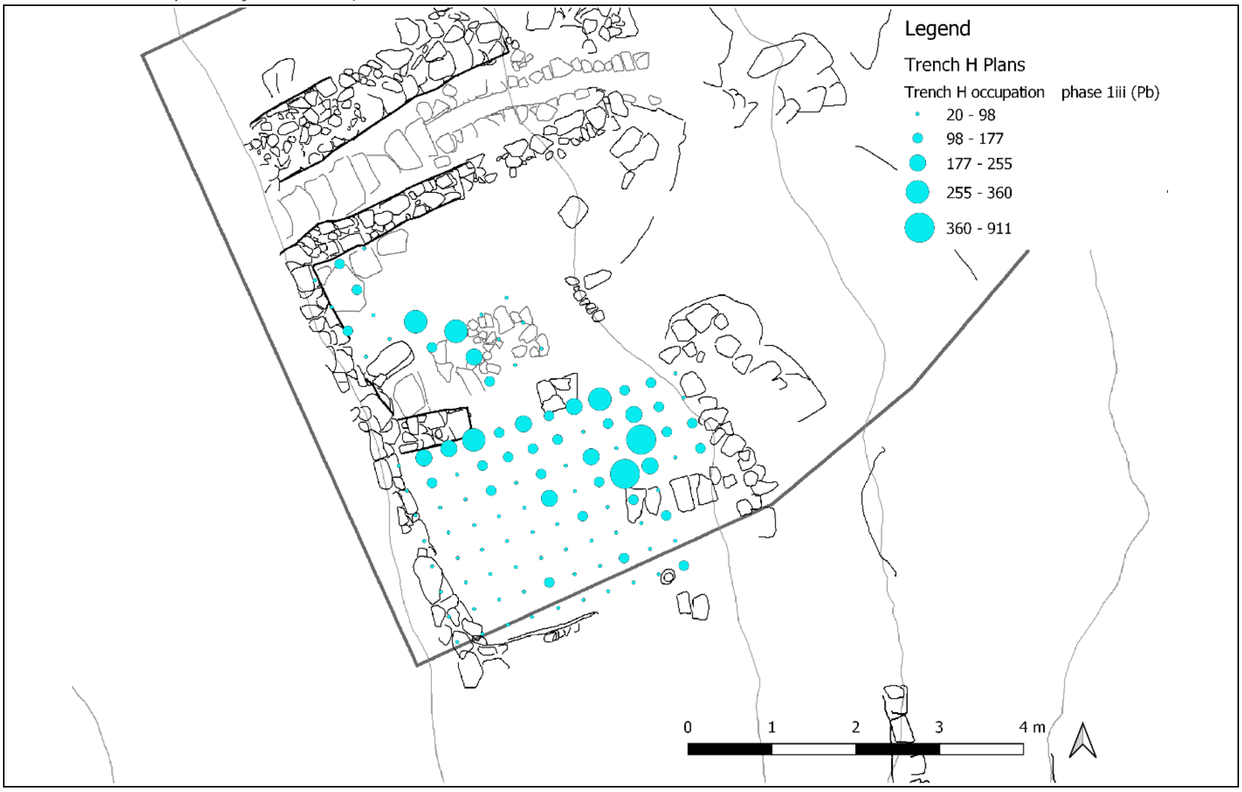

Figure 5.56: *Spatial distribution of Pb concentrations from occupation phase 1iii in Trench H. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).*

Copper values ranging from below the limits of detection to a maximum value of 579.71 ppm and a mean value of 144.9 ppm across 108 samples. Cu is varied in its concentration across the area with structure favouring the north and north-west of room 1 and the south-west of room 2. However, because this was one coherent space during Dhaskalio phase A, the structure to the elevated concentrations from rooms 1 and 2 serve to create a single area of intensity within the central area of the room. These concentrations are indicative of metallurgical practice, and the structured high values may be considered an indication of where past workflow was centred. However, Cu values are not present in as high concentrations as witnessed from lower strata. This may imply less intensive, or less sustained, practice during occupational phase 1iii.

Lead concentrations are also highly elevated, ranging from 20 ppm to a maximum value of 911.2 ppm with a mean value of 108.3 ppm. High Pb concentrations are structured favouring the same areas as Cu. Again, these corresponding structures across the two elements indicate that both Cu and Pb are likely associated with similar practices. However, unlike with previous surface phases of Trench H, concentrations of Pb were detected in higher values than Cu, and both elements present in lower concentrations than previously witnessed. This could mean that metallurgical practice was not as intensive during this final phase of early occupation in the area, or simply that these surfaces were not as long-lived as earlier floor features which did not allow for the same scale of accumulation of Cu and Pb in makeup of these surfaces.

Trench H: occupation phase 2

The second phase of occupation at Trench H came after a small phase of construction and has been preliminarily dated through pottery analysis to Dhaskalio Phase A. The following section will report the spatial analysis of geochemical data from surfaces in rooms 1 and 2 of trench H from *occupational phase 2.* To that end, Figures 5.57 and 5.58 display the spatial projections of Cu and Pb respectively for contexts H-73 (room 1) and H-101 (room 2) (68 samples).

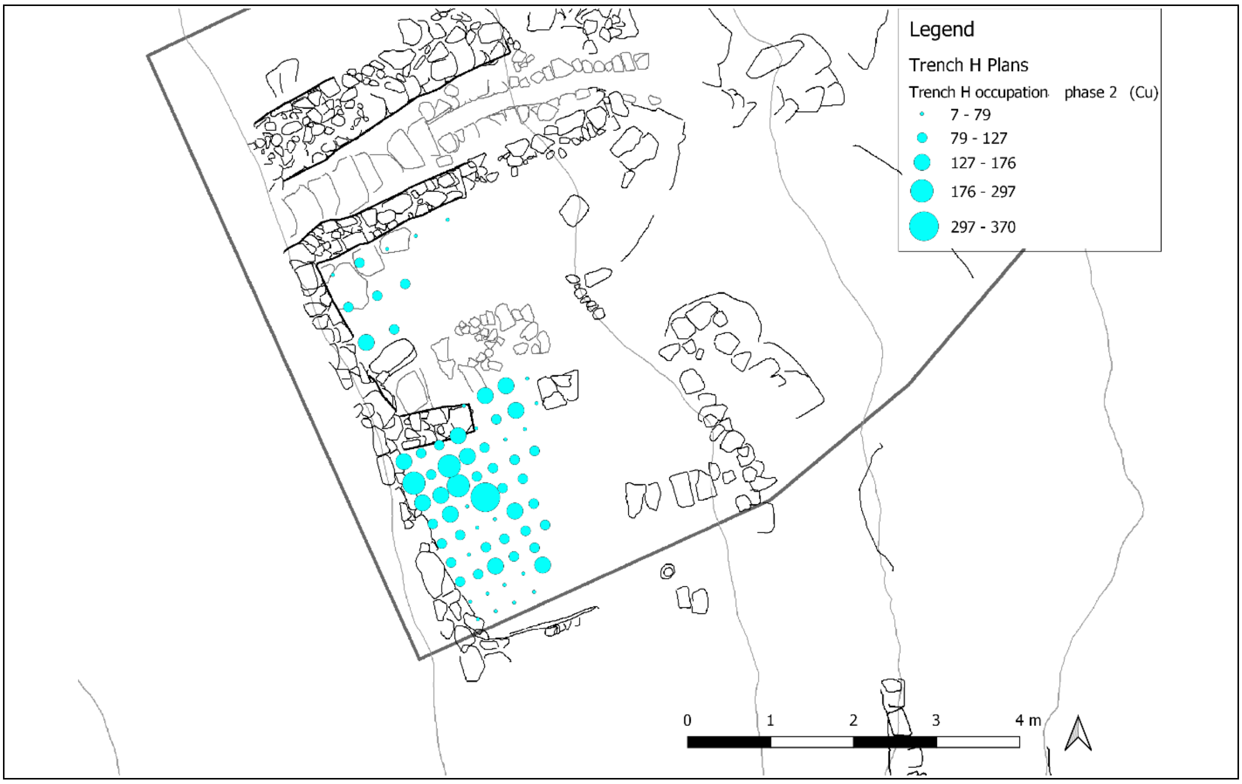

Figure 5.57: *Spatial distribution of Cu concentrations from occupation phase 2 in Trench H. All values are displayed in ppm. Note that the value of 7 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).*

Figure 5.58: *Spatial distribution of Pb concentrations from occupation phase 2 in Trench H. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).*

Copper values for this second phase of occupation range from below the limits of detection to 369.6 ppm. Whilst these Cu values are not as high as those analysed from the previous phase of occupation, the spatial variation of Cu concentrations across the surveyed space is high, with structure favouring the centre of the space (north-west room 1/H-73). The highest concentrations of Cu are indicative of metallurgical practice, and the observable structure is suggestive of where these activities were most intense. This would suggest that the main focus of practice was within the centre of the room (wall 8 was still yet to be constructed).

Lead concentrations range from below the limits of detection to of 369.6 ppm with a mean value of 69.7 ppm (68 samples). The variability of Pb concentrations is significant (RSD= 72.7%), with observable structure favouring the south-western extremity of room 1 (H-73), with consistent high Pb concentrations also organised within the centre of the combined space. Pb values are low in comparison to previous surface phases. Taken in isolation, these Pb concentrations are consistent with the Dhaskalio average (211 ppm). Therefore, it is difficult to offer definitive conclusions as to whether or not these Pb values are indicative of metalworking. However, given the past use of this space, and that Cu is presented in values associated with metallurgical practice, it seems likely that Pb is elevated in these contexts through similar processes, albeit likely not as intensively.

Trench H: occupation phase 3

The final phase of occupation at Trench H has been dated through to Dhaskalio Phase B and follows a significant phase of construction. It is during this construction phase that wall 8 was built, thereby separating the main space into two rooms (1 and 2). The following section will report the spatial analysis of 28 points of geochemical data from surfaces H-66 and H-75 in rooms 1 and 2 respectively. Figures 5.59 and 5.60 display the spatial projections of Cu and Pb respectively for contexts from *occupational phase 3* at Trench H.

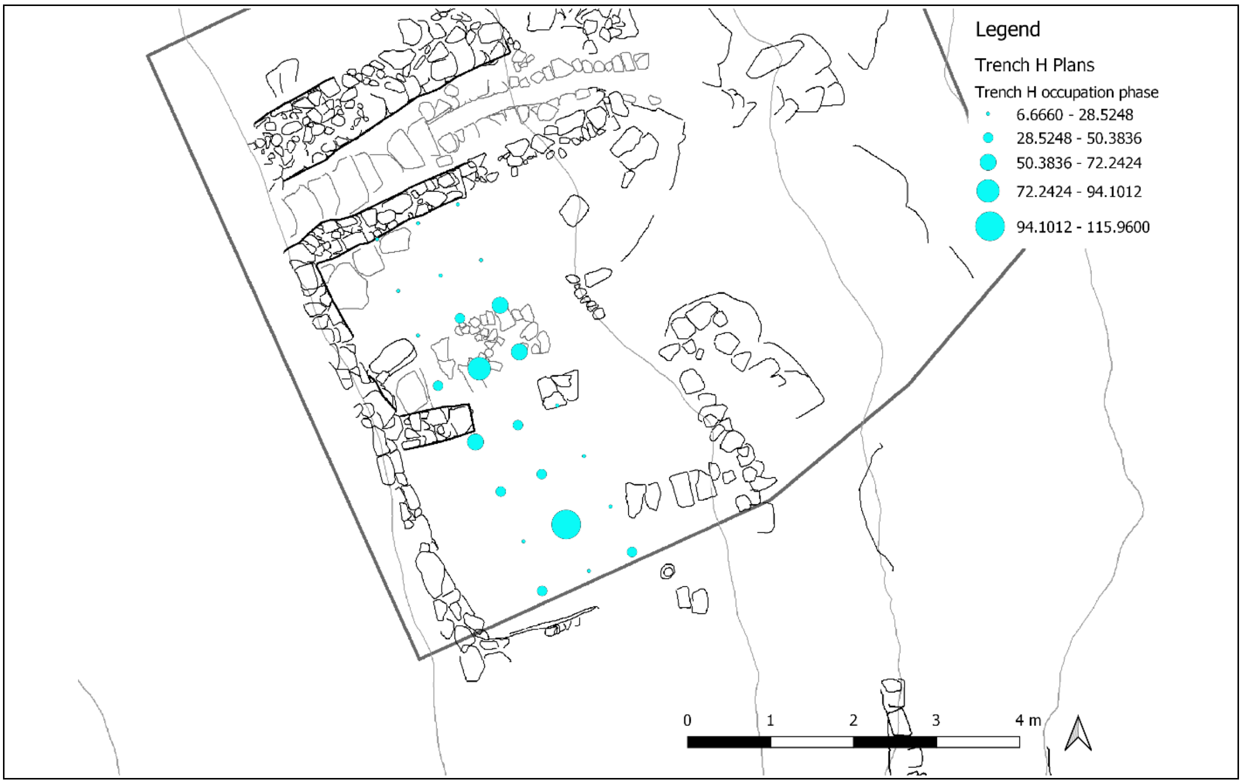

Figure 5.59: Spatial distribution of Cu concentrations from occupation phase 3 in Trench H. All values are displayed in ppm. Note that the value of 6.666 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).

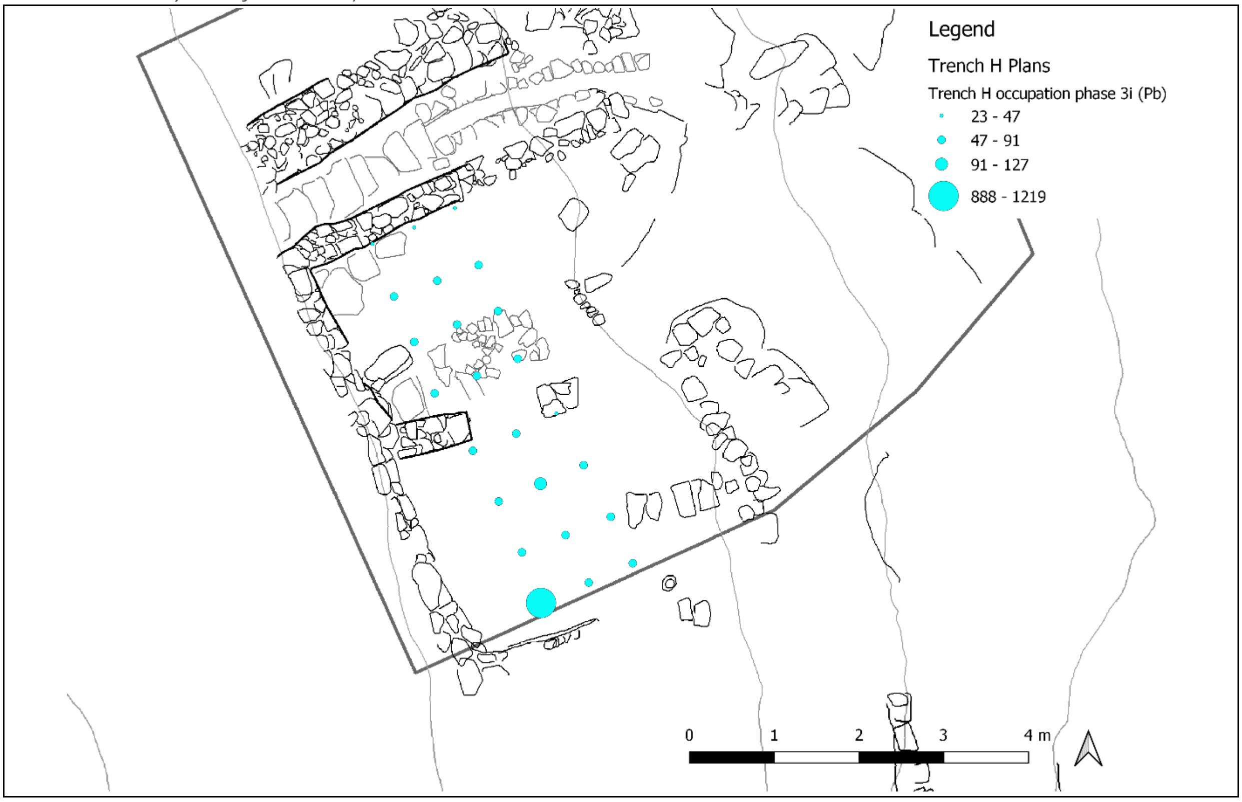

Figure 5.60: Spatial distribution of Pb concentrations from occupation phase 3 in Trench H. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).

Copper values range from below the limit of detection to 116ppm with a mean value of 33.3 ppm across 28 points of analysis. Concentrations of Cu are varied, with a relative standard deviation of 94%. The highest concentrations of Cu are structured favouring the centre of room 1, and the south of room 2 in the area representing the threshold between rooms 1 and 2. Copper values are low in comparison to previous phases of occupation at Trench H, falling below the site Cu average of 146.4 ppm. Therefore, these concentrations of Cu are likely not indicative of metallurgical practice.

Lead values range from 29.5 ppm to 1218.8 ppm with a mean value of 113 ppm (28 analyses). However, this high maximum value is somewhat misleading, as it represents a single point of analysis. Without this outlier, Pb values range from 29.5 ppm to a maximum value of 95.5 ppm and a mean of 65.4 ppm. This single high value may be explained as intrusive contamination from either past or modern activity (during the excavation), as the surrounding Pb concentrations and structure do not suggest that this area was used for metallurgical activity during this phase of occupation.

Since concentrations of Cu and Pb are not indicative of metallurgical practice, the structure they present may be understood as evidence for increased general human activity. Therefore, it is worth analysing the spatial distribution of Zn for this occupation phase at Trench H (figure 5.61), as this element has been shown to be useful in identifying increased human practice on the site.

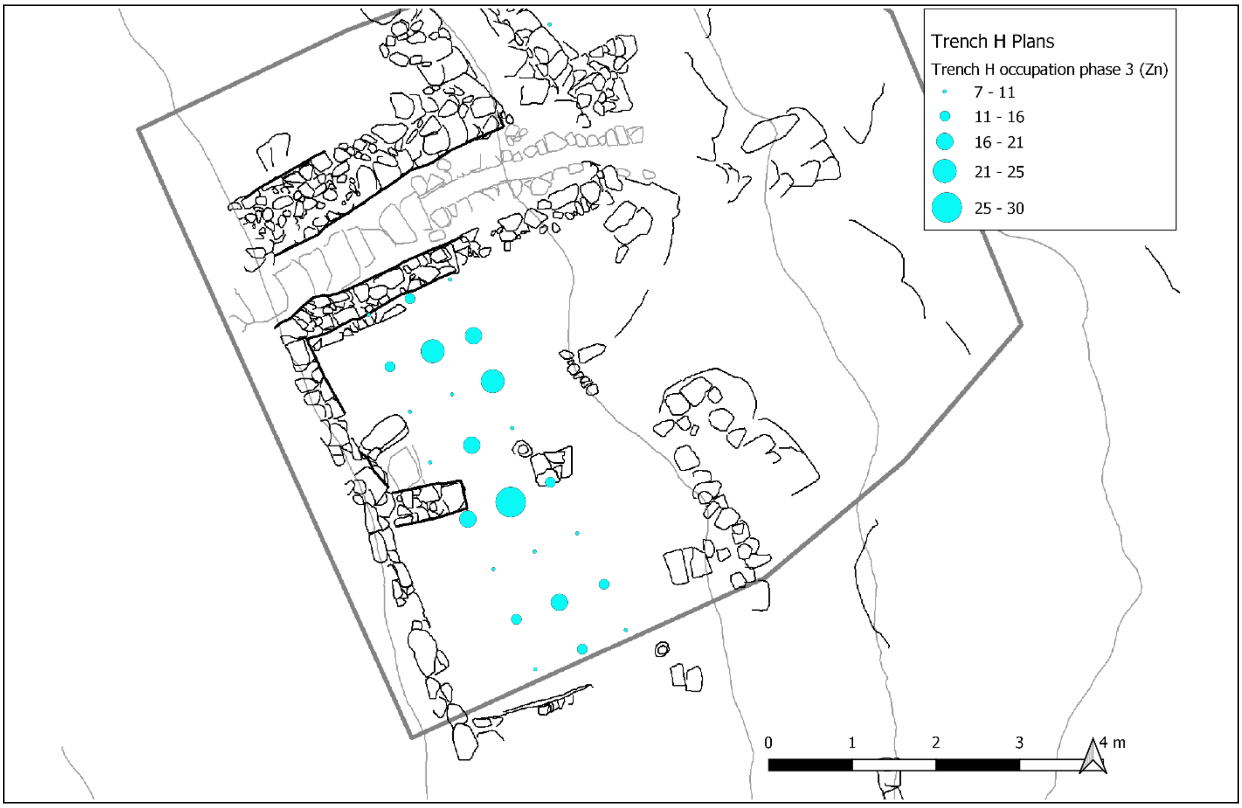

Figure 5.61: Spatial distribution of Zn concentrations from occupation phase 3 in Trench H. All values are displayed in ppm. Note that the value of 7 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).

Zinc values range from below the limit of detection to 29.8 ppm, with a mean value of 15.3 ppm and relative standard deviation of 53.4%. High concentrations of Zn have observable structure which favours the centre of room 2 and the northern extent of room 1. This is a similar spatial structure to Cu and is suggestive of increased past movement and practice. Whilst specific human practice cannot be ascertained, the use of this space during this period was more 'domestic' in function as compared with previous occupation phases at the Trench.

Trench H: summary

The main architectural space at Trench H witnessed three separate occupation phases spanning Dhaskalio Phase A and Phase B. The initial two phases are dated to Dhaskalio Phase A and show strong chemical evidence for intensive copper and lead working. This evidence persists throughout all surface phases of Trench H occupational phases 1 and 2. Interestingly, the soil chemical evidence for metalworking is absent in the occupation phase attributed to Dhaskalio Phase B. Instead, the once metallurgical workshop seemingly shifted in function, becoming an area associated with more domestic activities.

4.4.7 Trench L

Trench L is located to the north of the central region of Dhaskalio with views over the Kavos promontory (**figure 5.62**). The trench measures 11 x 5m and contains a number of architectural features including three levels of terracing and defined rooms. Trench L was opened at the start of the 2016 field season, and excavation of Trench L continued throughout the 2017 field season. The first occupation phase at Trench L is attributed to Dhaskalio Phase A, with a subsequent phase of occupation occurring during Phase B. The following section will detail the spatial distribution of soil chemical analysis from surfaces stratigraphically assigned to these two phases of use.

Figure 5.62: *Satellite image depicting the location of Trench A on Dhaskalio (image source: author/ Google Satellite 2021).*

Trench L: occupation phase 1

Excavation of Trench L revealed remnants of several surfaces attributed to Dhaskalio Phase A and, consequently, the first occupation phase at the trench. Each area of surface analysed is small (<50 x 50cm). However, by combining these contexts into a coherent phased plan, some insight into the likely use of the area during this initial phase of occupation may be achieved. To that end, figure 5.63 displays a plan of surface contexts included in the spatial analysis of *Trench L occupation phase 1*, and figures 5.64 and 5.65 display the spatial distribution of Cu and Pb from 38 analyses across these layers. Contexts include L-21, L-34, L-53, L-78, L-92, L-95, L105, and L-109.

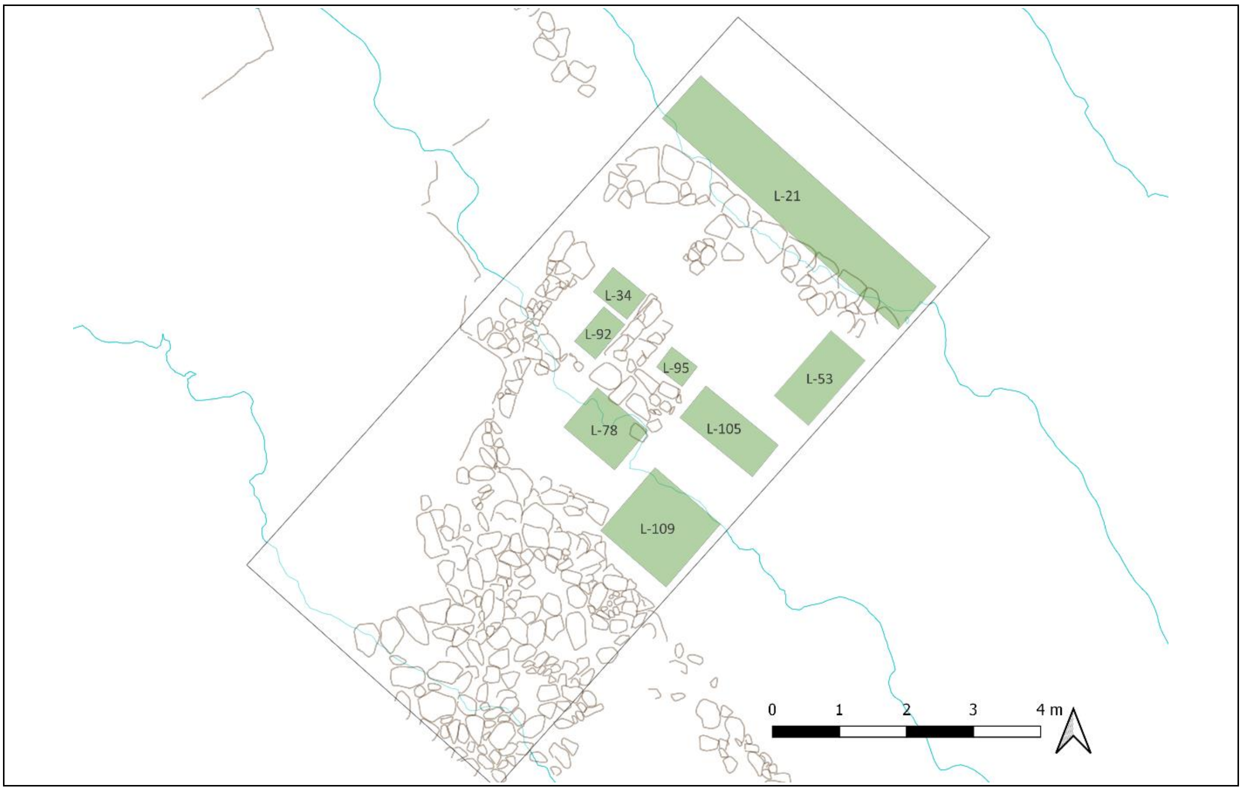

Figure 5.63: *Image detailing the location of individual contexts associated with occupation phase 1 at Trench L. Green represents features which are included in the spatial analysis of soil chemistry (image source: author/Keros-Naxos Seaways Project 2018).*

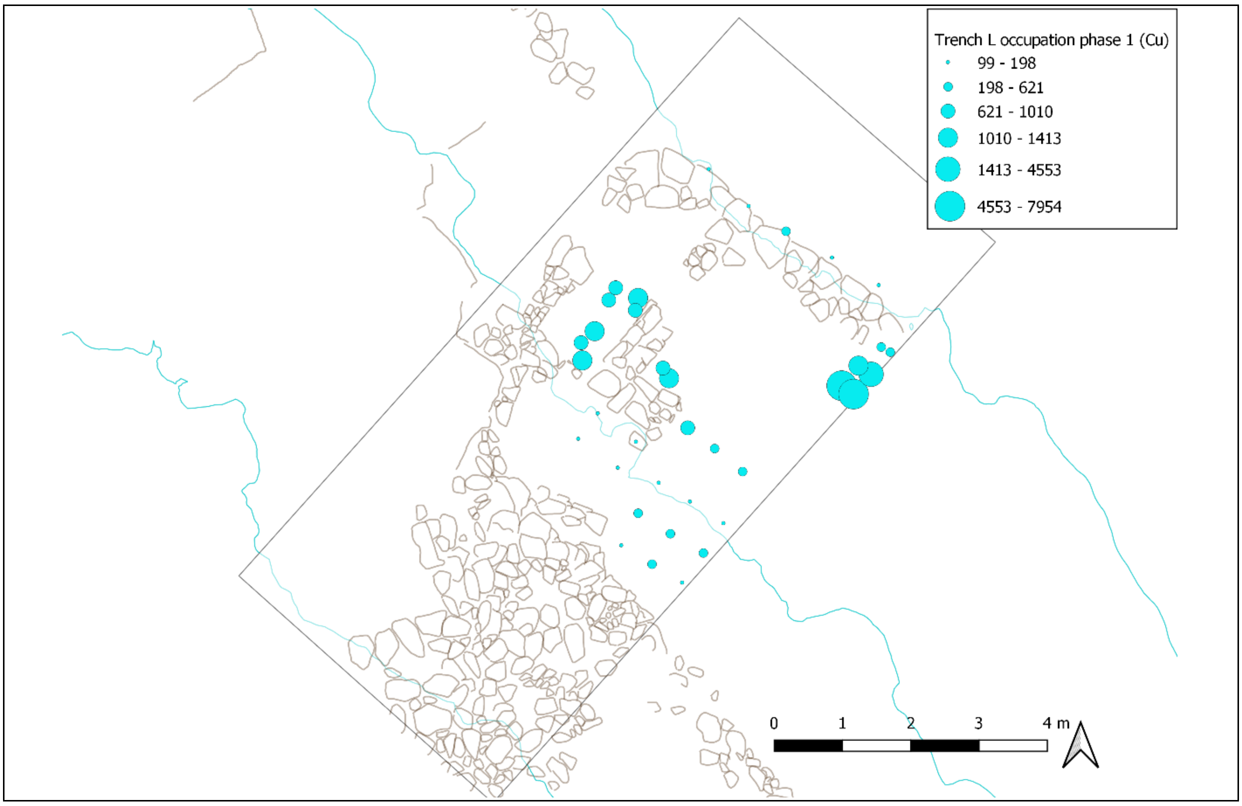

Figure 5.64: Spatial distribution of Cu concentrations from occupation phase 1 in Trench L. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).

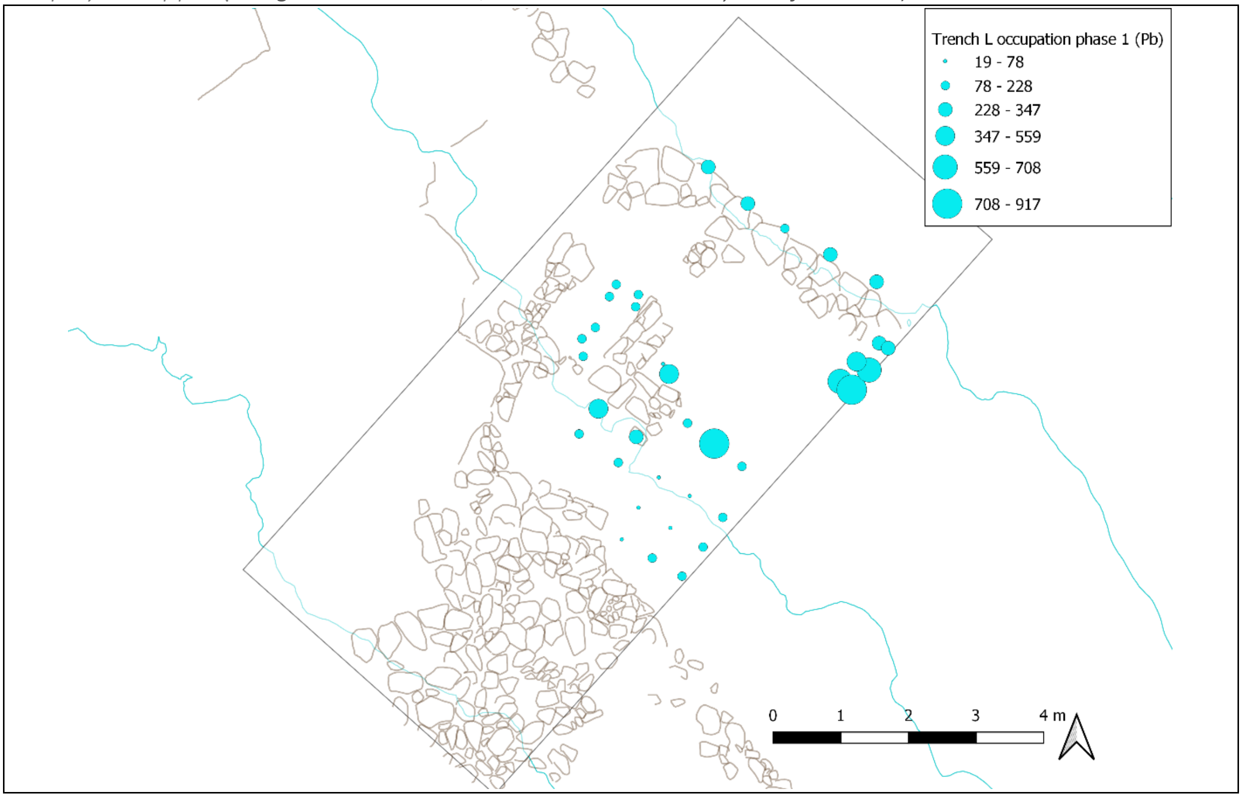

Figure 5.65: Spatial distribution of Pb concentrations from occupation phase 1 in Trench L. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).

Copper concentrations range from 99.1 ppm to 7953.7 ppm, with a mean value of 853.1 ppm across 38 points of analysis. These values of Cu are extremely high, comparable to those analysed from Phase A contexts at Trench H and are indicative of metallurgical practice. The spatial distribution of elevated Cu concentrations suggest that these practices were organised within the central space of the area (L-34, L-78, L92, L95), with additional structure favouring the south-west of context L-53. During this phase of occupation, the 'L' shaped wall within the central terrace (structures 45 and 61) was yet to be constructed, meaning that structured anomalies of Cu within the central area can be seen as representing a single working room. Unfortunately, the area between L-53 and the central region lacks a coherent phased surface and so high-resolution spatial analysis may not be achieved for the overall area. However, this space may be characterised in the same manner as the early phase of occupation at Trench H. That is, a metallurgical workshop.

Lead concentrations range from 19.3 ppm to 916.6 ppm with a mean value of 236 ppm (38 samples). As with Cu, Pb concentrations for this initial phase of occupation are very high and can be considered indicative of metallurgical practice. High concentrations of Pb are spatially structured within the same areas as Cu, suggesting an allied practice of both lead and copper working.

Trench L: occupation phase 2

The second phase of occupation at Trench L is likely dated to Dhaskalio Phase B (final phasing is yet to be determined as of writing) and follows a period of construction whereby the central terrace was partitioned into separate rooms. As with the previous phase at Trench L, no coherent floor feature was excavated which spanned the entire space. However, chemical analysis has proved helpful in understanding likely activities taking place in the area during Dhaskalio Phase B, and spatial analysis of those data may provide evidence as to how these activities were organised within the space. This analysis includes 23 samples from contexts L-33, L35, and L-43, and are displayed within the context of Trench L in figure 5.66, whilst spatial projections of Cu and Pb values are shown in figures 5.67 and 5.68 respectively.

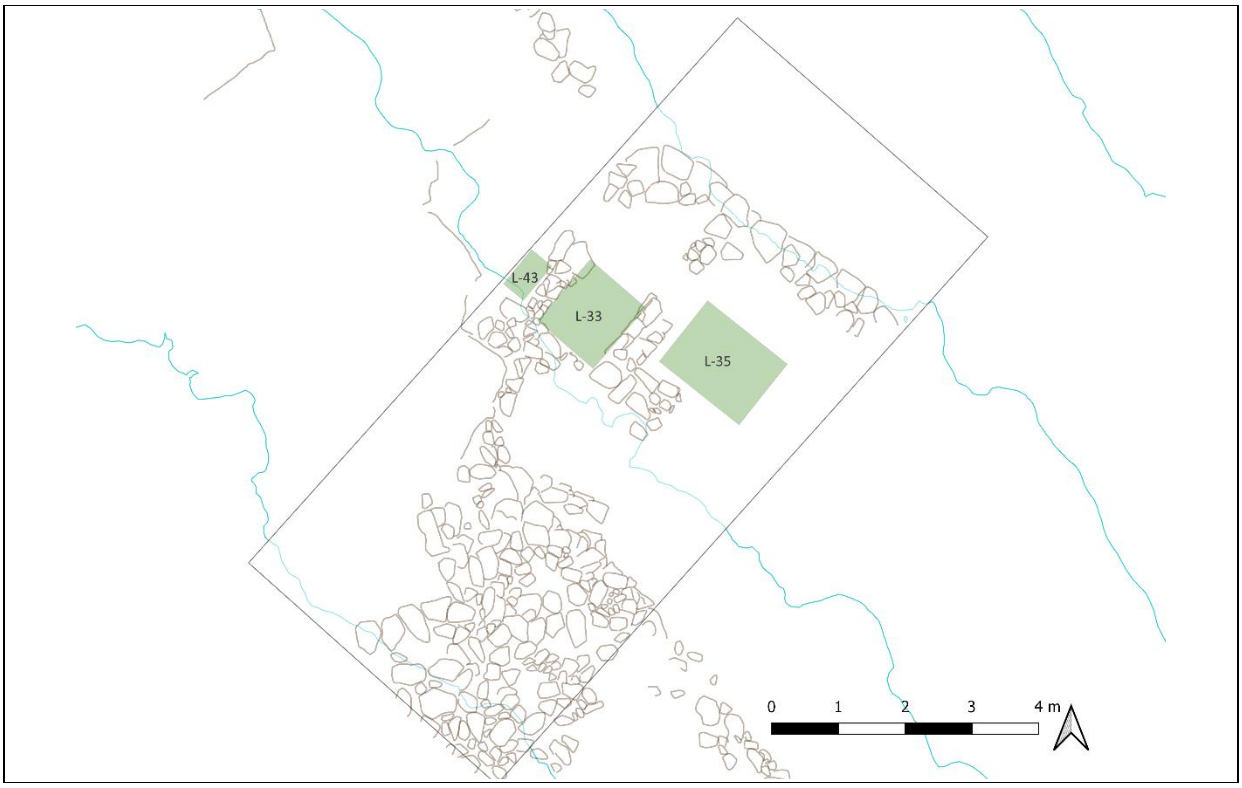

Figure 5.66: *Image detailing the location of individual contexts associated with occupation phase 2 at Trench L. Green represents features which are included in the spatial analysis of soil chemistry (image source: author/Keros-Naxos Seaways Project 2018).*

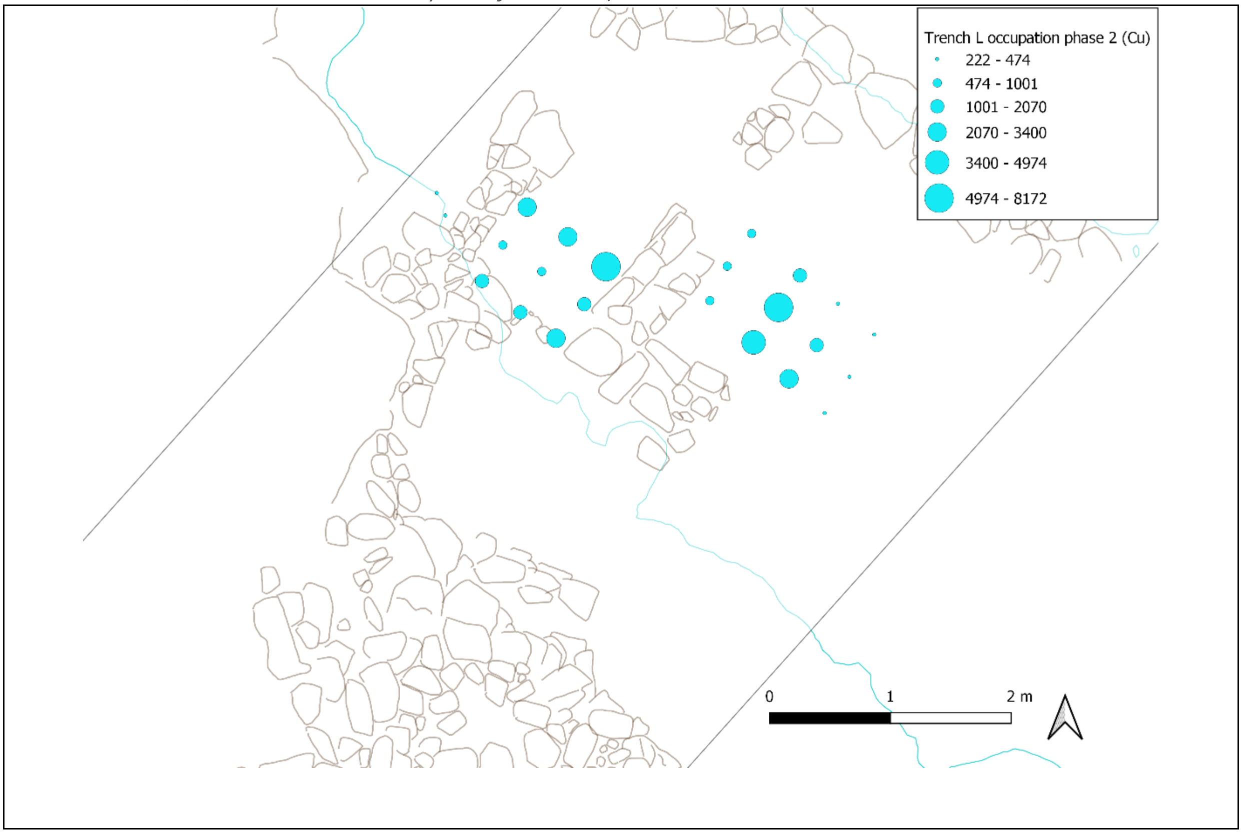

Figure 5.67: Spatial distribution of Cu concentrations from occupation phase 2 in Trench L. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).

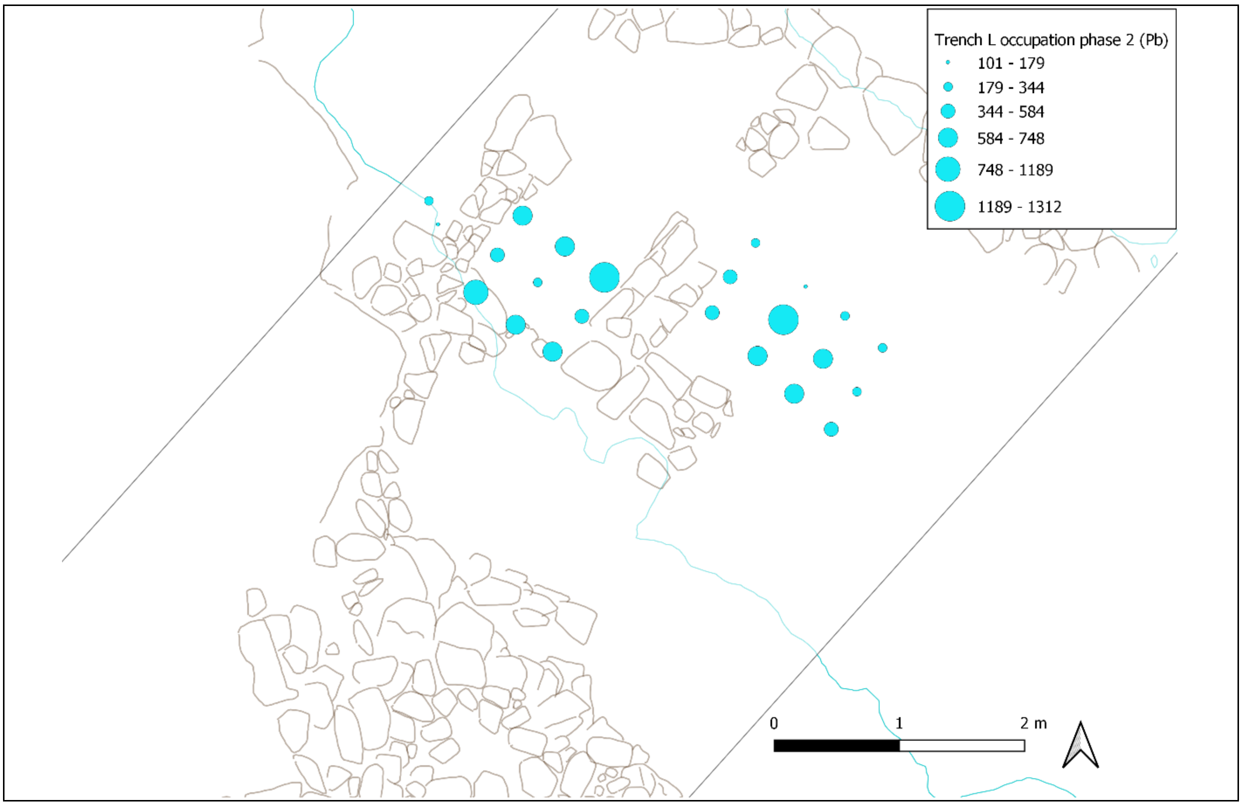

Figure 5.68: Spatial distribution of Pb concentrations from occupation phase 2 in Trench L. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).

Copper values range from 177.5 ppm to 8172.3 ppm with a mean value of 1508.9 ppm (23 samples). These values are very high throughout the analysed space. However, there is also high variability to Cu concentrations (RSD= 120.8%) with observable spatial structure favouring the central region of L-35 and the north-west region of L-33. These very high Cu values are, again, indicative of metallurgical practice, suggesting that the space represented by L-45 and L-33 was likely used directly for copperworking.

Lead values are also highly concentrated, ranging from 101.3 ppm to a maximum value of 1311.6 ppm (μ= 441.8). As in the case of Cu, concentrations of Pb show high variability (RSD= 71.4%) with anomalous values structured favouring the same areas as Cu. This indicates that both Cu and Pb are likely associated with the same process of enrichment which, in this case, pertains to metallurgical activities. Copper and lead values in the area to the west of the trench (context L-43) are not presented in as high concentrations as surfaces within the central area. This suggests that metallurgical practice was confined to the rooms within the central space. However, geochemical data are absent for areas beyond the trench boundary, so this conclusion cannot be confirmed.

Trench L: summary

The excavation of Trench L provided evidence for two consecutive phases of occupation spanning Dhaskalio Phase A and Phase B. Geochemical analysis has provided evidence that the space within the central terrace was likely utilised for intensive metallurgical practice during the initial phase of occupation. This practice continued following a period of construction, whereby the open central space was partitioned into two smaller open-faced rooms. Both Cu and Pb are highly concentrated within these two spaces, suggesting that metallurgical activity continued in its intensity during this second phase of occupation, yet with changes to the spatial organisation of practice.

4.4.8 Trench N

Trench N is located to east of the central, summit area of Dhaskalio with views over Kavos on Keros (**figure 5.69**). The trench measures 5 x 3m and includes several architectural features including a large terrace wall. Trench N was opened at the start of the 2017 field season in order to explore these terrace features and to assess the relationship between areas excavated during the 2006 to 2008 excavation seasons. The stratigraphic phasing for Trench N is still in progress at the time of writing. However, preliminary assessment suggests that the main area of the trench was occupied during both Dhaskalio Phase A and Phase B. The following section will report geochemical results from surfaces within the main room structures at Trench N, although precise phasing for these surfaces is unclear (possibly Dhaskalio Phase B).

Figure 5.69: Satellite image depicting the location of Trench A on Dhaskalio (image source: author/ Google Satellite 2021).

Trench N: occupation surfaces

Figure 5.70 displays a plan of surface contexts included in the spatial analysis of Trench N occupation. Contexts include N-37, N-47, and N-66 for a total of 26 samples. Figures 5.71 to 5.73 display the spatial distribution of Cu, Zn, and Pb respectively.

Figure 5.70: Image detailing the location of individual contexts associated with occupation at Trench N. Green represents features which are included in the spatial analysis of soil chemistry (image source: author/Keros-Naxos Seaways Project 2018).

Figure 5.71: Spatial distribution of Cu concentrations from occupation layers in Trench N. All values are displayed in ppm. Note that the value of 6.666 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).

Figure 5.72: Spatial distribution of Pb concentrations from occupation layers in Trench N. All values are displayed in ppm (image source: author/Keros-Naxos Seaways Project 2018).

Figure 5.73: Spatial distribution of Zn concentrations from occupation layers in Trench N. All values are displayed in ppm. Note that the value of 7 ppm is proxy for < LOD (image source: author/Keros-Naxos Seaways Project 2018).

Copper values range from below the limit of detection to 342.6 ppm with a mean value of 129.9 ppm across the 26 samples. High concentrations of Cu are structured favouring the eastern extent of context N-47 in the north-eastern room of the Trench. These values are high and may be considered as associated with metallurgical activities or allied practice, although areas of in situ practice in various areas of the settlement have presented higher Cu concentrations than those seen in this trench. This may suggest that copperworking was taking place nearby and the architectural spaces associated with Trench N were used for ancillary activities. However, context N-47 is truncated by the eastern section of the trench, suggesting that the room space extends beyond the trench edge. Therefore, it is possible that Cu may be present in higher concentrations in areas of the room which were unavailable for analysis. Indeed, the spatial structure of high Cu values supports this hypothesis, with anomalous concentrations rising towards the east of the context. However, without further excavation and analysis, the details as to specific metallurgical practice remains ambiguous.

Lead values range from 22.2 ppm to 502.9 ppm with a mean value of 128.3 ppm (26 analyses). These are, again, highly elevated above the site average, and may suggest metallurgical activities were taking place in the area. High concentrations of Pb are structured within the same general areas as Cu, suggesting that these two elements were enriched by the same process. As with copper, Pb is not present in concentrations which have been seen in areas of intense, in situ metalworking in other areas of the settlement, such as Trench A, H, and L. This likely suggests that either in situ metallurgical activities were not taking at Trench N and these high values represent ancillary practices (for example, storage), or metalworking was not as intensive or long-lived as in other areas of the settlement.

Zinc values range from below the limit of detection to a maximum value of 61.41 ppm. Concentrations of Zn are spatially varied across the area, with notable structure favouring the north-east of context N-47. Concentrations of Zn, when detected, are present at levels which might be considered indicative of a broad range of human practices, with the spatial structure suggesting areas of more intense activity.

Trench N: summary

The excavation of Trench N provided evidence for occupation spanning Dhaskalio Phase A and Phase B. However, precise stratigraphic phasing is presently unclear. Therefore, spatial analysis of geochemical data has been provided for surfaces of possible mixed phasing which encompass the main architectural spaces of the trench. Evidence suggests that the space within the north-east of Trench N was possibly utilised for metallurgical practice or ancillary activities, although the precise nature or location of these activities is unclear. Both Cu and Pb are concentrated within the same space, suggesting that metallurgical practice in the region was not confined to a single process.

4.5 Results summary

This chapter has reported results from wide-area geochemical surveys of Kavos and Dhaskalio, as well as soil chemical analysis from across defined surfaces of occupation at Dhaskalio. This was done in order to assess the spatial distribution of activities at the maritime sanctuary at Kavos, and associated settlement of Dhaskalio. Principal component analysis of data from the surface surveys offered insight into which analysed elements may be most useful for determining anthropogenic activity. The wide area-surveys also offered the suggestion that metallurgical activity was prevalent at the site during the EBA. Consequently, geochemical results from occupation contexts have been largely reported as either 'metallurgical' or 'domestic'.

Trench A was occupied during Dhaskalio Phase A and Phase B. Combined occupation surfaces displayed values of Pb which are considered indicative of metallurgical practice. These elevated concentrations were organised across several areas of the trench, but in particular within the central room space and complex of passageways. There is also evidence suggesting leadworking taking place within a second story room that subsequently collapsed.

Trench B witnessed a main phase of occupation during Dhaskalio Phase B and contains major architectural features, including the remnants of a substantial stone stairway, terraces paved with large slabs, and a number of adjacent rooms. Chemical analysis of surface features from within these rooms suggest that the area represented by Trench B was not utilised for in situ metallurgical practice. Rather, the room features were likely used in a more domestic capacity. The exception to this is a small charcoal rich deposit to the south of the trench may represent a hearth feature or secondary deposit associated with metallurgical activity. However, the exact purpose of this feature remains ambiguous.

Trench C saw two occupation phases which are dated to Dhaskalio Phase A and Phase B. The trench contains a number of architectural features, including large terrace walls, smaller building elements, and drainage systems. Routine human action appears to have been the norm during the initial phase of occupation at Trench C. This is suggested by the structured concentrations of anthropogenically significant elements within specific areas of the architectural spaces. This period of routine occupation was followed by a phase of abandonment and subsequent reuse. The spatial variability of Cu, Zn, and Pb are low during this period, suggesting that these chemical enhancements were not caused by repeated domestic or craft practice. Instead, this evidence is likely indicative of depositional practices or 'natural' processes related to abandonment and collapse of surrounding features.

Trench F contains a number of architectural features including defined rooms and passageways and was likely constructed and occupied during Dhaskalio Phase C. Chemical concentrations of anthropogenically significant elements (Cu, Zn, Pb) suggest that the building complex at Trench F was used for domestic activities, rather than craft practice during the EBA.

The stratigraphic sequence of Trench H determined three phases of occupation spanning Dhaskalio Phases A and B. The trench contains a main building complex and a significant stairway leading from the coastline to the upper terraces of the settlement. The initial two phases of occupation (dated to Dhaskalio Phase A) show strong chemical evidence for intensive copper and lead working. However, evidence for metalworking is absent in the occupation phase attributed to Dhaskalio Phase B. Instead, the once metallurgical workshop seemingly shifted in function, becoming an area associated with more domestic activities.

Trench L contains a number of architectural features including three levels of terracing and defined rooms. The first occupation phase at Trench L is attributed to Dhaskalio Phase A, with a subsequent phase of occupation occurring during Phase B. High concentrations of Pb and Cu suggest that the space within the central terrace was likely utilised for intensive metallurgical practice during the initial phase of occupation. This practice continued following a period of construction, whereby the open central space was partitioned into two smaller rooms, suggesting that metallurgical activity continued in its intensity during this second phase of occupation, yet with changes to the spatial organisation of practice.

Trench N was likely was occupied during both Dhaskalio Phase A and Phase B and contains several architectural features including a large terrace wall. Evidence suggests that the area to the north-east of the trench was possibly used for metallurgical practice or ancillary activities, although the precise nature or location of these activities is unclear.

Geochemical data from Dhaskalio has been used for establishing places of metallurgical craft production and how those practices differ throughout the site and phases of occupation. This may be used in order to offer insight into how Dhaskalio-Kavos was established and maintained as a centre of significant activity in the EBA. The following chapter will discuss the results presented here within the overarching context of occupation at Dhaskalio-Kavos, and what the spatial organisation of craft activities may offer to our understanding of this unique EBA maritime centre.

CHAPTER6: Discussion

6.1 Introduction

The aims of this thesis are twofold: to understand the character and spatial organisation of activities associated with the EBA cult centre at Dhaskalio-Kavos, and to better explore the role that geochemistry can play in archaeological research. In order to achieve these aims, it is necessary to critically discuss matters pertaining to both the archaeological implications of the results presented in the previous chapter, as well as assess, in detail, the methodological approaches used for obtaining those data. The rich material culture present at Dhaskalio-Kavos, coupled with the extensive programme of excavation and analysis under the auspices of the Cambridge Keros-Naxos Seaways Project, offered a unique case study for exploring such methodological innovations. Whilst the wider project is (at the time of submission) still in a period of post excavation analysis and, therefore, certain contextual and material data are not yet available for scrutiny, it is suggested that the following discussion demonstrates how the careful application innovative geochemical techniques in archaeological research can impact our understanding of the past.

6.2 The spatial organisation of Dhaskalio-Kavos in the EBA

The nature of activities taking place at Dhaskalio-Kavos during the EBA have been widely debated since the 1960s. Extensive research since that period has cemented our understanding of the site as broadly ‘ritualistic’. This is, to a large degree, due to the discovery of the ‘special deposits’ which were recovered during excavations by Cambridge University in 2006-2008 and give claim to the site as the world’s earliest maritime sanctuary. These ‘special deposits’ are separate, yet in close proximity to the headland settlement of Dhaskalio and emphasise the significance of partitioning specific practices at the site. Extensive excavation revealed a stratigraphic sequence at Dhaskalio which has allowed for the distinction of three successive phases of occupation, spanning the Early Cycladic II and Early Cycladic III periods (Renfrew et al., 2012; Sotirakopoulou, 2016). These phases of occupation, defined as Dhaskalio Phases A, B, and C, are represented by periods of architectural expansion, and changing settlement habits. All three phases of settlement were excavated in different areas of the site between 2016 and 2018 and offered a unique opportunity for high-resolution geochemical analysis to be conducted on contexts of human activity which encompassed the lifespan of the settlement. This is important, as it offers a glimpse of not only how space was utilised across the settlement, but crucially, how the use of these spaces changed in function throughout the EBA. Whilst a detailed interpretation of geochemical data for each trench has been presented in the previous chapter, the following discussion will combine these to offer insight into the spatial organisation and nature of activities at Dhaskalio throughout each of these phases of occupation. This section will then conclude with a summary discussion which aims to place activities at Dhaskalio-Kavos within the context of the wider EBA Aegean.

6.2.1 Dhaskalio Phase A

Dhaskalio Phase A is associated with the lowest archaeological strata on the site and, therefore, represents the earliest period of human activity on Dhaskalio during the Early Bronze Age. Typological analysis of the pottery assemblage from these layers has been used to place Dhaskalio Phase A in the Keros-Syros culture (Early Cycladic II) (Sotirakopoulou, 2016), and radiocarbon dating from a number of samples acquired during the 2006 to 2008 excavations dates this phase to between c.2750 BCE and c.2550 BCE (Renfrew et al., 2012). Contexts associated with Phase A were uncovered in Trenches A, C (construction phase), E, H, L, and N during the 2016 to 2018 excavations, which allowed for substantial geochemical data to be collected from Phase A contexts. Trench A lies to the west of the islet, slightly below the summit, Trench C and Trench L are located to the north-east of the settlement, Trenches E and N are positioned to the east of the central summit region, and Trench H is located at the (now)

Dhaskalio coastline overlooking Keros. This broad spread of phase A contexts across the settlement means that a fairly accurate understanding as to the nature of activities taking place during this early period, and spatial organisation of those practices, can be achieved.

It is immediately apparent when examining the geochemical data from Phase A contexts that this phase of settlement was dominated by widespread metalworking (figure 6.1). Geochemical signatures of elements associated with non-ferrous metallurgy (Cu, Pb), measured in concentrations considered indicative of craft practice, can be safely attributed to Phase A layers in Trenches A, H, L, and N. As illustrated above, these trenches are located variously across the site, indicating that activities associated with non-ferrous metallurgy was taking place throughout the settlement. Indeed, with the exceptions of Trench C, where Phase A is represented by a period of terrace construction, and Trench E, which proved problematic for routine soil chemical survey (see results chapter), elevated concentrations of Cu and/or Pb were observed in soils from all trenches where Phase A contexts were present. Therefore, it is likely that Dhaskalio was widely, if not primarily, utilised for metallurgical activities during this initial phase of occupation.

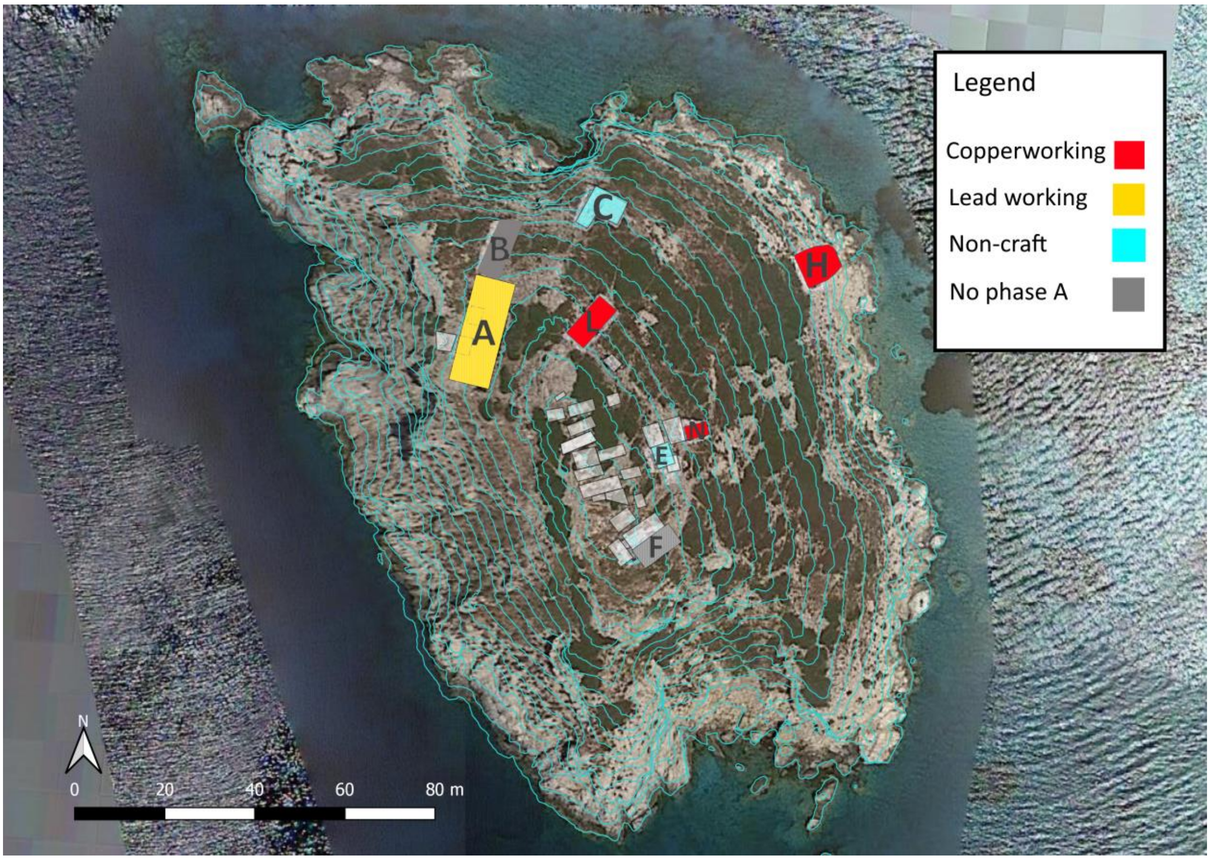

Figure 6.1: Image of copper (red) and lead (yellow) working on Dhaskalio during Phase A. Cyan areas indicate regions with no evidence for metalworking and grey indicates trenches with no evidence of Phase A. (image: author/Keros-Naxos Seaways Project 2018).

This evidence for widespread metallurgical activity on Dhaskalio during Phase A was, prior to recent investigation (for which this thesis contributes), largely unexpected. Metal objects and tentative evidence for metalworking (in the form of small copper spills and a single undiagnostic metallurgical ceramic sherd) were previously recovered from stratigraphic layers dated to Dhaskalio Phase A during the 2006 to 2008 excavations (Georgakopoulou, 2013). However, this period of excavation was limited only to the central region of Dhaskalio, and contexts associated with Phase A were extremely scarce. It was also acknowledged that the small number of proposed metal working finds were not necessarily indicative of in situ metallurgical practice (Georgakopoulou, 2013: 691-2). As with all portable objects, these small material indicators of metal working could have been moved from their context of use, either for storage or for deliberate disposal. Without evidence for their primary context, no definitive conclusions could be drawn as to the presence of metallurgical practice on Dhaskalio during Phase A.

This is a problem that is all too familiar with interpreting evidence from traditional excavation practices, and one which routine geochemical analysis aims to mitigate.

The latest programme of excavation at Dhaskalio has bettered our understanding, not only about the extent of Phase A at the site, but also with the widespread nature of metallurgical activity taking place during this period. However, with the exception of the hearths discovered in Trench H (see Chapter 5), and possibly the early phases of Trench A and Trench B, material evidence for metal working during Dhaskalio Phase A is still limited to small finds of metallurgical ceramics and metal spills. It is within this sphere of ambiguity that rapid, high-resolution, in situ geochemical analysis has played a pivotal role. Where material evidence is lacking, or where context of use is uncertain, chemical analysis of the surfaces of habitation aids the more detailed and confident interpretation of these spaces.

In terms of the spatial organisation of this early metalworking, results from the geochemical analysis of these Phase A contexts can offer some insight. Firstly, however, it is important to clarify the limits of this interpretation. Due to restraints of the project, in terms of time and resources, the excavation strategy included a limited number of trenches. Therefore, trench locations were selected in order to fulfil the main aims of the project which were, in the main, to understand the character of architecture on Dhaskalio, and gain insight into the construction of the large-scale terracing which dominated the settlement. Without total excavation of the site, our understanding of activities taking place at Dhaskalio during the EBA is incomplete. However, from this sample, Phase A layers which contained highly elevated concentrations of elements consistent with metalworking were widespread, appearing in the majority of trenches which contained Phase A contexts. Therefore, it is fair to suggest that these activities were taking place in small workshop-like spaces dispersed throughout the settlement during this early phase of the site. Whilst the exact nature of metallurgical activities may not be identified through geochemistry alone, material evidence suggests that these spaces were used for secondary metalworking processes (melting, casting, reworking etc) (see Georgakopoulou, 2013). The chemical data show elevated concentrations of both Cu and Pb in Phase A contexts located in

Trenches H, L and N, whilst chemical evidence for metalworking in Trench A is largely limited to Pb. As such, it is likely that a broad range of metalworking was taking place at Dhaskalio during this period. Since Phase A occupation of Dhaskalio occurred before the introduction of tin to the Cyclades during the Kastri Group period (Renfrew, 1972: 314), metalworking at the site would have been limited to pure copper, arsenical copper, and lead. This is further backed up by material evidence from previous periods of excavation which did not reveal evidence for the use of tin-bronzes during any period of occupation at Dhaskalio (Georgakopoulou, 2013).

With such widespread metallurgical activity taking place on Dhaskalio during Phase A, similarities may be drawn with the Early Minoan (EM) site of Posos-Katsambas on Crete. Evidence suggests that this EM I/EM II coastal site was an important trading hub in the EBA with a thriving metallurgical craft tradition and a distinct connection to the Cyclades (Dimopoulou-Rethemiotaki et al., 2007). Like Poros-Katsambas in its EM IIA phase, the settlement of Dhaskalio brought in pottery and other materials from a wide region across the eastern Mediterranean (Renfrew, 2013a), and the people occupying the site were evidently engaged in a range of metalworking. However, unlike at Poros, it is not clear that Dhaskalio represented a place for trade, or if there are different explanations for why such a varied assemblage of materials were brought to the island. Furthermore, Dhaskalio is only one part of the overall Dhaskalio-Kavos complex on Keros, and the presence of the Special Deposits and the rest of the Kavos coastline should not be ignored. These concerns will be addressed further in the discussion.

6.2.2 Dhaskalio Phase B

Dhaskalio Phase B is the second chronological period recorded from strata on Dhaskalio. Radiocarbon estimates place the transition between Phase A and Phase B at c.2550 BCE (Renfrew et al., 2012) and typological study of the Dhaskalio pottery places Phase B into the earlier phase of the 'Kastri group' (late Early Cycladic II) (Sotirakopoulou, 2016). Contexts dated to Dhaskalio Phase B were identified in Trenches A, B, C, E, H, L, and N. Therefore, as with Dhaskalio Phase A, layers associated with this phase of occupation are located throughout the settlement which offered the opportunity to collect significant geochemical data for interpretation. The general picture gained through excavation of Dhaskalio, is that the transition between Phase A and Phase B was a period of architectural expansion, changes in material culture, and somewhat changing settlement habits (Barrett & Boyd, 2021: 111). These changes can also be seen in the spatial organisation of activities within the settlement, as evidenced by the geochemical data (figure 6.2).

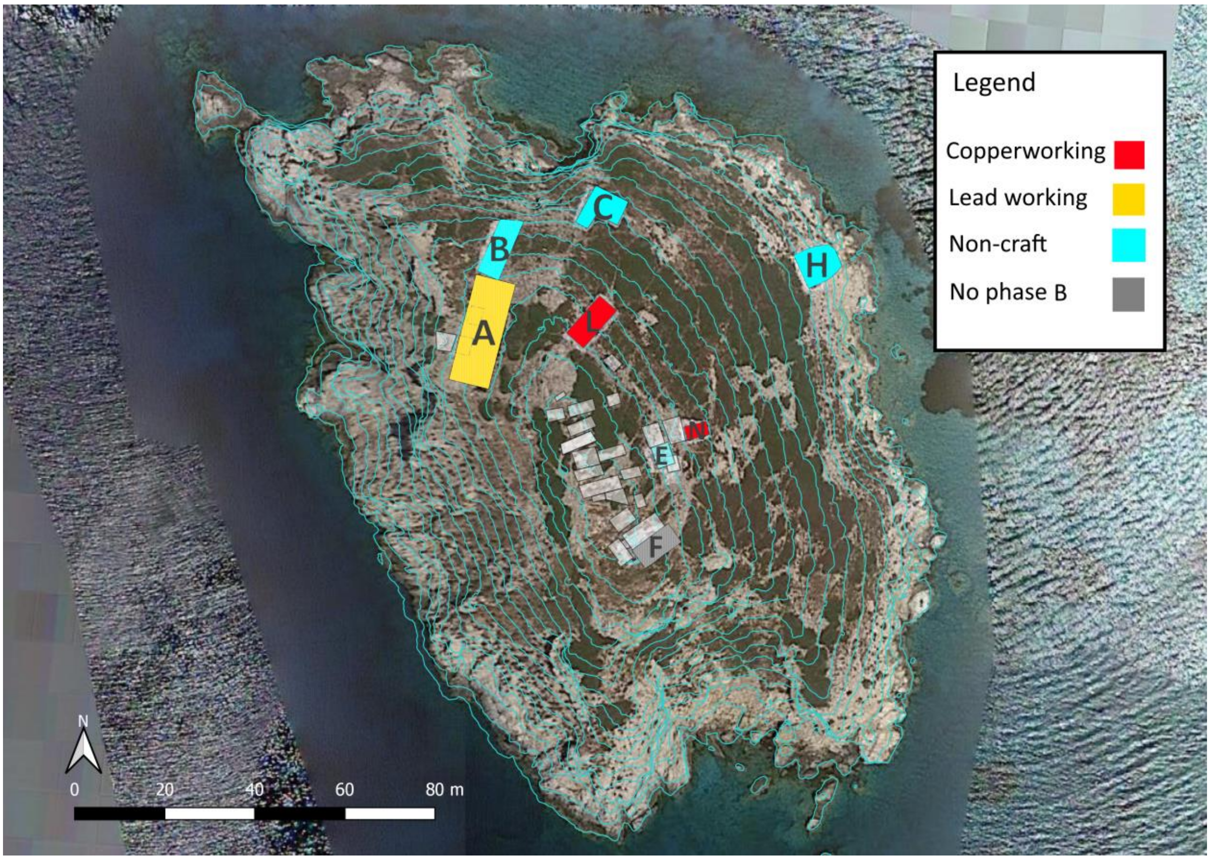

Figure 6.2: Image of copper (red) and lead (yellow) working on Dhaskalio during Phase B. Cyan areas indicate regions with no evidence for metalworking and grey indicates trenches with no evidence of Phase A. (image: author/Keros-Naxos Seaways Project 2018).

One of the major changes in use of space on Dhaskalio during Phase B is the distribution and organisation of metallurgical activities. Whilst metalworking appears to have been widespread and somewhat dispersed across the settlement during Phase A, metalworking during Phase B appears to be more confined to certain areas of the site. Take, for example, the Phase A metallurgical workshop in Trench H. The earliest layers within the main architectural space of Trench H were dominated by chemical signatures associated with Cu and Pb metallurgy. Yet, within the same space, layers associated with Dhaskalio Phase B held completely different chemical characteristics. Instead of a data set dominated by elements indicative of metalworking, the Phase B surfaces displayed chemical signatures which are suggestive of a more domestic usage. This inference from the geochemical analysis is corroborated by the pottery assemblage from this area, which change from metallurgical ceramics during Phase A, to principally large storage vessels during Phase B. Taken in isolation, the evidence from Trench H could suggest that metalworking had diminished on Dhaskalio during Phase B. However, the geochemical evidence from the other trenches with Phase B contexts suggests that this was not the case, with Trenches A, L, and N all including Phase B layers with enhance levels of Cu and/or Pb.

The previous programme of excavation on Dhaskalio, between 2006 and 2008, presented evidence for continued metalworking on the site during Phase B (Georgakopoulou, 2013). Metallurgical artefacts, including several tuyère fragments as well as a complete specimen, were uncovered from Trench I (Georgakopoulou, 2013: 670). Indeed, with the exception of single small metallurgical ceramic fragment from Trench II, all metallurgical finds dated to Phase B were uncovered from this single space in Trench I (Georgakopoulou, 2013: 690). During the 2016 to 2018 excavations, Trench N was opened on the SE edge of Trench I (part of the remit for opening Trench N was to assess the relationship between previously excavated areas). It is no surprise, then, that evidence for metallurgy was uncovered in this area during the recent excavation seasons. However, since the 2006 to 2008 campaign of excavation was largely focussed on the area close to the summit of the islet, the extent of metalworking on Dhaskalio during Phase B was largely unknown.

In addition to evidence of metallurgy in Trench N, Phase B layers from Trenches A and L also displayed geochemical signatures associated with metalworking. However, unlike the evidence for metallurgy from Phase A, which came from excavated areas across the whole site, all trenches with evidence of Phase B metalworking are located on the upper tier of the terraced structure of Dhaskalio, immediately below the summit area. Without total excavation of the site, it is difficult to draw conclusions as to whether or not metallurgical activities were taking place on the lower tiers of the settlement during Phase B. The excavation of trench H, which can be conclusively associated with metalworking during Phase A, but has no such clear evidence from layers dated to Phase B, currently provides the only evidence for the types of activities taking place on the lower extremity of Dhaskalio during this middle phase of occupation. Undoubtedly, one trench should not be used in order to draw definitive conclusions about the use of space across the entire site. However, the abandonment of metallurgical activities in an area which previously featured such practices so heavily, alongside the continuation of metalworking in more central areas of the site, is suggestive of a change in the organisation of activities on the settlement. Indeed, this more centralised distribution of metallurgical practice differs starkly to the picture offered by the evidence from Phase A, which suggests that metalworking was more dispersed throughout the settlement.

Although the evidence suggests a change to the spatial organisation of metallurgical practice on Dhaskalio during phase B, this more centralised distribution of metalworking does not necessarily imply a reduction in the scale of activities. More generally, the early stage of Dhaskalio Phase B was a period of architectural growth within the settlement, and it appears that these newly established spaces were, at least in part, utilised for the continuation of metalworking on the site. An example of this can be witnessed in Trench A. Here, a substantial staircase was constructed which linked the buildings in the area of Trench A to the summit of the settlement. This staircase also branches out towards the central rooms in Trench A, where detailed excavation of this area provided evidence for the construction of a second story. Whilst the upper floor of this building complex has long since collapsed, geochemical analysis of the collapse layers provided strong evidence for lead working. The construction of a second floor would not have been undertaken without consideration. Most of the marble used for the construction of buildings on Dhaskalio is known to have originated in Naxos (Renfrew, 2013a) some 12km (7.5 mi) away. Consequently, the importation of this stone, when the only means of interisland travel during this period was by rowboat (Broodbank, 2000) would have been a significant enterprise. This means that any architectural expansion on Dhaskalio would likely only have taken place in order to fulfil a vital purpose. Although it is unlikely that the upper story was constructed merely for facilitating the expansion of lead working, the fact that newly available space was seemingly immediately utilised for this purpose suggests that these activities continued to occupy a prominent position within the overall function of the settlement.

6.2.3 Dhaskalio Phase C

Dhaskalio Phase C corresponds to the Early Cycladic III period, supported by a pottery assemblage associated with the later or main phase of the Kastri Group (Sotirakopoulou, 2016: 1). This is known to be the final phase of occupation of Dhaskalio during the Early Bronze Age, with radiocarbon estimates dating the beginning of Phase C to c.2400 BCE and ending in c.2300 BCE (Renfrew et al., 2012). Whilst significant information pertaining to the Phase C occupation of Dhaskalio is known from the 2006 to 2008 excavations, layers associated with Phase C were only uncovered in one trench (Trench F) during the most recent investigation, meaning that only very limited geochemical data are available for this period. As such, it will not be possible for a detailed interpretation of the spatial organisation of activities to be achieved for this period using geochemical data alone. Instead, geochemical data from Trench F will be discussed alongside more traditional archaeological evidence from previous excavations on Dhaskalio in order to consider how the settlement was organised spatially during Phase C.

The main area of activity during Dhaskalio Phase C appears to have been focussed in the central area of Dhaskalio, located at the summit of the islet. This is evidenced by the lack of layers associated with this late phase in any of the trenches excavated outside this area (figure 6.3). Consequently, Phase C represents a dramatic restructuring of settlement habits on Dhaskalio, with all but the central region of the settlement seemingly being abandoned or disused (Barrett & Boyd, 2019: 111). It was this central region of Dhaskalio which was the main focus of excavations during the 2006 to 2008 field seasons of the Cambridge Keros Project (Renfrew, 2013a). There, a significant building complex was uncovered, including a substantial architectural space characterised by Renfrew as the 'Hall' (Renfrew, 2013a: 16). This intense aggregation of buildings at the summit of the site, with an almost 'urban' character (Renfrew, 2013a: 17), has comparisons to the contemporaneous settlement of Skarkos on Ios (Angelopoulou, 2017), albeit at a limited scale. However, unlike Skarkos, which has been characterised as having a largely domestic, residential function (Marthari, 2008), the central structures associated with Dhaskalio Phase C likely continued to be utilised for more craft related activities, although evidence for the scale of this activity remains up for debate.

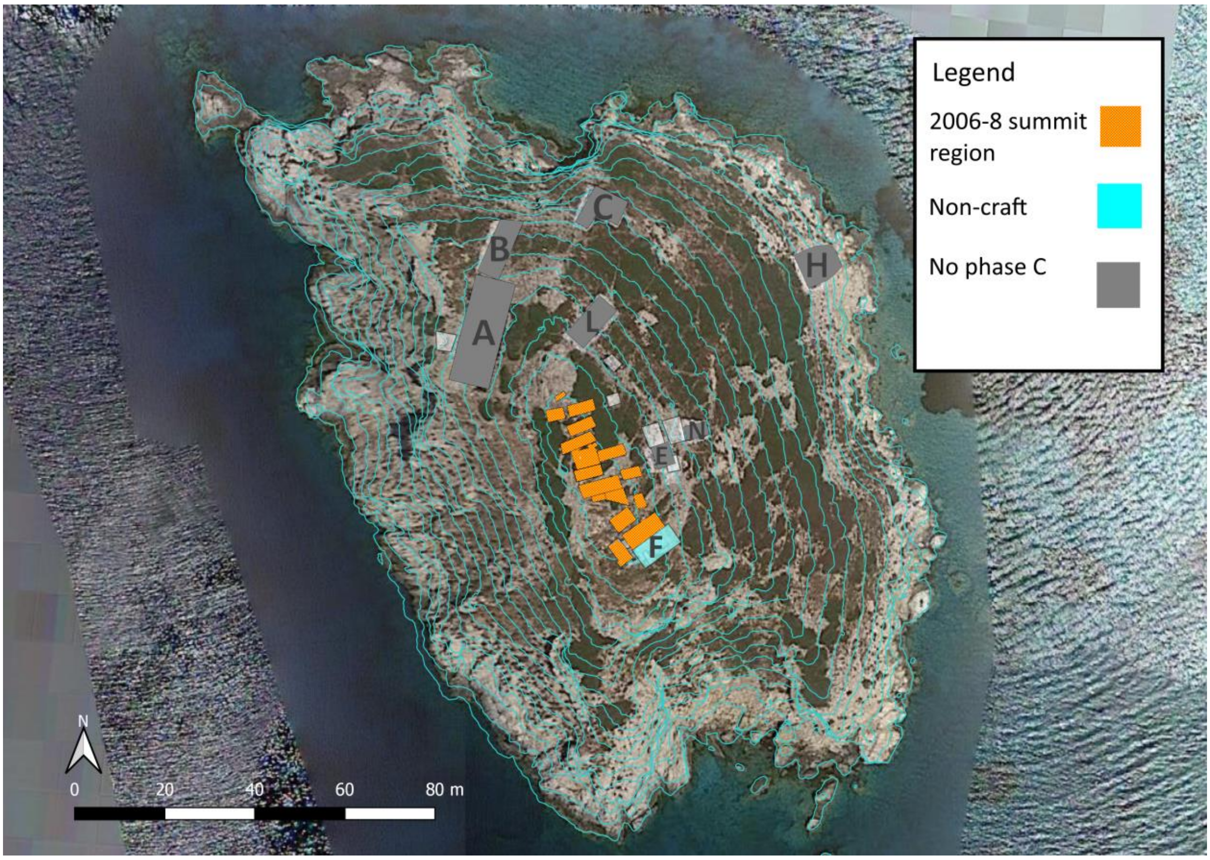

Figure 6.3: Image of activity areas on Dhaskalio during Phase B. Cyan areas indicate regions with no evidence for metalworking, grey indicates trenches with no evidence of Phase C and orange denotes indicates the summit region excavated between 2006 and 2008. (image: author/Keros-Naxos Seaways Project 2018).

Geochemical analysis of Phase C contexts in Trench F did not reveal any significant evidence related to metallurgical activity. Indeed, the data suggest that this area of the site was exclusively used for more 'domestic' functions, such as storage. However, because layers associated with this chronological phase of the site were only uncovered in Trench F during the 2016 to 2018 excavations, the limited geochemical data set available for analysis should not be regarded as indicative of the entire site during this period. Rather, the area excavated within Trench F, located at the southernmost extent of the central complex, may have fulfilled a more ancillary function to those of the more central spaces, constituting an area of organised storage which facilitated other activities on the site (Barrett & Boyd, 2019: 112). When the central, summit region of Dhaskalio was excavated, the Cambridge Keros Project uncovered significant evidence which suggested a continuation of metalworking on Dhaskalio during Phase C. This evidence included metallurgical ceramics (including an intact tuyère and mould fragments), small copper fragments characterised as possible spills, and a small lead shafthole axe head, which may have been used for creating moulds for casting a final copper version of the artefact (see Georgakopoulou, 2013: 673-685). Whilst it is conceded by Georgakopoulou (2013) that none of the excavated evidence confirms in situ metalworking, the material evidence from Phase C contexts certainly suggests some level of continuation of metalworking traditions on Dhaskalio during this period. However, without available geochemical data for the central structures, the exact spatial organisation of this activity on the site remains unclear.

6.2.4 Dhaskalio-Kavos in context

So far, this discussion has been concerned with offering a broad interpretation of the spatial organisation of activities on the settlement of Dhaskalio, and how the use of space changed throughout the history of the site. Whilst archaeological geochemistry is suitable for detecting a range of past human activities, it is clear from the geochemical analysis of Dhaskalio that the main focus of activity on the site during the EBA was related to production, specifically metallurgy. Indeed, Barrett and Boyd (2019: 111) have recently gone so far as to suggest that Dhaskalio may not be considered a settlement in any traditional sense of the word as a broad range of domestic activities implied by that word are not well evidenced. Instead, the more ‘domestic’ activities observed on the site may be considered as evidence for ancillary practices, such as organised storage, which merely facilitated the more dominant acts of production taking place on the site. With this in mind, it becomes likely that Dhaskalio constituted a significant metalworking centre. However, the settlement of Dhaskalio is only one part of the overall Dhaskalio-Kavos EBA complex. Therefore, it is important to discuss the evidence for activities on the nearby and unequivocally related Keros coastline, and how they relate to activities on the settlement of Dhaskalio. By evaluating the spatial organisation of activities across the wider landscape, a better understanding of how the site fits in to our understanding of the Early Bronze Age Cyclades can be achieved.

One of the most important discoveries on Dhaskalio-Kavos, has been that of the smelting site on the Kavos Promontory. Prior to its discovery, it was understood that primary metal production in the Cyclades during the EC II period was restricted to the western 'metal-rich' islands, with activities taking place close to mineral extraction sites (Barber 1987: 112; Broodbank 2000: 293-7), and that only secondary metalworking activities were carried out within or close to settlements (Georgakopoulou, 2007: 174). The only known comparable site from this period is Chrysokamino on Crete, where a significant metallurgical production centre is located on a rocky outcrop with seemingly no available local ore source (Betancourt et al., 1999). Like Chrysokamino, the windswept Kavos Promontory is perfectly situated to take advantage of the north-easterly meltemi winds between the months of May and October (Brodie & Georgakopoulou 2015: 512) which would have provided sufficient airflow for the use of perforated shaft furnaces which are found at various sites in the Aegean during the EBA (Doonan & Marks, 2022; Georgakopoulou, 2017). Indeed, the geochemical survey of the Kavos Promontory confirms the results of earlier survey work which suggested that the metallurgical activities on the Promontory were organised to the north of the outcrop, offering unobstructed access to the northerly winds. However, unlike at Chrysokamino, which produced large quantities (over one ton) of slag and likely constituted a large-scale production centre (Catapotis and Bassiakos, 2007: 68), the material evidence from the Kavos Promontory suggests that smelting was either small-scale, short-lived, or both (Brodie & Georgakopoulou 2015: 520). Furthermore, the evidence available from

Chrysokamino suggests that the Cretan site was the location of only one part of the metallurgical production process, with only primary smelting taking place (Betancourt et al., 1999: 367). Remelting of smelted copper in crucibles and the casting of tools and other objects occurred somewhere else. This is clearly not the case with Dhaskalio-Kavos, as secondary metalworking was ubiquitous on the built-up settlement of Dhaskalio. Instead, Dhaskalio-Kavos remains unique in the fact that, with the exception of mineral extraction and refinement, it is likely that all parts of the metallurgical process were taking place in the same area, although it cannot be confirmed if different stages of the metallurgical process involved different specialised craftspeople (e.g. Doonan et al., 2007).

Despite the presence of both primary and secondary metallurgical practices taking place, it is important not to see Dhaskalio-Kavos as merely a settlement striving for self-sufficiency, where local smiths would voyage to ore-sites and return in order to produce metal artefacts. It is not only ore and metals which were imported, everything from marble for the construction of Dhaskalio, to food was imported (Renfrew, 2013). Instead, Dhaskalio-Kavos can be seen as an important central node in Aegean networks (Barrett & Boyd, 2019: 66; Broodbank, 1993), bringing in materials and people from a wide region in order to facilitate or participate in the activities taking place on the island, for which metallurgy seemingly played a central role. This was highlighted by Broodbank (1993) when he included Dhaskalio-Kavos in his list of major 'trader sites' in the region due to the site's inferred connectivity and rich material culture. However, this regional connectivity was likely important for cementing Dhaskalio Kavos as a pilgrimage site and a centre for formalised ritual practice, rather than as a trading hub (Renfrew, 2014).

It is also important to acknowledge the significance of the Special Deposits on Kavos. Although distinct, both spatially and in terms of practice, to the metallurgical activities taking place on the Kavos Promontory and Dhaskalio, the proximity of the Special Deposits to these production centres cannot be ignored. Material and geochemical evidence from the Special Deposits suggests that the southern region of Kavos was not utilised for in situ metallurgy. However, the geochemical survey of the Special

Deposit South may suggest a link between the ritual activities taking place on Kavos and the technological processes occurring elsewhere on the site. Indeed, whilst the measured concentration of Cu in the region of the Special Deposit South should not be considered indicative of in situ metalworking, it is nonetheless significantly elevated as compared to the natural background of the site. It appears likely, then, that the elevated concentrations of Cu in this area is present as a result of contamination by people using the site. This would suggest that at least a proportion of those people who convened at the Special Deposit South were readily involved with metallurgical processes.

This connection between the Special Deposits and the metalworking taking place at Dhaskalio-Kavos may also be attested to by the spatial organisation of copper workshops on Dhaskalio. Although the distribution of copperworking on Dhaskalio changed somewhat over the extent of the settlement's use (see above), an important spatial quality remained constant. That is, with the exception of the use of the summit area during Phase C, all hitherto known copper workshops were located on the eastern/north-eastern face of the islet (figure 6.4). As with the Kavos Promontory, this evidence places copperworking on the windward side of the island. However, unlike the act of smelting taking place on the Kavos Promontory, metallurgical practices on the settlement of Dhaskalio were almost certainly secondary production methods (melting, casting etc), utilising small hearths with tuyères and manual airflow (Georgakopoulou, 2013). Therefore, there is little practical reason why these activities needed to be orientated in the direction of the prevailing winds. Instead, perhaps the explanation for the spatial distribution of copper metallurgy on the site is a less pragmatic one, and more to do with the act of production itself and its association within the 'special' activities taking place at Dhaskalio-Kavos.

To deepen our understanding of the spatial organisation of a craft practice at Dhaskalio-Kavos, it is essential to integrate theories on the use of space and craft activities, specifically focusing on metallurgical production. According to Ingold's concept of the 'taskscape', defined as 'the pattern of dwelling activities' (Ingold 1993: 153), the landscape and the arrangement of practices carried out within it develop concurrently. In other words, the landscape is not merely a backdrop to human activity but is continually shaped by, and in turn shaping, these activities in a temporal and social process.

With regard to Dhaskalio, we can see that the settlement's spatial organisation reflects a complex interplay of tasks, particularly metalworking, which appears central to the site's function. The location of copper workshops on the eastern/northeastern face of the islet, overlooking the coastline of Kavos, highlights a taskscape where practical and symbolic considerations intersect.

Indeed, Ingold (2017) explains that temporality in the taskscape is about the 'ongoingness' of time, a process emerging alongside dwelling activities. This concept can be applied to understand how metallurgical practices at Dhaskalio were not just technical tasks but integral to the social and ritual life of the community. The spatial arrangement of metalworking activities may have been designed to facilitate not only production efficiency but also ritual aspects of production. This is particularly evident in the separation of primary smelting activities on the Kavos Promontory from secondary metalworking on Dhaskalio, which could indicate a structured approach to the spatial and temporal dimensions of these practices.

Erb-Satullo's (2022) work on the spatial archaeology of crafting landscapes further informs this understanding by highlighting how the organisation of space is conditioned by resources, economic needs, social considerations, and ritual beliefs. The evidence from Dhaskalio suggests that the site functioned as a comprehensive metallurgical centre where different stages of metal production were integrated within a coherent spatial framework. This organisation likely supported both utilitarian and ritualistic aspects of metalworking.

The proximity of primary smelting sites on the Kavos Promontory to secondary metalworking areas on Dhaskalio suggests a deliberate spatial strategy. While primary smelting utilised the natural advantages of the promontory, such as exposure to winds for furnace airflow, the secondary metalworking on Dhaskalio likely involved more controlled and possibly ritualised processes. The elevated concentrations of copper in the Special Deposit South area of Kavos, despite not being indicative of in situ metalworking, imply a link between metallurgical activities and ritual practices.

The concept of articulation, as discussed by Erb-Satullo (2022), refers to the relationships among people and activities within the crafting landscape. This includes interactions between craftspeople, administrators, merchants, and consumers, as well as the physical spaces where these interactions occur, such as workshops and administrative buildings (Erb-Satullo, 2022: 573). At Dhaskalio, the spatial manifestations of control and organisation within the metallurgical landscape indicate a sophisticated approach to managing both the technical and social aspects of production. The isolation of smelting on the promontory, combined with the centralised secondary metalworking on the islet, may have facilitated control over the production process and underscored the ritual significance of metalworking activities. The spatial organisation of Dhaskalio and Kavos reflects a nuanced interplay of practical, social, and symbolic dimensions, illustrating how the landscape was continually shaped by and shaping the metallurgical practices that appear central to the site's identity.

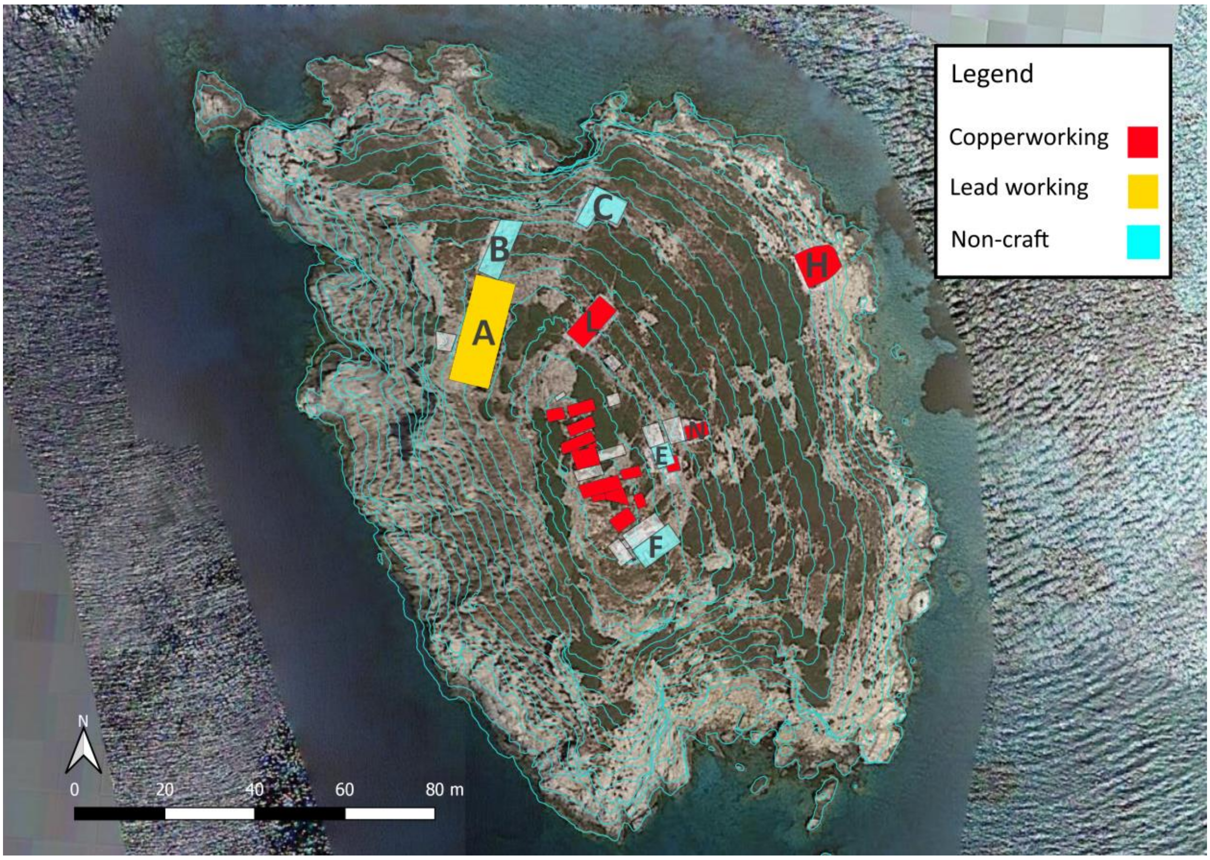

Figure 6.4: Image of copper (red) and lead (yellow) working on Dhaskalio throughout phases A, B, and C. Cyan areas indicate regions with no evidence for metalworking. (Note: copperworking in the summit area is based on evidence from 2006-8, not geochemistry) (image: author/Keros-Naxos Seaways Project 2018).

The study of metallurgy in the Aegean, and within archaeology in general, has often focussed on typological distinctions, technological change, and the display and consumption of elite goods. These studies often encourage a largely practical interpretation of metallurgical practices, as well as a focus on the finished artefact. What is often missing from these discussions, is the performative nature of metal production and metalworking. Evidence from campaigns of experimental metallurgy have demonstrated the intrinsic drama involved with the acts of metallurgical practice (e.g. Dungworth, 2013), and archaeological evidence has shown indication that prehistoric metal production may have, in some instances, served an important social purpose rather than a purely economic one (e.g. Avery et al., 1988).

Doonan et al (2007: 115) describe acts of metallurgical practice in the third millennium Aegean as a "technological liturgy" whereby metallurgical performances held a social purpose, and where social relations were constructed on the act itself, rather than technological success. In this way, the very act of metallurgical production, with a precise choreography of actions building anticipation towards the eventual creation of an artefact, would be the foundation of these social relationships. Any artefact produced may have been seen as a symbol of participation in such acts, imbued with the social significance and relationships forged during its production. Perhaps, too, the places of these performances became important in creating this social meaning of production, and the spatial organisation of copperworking on Dhaskalio, with workshops located on the eastern face of the settlement, overlooking Kavos and the Special Deposits, was a deliberate effort to associate the performance of copper metallurgy to the acts taking place on Kavos.

It may be beyond the scope of this thesis to offer a definitive conclusion pertaining to the link between the specific ritual depositions on Kavos and that of metalworking. However, the association between religion and metalworking in the eastern Mediterranean during later periods of the Bronze Age has been widely noted (Renfrew, 2013; Schallin, 1997; Westover, 1998). It has been observed in particular in Late Bronze age Cyprus at Kition and Enkomi (Knapp, 1986; Knapp, 1988), and the proximity of metalworking to a shrine has been discussed in relation to the Unexplored Mansion at Knossos and the shrine at Phylakopi in Melos (Hitchcock, 2006). Regardless of the specific connection between the activities at the Special Deposits and Dhaskalio, however, all hitherto evidence suggests that metalworking, specifically copper metallurgy, was important in establishing Dhaskalio-Kavos as a 'special' place for ECII peoples. Perhaps, then, Dhaskalio-Kavos should not be seen as merely an important production centre which drew in people and resources from across the Aegean, with parallels at Poros-Katsambas (see Dimopoulou-Rethemiotaki et al., 2007). Rather, it may be understood as a place where smiths from throughout the Cyclades would gather in order to participate in the acts and performances which created their identity as artisans. Parallels may be drawn with Prepalatial Phaistos, where evidence suggests that pottery production was activity conducted by specialists working for specific and temporarily restricted occasions in a specific social context (Day et al, 2010). It appears that these periodic episodes of intensive production may have been occasions where technological tradition was shared, that is a face-to-face transmission of knowledge regarding raw material choice, paste recipes and different modes of firing from one generation of potters to the next (Day et al, 2010: 217-18). The similarities between Prepalatial Phaistos and Dhaskalio-Kavos, in terms of the congregation of craftspeople and participation in craft specialisation, are intriguing. Indeed, the notion that material choice and technological tradition might have had a deep meaning in terms of group identity (Day et al, 2010) may offer some understanding as to the material evidence and continuity of metallurgical practice at Dhaskalio-Kavos. The fact that pure-copper and arsenical-copper traditions endured at the site subsequent to the introduction of tin-bronzes to the Cyclades during the Kastri Group period (Gale and Stos-Gale, 1984: 268-69; Georgakopoulou, 2013; Renfrew, 1972: 314) may suggest that the craft activities taking place at the settlement were rooted in lasting technological traditions which cemented group identity. The evidence is clear that the symbolic attraction of Keros had lost its power by the end of the EBA (Renfrew, 2014). Perhaps one reason for this lies in the inevitability of technological change and an adaptation to an increasingly hierarchical socioeconomic landscape (Cherry, 1984).

Indeed, the chronological spread of activity at Dhaskalio-Kavos provides a nuanced understanding of cultural continuity and technological practices in the Early Cycladic period. During the early phases of occupation (Dhaskalio Phase A), primary smelting took place on the Kavos promontory, utilising the advantageous natural wind conditions. Concurrently, secondary metalworking activities were conducted on the eastern and northeastern faces of Dhaskalio. This spatial organisation largely persisted throughout the site's occupation, reflecting a deliberate and consistent approach to metallurgical production.

Importantly, despite the broader introduction of tin-bronzes to the Cycladic community during the Kastri Group phase, evidence suggests that Dhaskalio-Kavos continued the earlier metallurgical traditions of using pure copper and arsenical-copper alloys. This is particularly noteworthy considering the economic and utilitarian benefits associated with the adoption of tin-bronzes, which were prevalent in the wider Aegean and Anatolian contexts. The persistence of these earlier metallurgical practices at Dhaskalio-Kavos could indicate a deeply rooted cultural tradition that may have been maintained for reasons beyond practicality, such as social, ritualistic, or identity-related factors.

The Kastri Group period, characterised by increased external influences and technological advancements, marks a significant phase in Cycladic prehistory. The introduction of new pottery styles and drinking customs with Anatolian origins, along with an increase in fortified settlements, suggests a period of cultural exchange and adaptation. However, the absence of tin-bronze working at Dhaskalio-Kavos, despite its availability and advantages, highlights a selective adoption of new technologies. This selective adoption may be interpreted as a form of cultural continuity, where the community at Dhaskalio-Kavos consciously chose to maintain their established metallurgical traditions. This selective continuation of metallurgical practice also supports the view that the Kastri Group phase was not characterised by wholesale Anatolianisation of the Cyclades.

The continued use of pure copper and arsenical-copper alloys at Dhaskalio-Kavos may suggest that the site functioned as a centre for the preservation and transmission of earlier metallurgical knowledge and practices and implies a strong sense of cultural identity among the artisans and metalworkers at Dhaskalio-Kavos who may have viewed their metallurgical practices as a core element of their social and cultural identity. Furthermore, the spatial organisation of the site, with workshops overlooking the Special Deposits on Kavos, indicates a deliberate association of metallurgical activities with ritualistic or ceremonial practices.

The chronological significance of Dhaskalio-Kavos lies in its role as a centre for the preservation of early Cycladic metallurgical traditions amidst broader cultural changes. The site's resistance to the adoption of tin-bronze technology, despite its widespread use elsewhere in the Cyclades during the Kastri Group phase, allows for a deeper exploration of cultural continuities and factors that influenced technological choices, and underscores the importance of these traditions in maintaining group identity and social cohesion, highlighting the site's critical role in the cultural landscape of the Early Cycladic period.

6.3 Methodological considerations

The excavations at Dhaskalio, under the auspices of the Keros-Naxos Seaways Project, offered a unique, arguably unparalleled, opportunity to better explore the role that geochemistry can play in archaeological research and how the use of handheld portable X-ray fluorescence (HH-pXRF) can facilitate a campaign of rapid, in situ soil analysis within the contexts of excavation. This has allowed geochemical analysis to be used in order to inform the archaeological interpretation of technological practice and the past use of space in a manner that is not routinely undertaken. Therefore, whilst the data generated throughout this project has served to further our understanding of Dhaskalio-Kavos, the remainder of this discussion will focus on the methodological aspects of this research. It is hoped that this will highlight the benefits of using in situ geochemical analysis within an excavation context and, in doing so, make the case for a more widespread adoption of such methods.

6.3.1 Implementation and integration of soil chemistry on Dhaskalio

Regardless of the precise techniques employed, archaeological geochemistry is a method for understanding space. Therefore, it is not enough to merely conduct a campaign of geochemical analysis only to offer findings which are constrained to the empirical. All too often, results of archaeological geochemistry are offered with little interpretation beyond ‘this happened here’ (Cannell, 2017: 31). Certainly, the level of this interpretation may vary, depending upon the scale of analysis. With single element analysis, this can be as broad as ‘people lived here’, whereas multi-element analysis at least attempts to offer conclusions as to specific activities taking place, such as prepared food (Hjulström et al., 2008), worked metals (Cook et al., 2010), butchered meat (Coronel et al., 2014), or even buried their dead (Bethell and Smith, 1989). However, in each case, it appears to be sufficient to identify and explain functional areas in merely practical, structuralised terms. Whether a symptom of the continued dichotomy between the scientist and humanist, or merely an expectation of the science-led journals within which these studies are often published, this type of data reporting fails to utilise the scope of archaeological interpretation which geochemistry can afford.

Despite the many (and ever growing) subdisciplines within the field, archaeology, at its most fundamental level, must be concerned with understanding past change and past human experience. Whilst geoarchaeological studies without social theory are capable of explaining change, without also applying or integrating humanistic approaches, they risks missing the complexities of social and cultural dimensions in that change (Cannell, 2016: 19). For the archaeological geochemist, it is not sufficient to offer interpretations which merely focus on function and activity. By focussing solely on 'what' happened, these explanations ignore the significance of motion, reference, and relationships in human-created spaces. Instead, it is important to understand the social meaning of space within the contexts investigated. The use of space, as a social and physical construct, is fundamental to our understanding of, and how we relate to, the world around us. How people engage and live within spatial divisions, whether architectural or otherwise defined, can be seen as the piecemeal accumulation of behavioural responses to sociocultural and external environmental factors. Archaeological geochemistry is uniquely placed to answer such questions of past use of space. However, it is crucial to adopt a methodological practice which allows for this detailed understanding of how spaces were used on a human level.

In order to achieve the level of analysis necessary for high-resolution spatial interpretation, an appropriate methodological approach needed to be devised. Due to the complex stratigraphic phasing on Dhaskalio, known from previous excavations on the site (Renfrew et al., 2013), merely conducting a total surface survey prior to excavation was deemed insufficient. Although such a survey was undertaken, the data produced were most useful for an initial prospection of Dhaskalio. Therefore, it was deemed important that geochemical analysis be conducted during the excavation process. Instead of focussing analysis across a two-dimensional, horizontal plane, where time, in effect, ceases to matter, this method allowed geochemical analysis to be undertaken on every layer of habitation and use. In this manner, it became possible to not only gain insight into the possible function of different areas of the settlement, but also evaluate how these functions changed throughout the use of the site.

Incorporating geochemistry within areas of excavation also allowed for context specific analysis to be achieved. This was aided by the excavation methods developed by the Keros-Naxos Seaways Project. The excavations at Dhaskalio placed great emphasis on single context recording, rather than arbitrary systems which are common in Aegean archaeology (Boyd et al., 2021: 64). This was important, as excavations using a single context system offer a higher resolution of interpretation as compared to arbitrary systems. This is because single context methods aim to excavate and record features in stratigraphic order (Drewett, 2011: 102), whereas arbitrary systems employ retrospective stratigraphic interpretations based on artefact typologies and vertical data preserved in the sections at trench edges. The advantage of defining individual contexts for in situ soil chemistry, was that different parts of the excavated area were clearly delineated during the excavation process. This meant that geochemical analysis could take place within a precisely defined area of archaeological interest. This not only allowed for a higher resolution of survey than could be achieved if a larger, undefined area of the trench needed to be surveyed, but also held interpretive value in the sense that spatial patterns could be attributed to a single, known area of use.

The precise method of single context excavation employed during the Dhaskalio excavation also placed a greater emphasis on floors and surfaces which are not treated as separate context types in traditional single context recording (Boyd et al., 2021: 66-67). At Dhaskalio, floors and other surfaces are features of great importance as they can preserve evidence for specific activities. A 'surface', in the context of the Dhaskalio excavation, is defined by Boyd et al (2021: 67):

> "For us, a surface is an area exposed and a focus of activity over a period of time. A surface may lie above a deliberate deposition (a "make-up") or it may be the walked-on part of a built structure… Material recovered directly from the surface is related to the period of use of the surface rather than the fill above or the makeup (or construction) below, and, similarly, samples taken directly from the surface are related to the use of the surface".

This has the implication that material and samples taken from defined surfaces can be considered as related to the use of the surface. This is particularly significant for soil chemistry, as anthropogenically significant chemical residues retained on the surfaces of these features can be regarded as direct evidence of the past human activity. By defining surfaces as distinct archaeological features during excavation, intensive geochemical analysis could be undertaken at a resolution consistent with the scale of human movement (see Slater, 2014: 87). In this way, geochemical survey could offer insight into how past activities on Dhaskalio were organised spatially on a human scale. An example of this method in practice may be given with the metallurgical workshop in Trench H (figure 6.2).

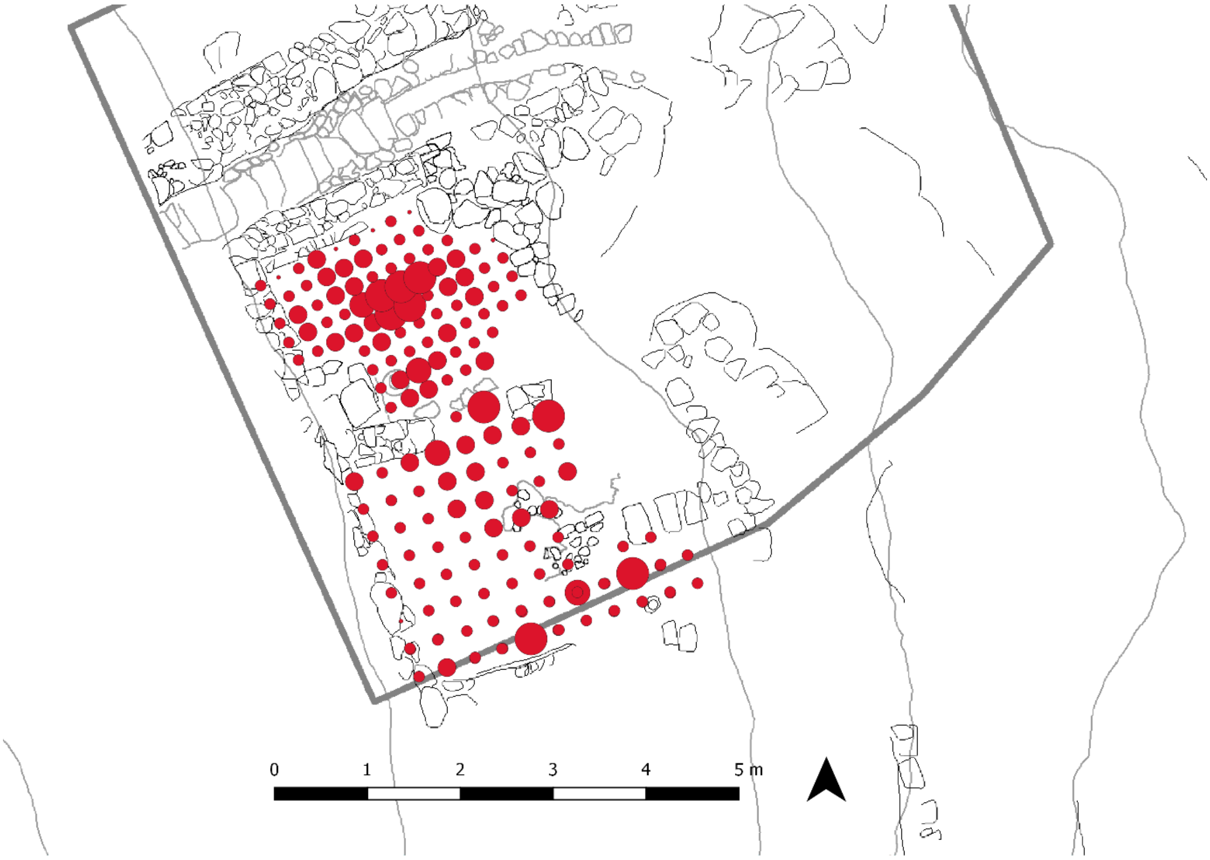

Figure 6.2: Image displaying the spatial patterning of CU in the metallurgical workshop located in trench H during Phase A (Image: author/Keros-Naxos Seaways Project 2018).

As previously mentioned, Trench H is situated on the (now) eastern coastline of Dhaskalio and includes a marble staircase which is thought to have been the once entrance to the settlement from Kavos proper, with access to the *Special Deposits* by way of a now submersed causeway (Dixon & Kinnaird, 2013). The earliest strata of rooms 1 and 2, immediately adjacent and south of the staircase, are dated to Dhaskalio Phase A. During this phase, the two rooms were encompassed in one unified space. This space is known, largely because of the presence of two ceramic lined hearths, to have been a metallurgical workshop, likely used for secondary copper and lead working. Geochemical survey was undertaken at a resolution of ~30cm in order to analyse the spatial patterning of chemical concentrations associated with these activities and allow a glimpse at how the working space may have been organised on a human scale. The highest concentrations of Cu are located, for the most part, centred around the hearths in the central and northern regions of the space. However, the spatial patterning of Cu also suggests that a significant part of the activity was taking place in the southern region of the space. Whilst concentrations are, as to be expected, extremely elevated throughout the entirety of the space, a clear distinction between the northern and southern areas is clear. This suggests a difference in intensity of practice between the two areas. A likely explanation for this is the presence on the entry staircase immediately to the north of the workshop. It is probable that those working within this workshop would have needed consistent access to the main thoroughfare of the settlement, thus organised their working routine within the area away from the staircase, accessing the hearths from the south. Although these findings may seem trivial, interpretation of space on this scale can rarely be achieved without analytical methods such as in situ geochemistry, or in the absence of an appropriate methodological framework.

As well as offering a means of high-resolution spatial interpretation of past human activities, routine geochemical analysis throughout the excavation process can be used as a tool for enhancing the on-site recording and interpretation of archaeological features. This was achieved on Dhaskalio through the collaborative framework established by the Keros-Naxos Seaways Project, and the use of an on-site digital recording system.

6.3.2 On-site recording and informing excavation

In addition to geochemistry, the 2016 to 2018 Keros-Naxos Seaways Project involved more than a dozen specialist archaeological techniques, including: archaeobotany, micromorphology, osteoarchaeology, photogrammetry (2D and 3D), zooarchaeology, and various material specialisations such as ceramics, obsidian, and metals (see. Boyd et al., 2021). It was the intention of those in direction of the project, in particular Prof. Colin Renfrew and Dr. Michael Boyd, that where possible, specialist techniques would be integrated into the excavation process, rather than remain a series of disparate processes in the field and during post-excavation phases (Boyd et al., 2021).

Therefore, the project was designed in order that every specialist and field process would be part of a heterarchical, cooperative workflow.

The theoretical framework for establishing such an integrated methodology is, now, fairly well established in archaeology. Indeed, this approach draws influence from 'Framework Archaeology' (Andrews et al., 2000), and methods developed by Ian Hodder at Çatalhöyük (Hodder, 1997), both of which addressed the structure of communication in the field and seek to increase the number of participants in the interpretative process. However, whilst these initiatives dealt with creating an environment of cooperation between participants and between different types of data (Hodder 1997, 694), they were not implemented on the same scale as the Keros-Naxos Seaways Project. The practical implications of establishing communication and interpretation among such a vast number of specialised techniques and field processes required the development of a common information framework within which integration of field, field laboratory, and post-excavation processes could take place (Boyd et al., 2021: 64). The greatest obstacle to establishing this integrated workflow was the need for mitigating the splintering of datasets among participants and locales (Boyd et al., 2021: 68). Therefore, the project decided to adopt a digital recording system which could be used as a means of not only recording in-field data, but also aid in the integration of specialist interpretations.

Digital recording systems have become increasingly well established in archaeological fieldwork over the past decade, particularly in large commercial practices. These systems allow for greater efficiency in the overall recording process of archaeological excavations and, crucially, improved intellectual engagement with archaeology in the field (Masson-MacLean et al., 2021: 595). The digital recording system adopted by the Keros-Naxos Seaways Project, known as iDig, was developed by marine archaeologist and programmer Bruce Hartzler in collaboration with the American School of Classical Studies at Athens, and is available on iOS for iPad. iDig represents a comprehensive digital recording interface and database which aims to facilitate paperless recording, real-time interpretation of excavations, and integration of diverse forms of archaeological data (Boyd et al., 2021). This meant that information from all parts of the excavation, whether from the field or field-laboratory, could be made available for everyone involved with the project with only the need for a mobile device (iPad).

This methodological framework established by the Keros-Naxos Seaways Project, aided in particular by the adoption of a coherent on-site digital recording system, allowed for soil chemistry to be used in a manner which had previously been unattainable. Indeed, the ability for field and laboratory data to be integrated into the iDig system permitted geochemical results to be disseminated to different areas of the project in close to real-time. Crucially, this meant that preliminary results could be used in order to aid interpretation of archaeological features and inform the ongoing excavation strategy.

These data were disseminated in various ways during the field seasons. Initially, immediate observations made during analysis were recorded in note form on iDig within the entry specific to the context being analysed. This gave immediate feedback to the trench supervisor, as well as acting as a permanent record of initial remarks for later reference. The use of iDig also allowed results to be circulated through visual means. Subsequent to each working day, all geochemical data from contexts analysed during that day were downloaded and organised by context into trench specific databases along with spatial data from iDig. Data for Cu, Zn, and Pb (see methodology chapter for interpretive value of these elements) from each context were then plotted spatially in QGIS and used in order to create a geochemical plan of current open contexts. The shapefiles of these plans were uploaded onto iDig where they could be accessed by trench supervisors in the field. This allowed those working in each area of a trench to have access to up-to-date geochemical data for the specific context which they were excavating, as well as an overall visualisation of chemical variation across the trench. These methods of dissemination, both at the point of analysis, and within a 24-hour turnaround, were useful in the field for differentiation between and within contexts, and for evaluating the potential for contexts to be associated with metallurgical practice. Whilst immediate observations allowed for real-time adaptation of excavation strategy, the visual geochemical plans served as a more long-term aid for interpretation.

Through regular feedback and dissemination of preliminary results, soil chemistry played an active role in aiding ongoing interpretation of open features and informing excavation and recording strategies. A clear example of this occurred in Trench A during the final stages of the 2017 field season. A routine analysis of context 58 in the central zone of Trench A revealed a unique structure to soil Pb. This context was defined as a region of wall collapse in the area between walls 52 and 56 which measured ~4.5m N-S and ~2.5m E-W. Because this context was identified as a region of collapse, not a specific surface or deposit corresponding to a phase of use, sample points were taken at a relatively low resolution (a regular grid with a ~1m interval). During and subsequent to geochemical survey of the area, anomalous concentrations of Pb were observed with a clear and distinct structure. Readings from the sample points to the north of the context showed extremely elevated Pb concentrations (~3000ppm), whereas analyses from the south of the context were much reduced, averaging at ~200ppm (figure 6.3). This clear distinction between the northern and southern regions of the context was surprising. Usually, chemical concentrations from one homogenous context are varied gradually throughout the area, with a gradual rise and fall of concentrations relative to the intensity of past activity. This was not the case with context 58, where readings of ~3000ppm were immediately followed by analyses showing ~200ppm in Pb. Therefore, it was concluded that this area of collapse was likely from two separate spaces. This hypothesis was confirmed in later layers, where evidence for lead working, likely taking place in an upper story, was present in the northern space, whilst the southern area displayed a completely different soil type. Through in situ soil chemistry, this distinction was realised prior to the removal of context 58, and allowed the excavation team to prioritise areas of the trench and adapt their excavation strategy.

Figure 6.3: Image displaying geochemical analysis of context 58 in trench A (Image: author/Keros-Naxos Seaways Project 2018).

In addition to aiding the differentiation between and within contexts, in situ soil chemistry also allowed for the adaptation of other sampling strategies. The Keros-Naxos Seaways Project included routine application of sediment screening by way of sieving and floatation. Whilst all soil was sieved through a ~1cm mesh, samples for floatation were taken at different frequencies depending on the perceived importance of the context. Renfrew (2013b: 712) notes that one of the most compelling types of evidence for metallurgical activity from previous seasons at Dhaskalio were small metal spills, but that the effectiveness of recovery may have affected their presence in the record. By establishing areas of likely metallurgical activity using rapid in situ soil chemistry, the frequency of samples for high-resolution screening could be increased, thereby offering an increased chance of recording vital evidence for craft practices.

6.3.3 Practical considerations

Whilst conducting a geochemical survey of every excavated layer clearly has interpretive value, certain practical issues were necessary to consider before finalising the eventual methodology. The main concern was how an intensive programme of geochemistry may negatively affect the routine workings of the excavation. Specifically, any time spent in a trench analysing for soil chemistry was time which could not be used for continuing the excavation process. As discussed above, in order to achieve a meaningful level of spatial interpretation, each context needed to be surveyed at a sufficiently high resolution. Consequently, it was often necessary for a large number of sample points to be analysed for each context. This was particularly pertinent when analysing surfaces, since these features represented exact contexts of activity, thus were likely to produce the most significant results pertaining to past use of space. Some contexts, for example, required 60 to 70 points of analysis in order to achieve the required resolution. With even one minute spent on locating, preparing, and analysing each sample point, these high-resolution contexts required upwards of one hour spent analysing soil chemistry, rather than excavating.

In addition, with multiple trenches open at any given time (anywhere between three and nine throughout the 2016 to 2018 field seasons), newly exposed contexts were ready for geochemical analysis at a relatively high frequency throughout a working day. With only one analytical instrument on site, analysis of contexts within any given trench needed to be concluded promptly so as not to impede on the workflow of other excavation teams. Consequently, it was necessary to consider how to limit the time spent analysing each context without compromising the interpretive value of geochemical results.

The main way to reduce the length of individual analyses was to limit the number of elements detected by the instrument. The XL3t uses multi-filter testing in order to either preferentially excite specific elements for increased sensitivity, or to cover a wider element range than one filter alone can provide. The Low Range filter adds the capability to analyse light elements which cannot be efficiently excited by the Main Range filter, and the Light Range filter adds the capability of analysing very light elements. Whilst it may seem apparent that it is most beneficial to detect the largest range of elements possible, different elements vary in their archaeological interpretive value. Several scholars have suggested that the elements with the most utility for characterising past human activity are: P, K, Ca, Cu, Zn and Pb (i.e. Wilson et al 2008; Aston et al 1998). The majority of these elements can be detected by the XL3t in the Standard Soil mode using the Main Range and Low Range filters. The main element with archaeological interpretive value which is not detected in these ranges is phosphorus (P), which is detected in Mining mode using the High Range filter.

In order to detect P with an acceptable degree of precision for this study, the instrument used requires a helium (He) purge. The reason why helium is used when analysing light elements is that it ensures the photons returning from the sample have an unobstructed path to the analytical part of the instrument. This is important because light elements are more readily attenuated than heavier elements and regulating the atmosphere in the nose of the instrument can mitigate this issue (Adams et al., 2020). More recent models of handheld pXRF, such as Niton analysers with GOLDD technology, can measure light elements without the need for a He purge. However, the instrument used for this study, whilst suitable for detecting a good number of heavier elements associated with anthropogenic activity, did not have this capability. The bulky nature of the He tank and attachments, as well as the need for a large supply of He throughout the course of a field season, made this method impractical for the type of in situ analysis required for this project. One possible way to remove the requirement of a He purge is to extend the duration of analysis for lighter elements. However, as highlighted above, practical constraints pertaining to the time taken for each analysis rendered this option unfeasible.

Phosphorus analysis is very prevalent in archaeological geochemical studies, often with only P being analysed (e.g. Cavanagh et al., 1988; Holliday and Gartner, 2007; Linderholm, 2007). However, whilst past studies shown the utility of P for archaeological interpretation, P alone is an unreliable source for interpreting specific human activity. This is because the element is present in a wide range of organic and inorganic materials utilised by humans, and often cannot be used to distinguish between past activities (Entwistle et al., 1998). Other elements detectable without the High Range filter, such as Cu (although higher concentrations can be indicative of craft practice) and Zn, are also useful proxies for more generic human activity (Entwistle et al., 1998; Oonk et al., 2009b). Consequently, it is possible to perform multi-element analysis without the inclusion of P whilst retaining a high degree of interpretive value.

6.4 Summary

In this chapter, results from high-resolution geochemical analysis of Dhaskalio-Kavos have been discussed. Evidence for widespread metallurgical practice is present in occupation layers from all chronological periods of the site. It is therefore likely that metalworking, and perhaps specifically copperworking, played an important role in establishing Dhaskalio-Kavos as a significant cultural centre in the Early Bronze Age Cyclades. These conclusions were made possible by the methodological approach created for this project. Routine geochemical analysis of archaeologically significant layers of excavation enabled a detailed understanding of the widespread presence of in situ metalworking and the spatial routines of these practices. In the absence of more traditional methods of archaeological investigation, such as the quantification of metallurgical debris, often struggle to establish areas of direct metallurgical practice. Metal objects and tentative evidence for metalworking were previously recovered from stratigraphic layers at Dhaskalio during the 2006 to 2008 excavations. However, these finds were not necessarily indicative of in situ metallurgical practice (Georgakopoulou, 2013: 691-2). As with all portable objects, this evidence for metal working could have been moved from their context of use, either for storage or for deliberate disposal. Without evidence for their primary context, no definitive conclusions could be drawn as to the presence or nature of metallurgical practice on Dhaskalio itself. This is a problem that is all too familiar with interpreting evidence from traditional excavation practices. It is within this sphere of ambiguity that rapid, high-resolution, in situ geochemical analysis plays a pivotal role. Where material evidence is lacking, or where context of use is uncertain, chemical analysis of the surfaces of habitation can aid in the interpretation of these spaces. Furthermore, the framework established by the Keros-Naxos Seaways Project, aided in particular by the adoption of a coherent on-site digital recording system, allowed for soil chemistry to be used in a manner which had previously been unattainable. Crucially, the routine geochemical analysis of archaeologically significant deposits during the course of excavation enabled HHpXRF to be used in order to aid interpretation of archaeological features and inform the ongoing excavation strategy.

CHAPTER 7: Conclusions

7.1 Concluding remarks about Dhaskalio-Kavos

In response to the aim of this thesis, high-resolution soil chemical survey has been used to characterise both the wider Dhaskalio-Kavos landscape and surfaces of occupation from excavated areas at Dhaskalio itself. Results from this intensive programme of analysis have highlighted the importance of metallurgical practice at the site, especially during Dhaskalio Phase A (EC IIA) and Dhaskalio Phase B (EC IIB), and perhaps for a period subsequent to these phases. Knowledge of metallurgical processes in the region have been identified as having FN origins (see chapter 2). Though, perhaps most salient for understanding the foundation of practices at Dhaskalio-Kavos are the metallurgical traditions of the EC I Late Kampos Group. In laying out the context for the current study, it was shown that this period was witness to an increase in connectivity and trade between the peoples of the Cycladic islands, the eastern Aegean, and northern Crete. The Kampos culture is significant to this study because of its likely regional origin in the *Mikres Kyklades*, the location of Dhaskalio-Kavos itself, as evidenced by the EC I cemeteries at Paros, Naxos, Antiparos, and Ano-Kouphonisi (Alram-Stern, 2011), but also because of its undeniable association with metallurgical practice.

The cemetery of Ayia Photia, Crete features graves not only with the ceramic and metal cultural components of the Kampos Group, but also some large metallurgical crucibles as grave goods. The settlements of Poros-Katasambas in northern Crete further revealed extensive metalworking debris alongside evidence for intense Cycladic influence during EM I, with Cycladic-style Kampos Group pottery produced locally (Betancourt, 2008; Davaras and Betancourt, 2004; Dimopoulou-Rethemiotaki et al., 2007; Doonan et al., 2007). Therefore, an EC I picture develops of metallurgically adept islanders travelling outwards from the central Cyclades, spreading their metallurgical, and perhaps other, traditions. This outward movement of Cycladic smiths during EC I lies in stark contrast to the practices taking place at Dhaskalio-Kavos during EC II.

Dhaskalio is a monumental settlement. The vast terracing and architecture, which is all constructed from imported stone, must have demanded the mobilisation of a large labour force, likely from a wide geographical location given the calculated average size of island populations during the period (Broodbank, 2000: 177: Broodbank, 2008: 55). Therefore, it is likely that Dhaskalio was built in this manner to fulfil a role as an important destination for peoples from across the Cyclades and perhaps beyond. Yet this warrants the question: a destination for what? Current understanding suggests that Kavos represents a significant *maritime sanctuary* (Renfrew, 2013). Certainly, the nature of the *special deposits* is supportive of this notion, suggesting that people from a wide region of the Aegean and perhaps mainland Greece travelled to the site for the purpose of ritual depositional practice. However, the results from geochemical analysis at the site show that the main activity taking place, at least at Dhaskalio, was metalworking. Therefore, if Dhaskalio-Kavos is indeed a sanctuary, this undeniable association with intense metalworking could change our perspective of metal production in the EC II.

The need for the mobilisation of a sizeable labour force for its construction, alongside the ubiquity of metalworking at Dhaskalio suggests that there was a great effort to monumentalise metallurgical production at the site. In an Aegean world where the role of metals played such an important role in social and economic change, facilitating an 'international spirit' (Renfrew, 1972: 34) of trade and dispersion of highly valued, socially significant objects, evidence from Dhaskalio not only represents the centralisation of craft production, but of social power. Indeed, metals are intrinsically linked to the power dynamics of the EC II period, whether through trade of prestige goods, or the conspicuous consumption of metals through funerary practices (Nakou, 1995). Therefore, the centralising and monumentalising of metalworking at Dhaskalio is not just the coming together of crafts people, it is a place which creates power through conspicuous production of metal and metal objects.

The multi-scalar approach to geochemical survey presented in this project, utilising high-resolution analysis of the wider landscape and within architectural features, also offers insight into the visibility of different metallurgical processes at Dhaskalio-Kavos. It is clear that primary production taking place at the Kavos promontory was necessarily open in order to take advantage of perforated furnaces and the strong northerly winds (Brodie and Georgakopoulou, 2015). Therefore, these practices would have been accessible for observation from across the wider Dhaskalio-Kavos area. In addition, the geochemical survey shows that metallurgical practice was widespread on Dhaskalio, something which portable finds cannot testify to.

Furthermore, the soil chemical analysis of occupation layers suggests that secondary metallurgical production at the site was organised spatially *within* the architectural features of Dhaskalio. If, as is suggested here, metallurgical practice was central to the activities on Dhaskalio, its planned, monumental construction must have consciously hosted that activity, with those who built the settlement making deliberate choices about access to and enclosure of specific spaces for different participants. The geochemical work presented here provides important insights even on this scale, in detailed association with architecture. We can now start to consider whether smelting represented a public display, whilst the process of casting and finishing needed to be conducted away from public view until the final object could be revealed.

Understanding Dhaskalio as a centralised site for metallurgical practice may also explain patterns to the spatial organisation of these practices throughout the different phases of occupation. Geochemical analyses of occupation layers associated with the initial phase of use at the site, the so called Dhaskalio Phase A, shows metallurgical processes were taking place in almost all areas of the site. This pattern of widespread metalworking appears to continue into Dhaskalio Phase B, although there are recognisable changes to the spatial distribution of these practices. This second period of occupation is associated with the beginning of the phase associated with the Kastri Group, which sees the introduction of material culture with a distinctive Anatolian origin into the Cyclades (Broodbank, 2000: 309-19). This period also sees the introduction of new metallurgical traditions, with an increased use of tin-bronze alloys (Gale and Stos-Gale, 1984: 268-69; Renfrew, 1972: 314). Mixing of alloys was certainly not a new phenomenon in the Cyclades during EC II, with deliberate mixing of arsenic and copper being practiced since the late EC I period (Doonan and Day, 2007). However, new Cycladic-Anatolian trade routes would have offered opportunity for the exploitation of new mineral sources, allowing for an increase to the scale of bronze production to those who controlled access to such trade. At Dhaskalio, almost all metal finds are of lead, copper, or arsenical-copper, suggesting that tin-bronze production was not the mainstay of the practices taking place at the site. This necessitates questions of whether the changing spatial organisation of metalworking witnessed at Dhaskalio over its period of occupation can be explained through these wider social changes during EC II.

The findings from Dhaskalio-Kavos underscore a nuanced understanding of metallurgical practice and social organisation. The spatial organisation at Dhaskalio reflects a dynamic interplay between craft production and social identity, emphasising the notion that the act of making is not merely about the creation of artefacts, but also about the shaping of social relationships and practices within specific spaces (Ingold, 2000; 2017). At Dhaskalio, the deliberate placement and monumentalisation of metallurgical activities suggest that the spatial practices were integral to the formation and reinforcement of social hierarchies and collective identities. The geochemical evidence of widespread metalworking offers insight into how material practices and spatial arrangements can reflect and reproduce social structures (Erb-Satullo, 2022), and highlights the role of spatial organisation in mediating social interactions and reinforcing cultural values. At Dhaskalio-Kavos, the extensive use of space for metallurgical activities, coupled with the varying visibility of these practices, likely served to solidify the settlement's role as a focal point for communal and ritual activities, reinforcing its status and the social power of its occupants into the broader ritual and social landscape of the EBA Cyclades. The persistence of copper and arsenical copper metallurgy, despite the broader trend towards tin-bronze adoption, further underscores the site's role in maintaining and projecting specific technological and cultural identities. By contextualising Dhaskalio-Kavos within these theoretical frameworks, we gain a deeper understanding of how spatial practices were used as a mechanism for crafting and sustaining social relationships and identities within the Cycladic Early Bronze Age.

7.2 Methodological conclusions

This thesis has offered insight into how craft practices were organised at Dhaskalio-Kavos, and how these practices may have established the site as an important EC II centre. Furthermore, by utilising a multi-scalar approach to geochemical analysis, incorporating both wide-area prospection survey techniques alongside high-resolution analysis of archaeological contexts throughout the period of excavation, the research has also explored the role that geochemistry can play in archaeological research. Therefore, this chapter will end by offering conclusions as to why the methodological approach taken here was successful, and suggest methods by which on-site archaeological geochemistry may be implemented in the future.

- The methods used here for rapid high-resolution soil chemistry took advantage of, and were made possible by, the specific properties of HHpXRF technology (Frahm &Doonan, 2013). That is not to suggest that portable XRF should replace existing laboratory methods. If the aim of research is to obtain as close to true values as possible, high precision instrumentation is required, such as MC-ICP-MS coupled with strong acid or total digestion of samples (Cannell, 2016: 82).
- Using HH-pXRF is a compromise between accuracy, flexibility, portability, and cost efficiency. However, the properties of hand-held instruments allowed for geochemistry to be used in ways which laboratory based instrumentation cannot facilitate, such as real-time geochemical data to inform the excavation strategy.
- Lab-based analysis serves to detach geochemical approaches from any integration of on-site methodology and reinforces the separation between fieldworkers and post-excavation 'specialists' Within the field of archaeological geochemistry, HHpXRF has the potential to bridge that gap because of its accessibility.

- This in-field value was only enabled by the methodological framework established by the Keros-Naxos Seaways Project.

Given the value which HHpXRF held for on-site interpretation at Dhaskalio, the following method of soil chemical analysis is recommended for future archaeological investigations:

- A multi-scalar approach to analysis should be taken, incorporating both wide-area survey techniques, alongside the routine analysis of excavated contexts.
    - This allows for the prospection and interpretation of the landscape, whilst also offering high-resolution interpretation of archaeologically significant deposits.
- Analysis should be conducted in situ:
    - This is the only way that data may be fed back to excavators at the point of analysis. This is important as it allows the spatial distribution of chemical concentrations to aid in the interpretation of different soil matrices.
- Analysis should be conducted using reliable, up-to date portable instrumentation.
    - Modern HHpXRF analysers are capable of analysing lighter elements within a fraction of the time needed with older models, even without the addition of a helium purge.
    - Whilst this project has been successful without this technology, sites which do not present such clear evidence for metallurgical production would benefit from a larger suite of elements which includes phosphorus.
- Feedback to excavators should also be made through preliminary spatial plots of each archaeological context.
    - This should ideally be performed with a <24 hour turnaround so that the context of analysis is still undergoing excavation.
    - This is where a digital recording system, such as iDig is beneficial since spatial plans of chemical data may be stored with plans of other archaeological information and often presented as georeferenced overlays within the trench specific interface.

It is hoped that this thesis has demonstrated the utility of high-resolution geochemical survey, and that this may help in some way to enable HHpXRF to become more widely accepted amongst the archaeological community, especially within a commercial setting where in situ geochemistry can aid rapid interpretation. However, it should be noted that the data produced during such investigations is only ever as relevant as the research question, and HH-pXRF is not a solution for every archaeological problem. Nevertheless, within an appropriate methodological framework, rapid in situ geochemistry has great potential for enhancing the interpretation of past human practice.

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APPENDIX 1: Standard Reference Material Data

Supplementary data file:

File name:

LESTER-Matthew-Appendix-1.xlsx

Description:

The accompanying Excel workbook shows the readings from the standard reference materials analysed prior to geochemical analysis of wide-area surveys and context surveys. In the column headings of each sheet "Reading No" represents the instrument's internal storage reading, and "Sample" represents the name of the SRM analysed filter settings. All elements analysed and their associated errors are given. All analyses were conducted in-line with the instrument settings outlined in "Chapter 4: methodology".

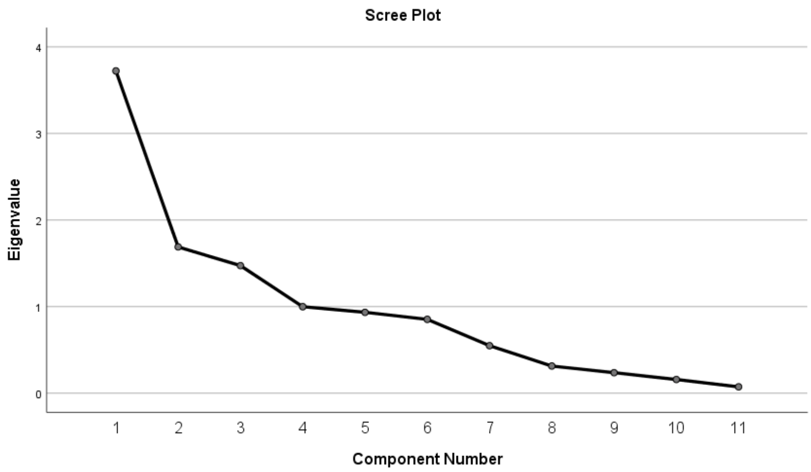
APPENDIX 2: Principal Component Analysis Data

Kavos survey

Total Variance Explained

Component	Initial Eigenvalues Total	% of Variance	Cumulative %	Extraction Sums of Squared Loadings Total	% of Variance	Cumulative %	Rotation Sums of Squared Loadings Total	% of Variance	Cumulative %
1	3.722	33.837	33.837	3.722	33.837	33.837	3.444	31.307	31.307
2	1.689	15.355	49.192	1.689	15.355	49.192	1.865	16.951	48.258
3	1.473	13.393	62.585	1.473	13.393	62.585	1.576	14.327	62.585
4	.999	9.079	71.664						
5	.934	8.490	80.154						
6	.853	7.753	87.907						
7	.549	4.988	92.895						
8	.313	2.849	95.744						
9	.237	2.154	97.898						
10	.158	1.436	99.334						
11	.073	.666	100.000						

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component 1	2	3
Zscore(Sr)	.164	.451	-.210
Zscore(Pb)	.538	-.574	.441
Zscore(As)	.342	.254	-.151
Zscore(Zn)	.789	.124	.065
Zscore(Cu)	.474	-.482	.556
Zscore(Fe)	.947	.083	-.133
Zscore(Mn)	.880	.179	-.226
Zscore(Ti)	.859	-.084	-.313
Zscore(Ca)	.012	.677	.388
Zscore(K)	-.180	-.566	-.613
Zscore(S)	.028	.137	.453

Extraction Method: Principal Component Analysis.

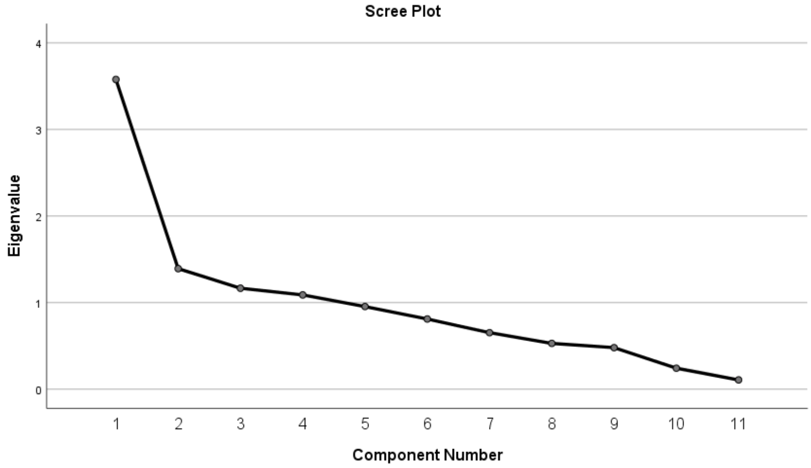
a. 3 components extracted.

Dhaskalio survey

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.577	32.522	32.522	3.577	32.522	32.522	3.502	31.832	31.832
2	1.392	12.657	45.180	1.392	12.657	45.180	1.265	11.497	43.329
3	1.166	10.602	55.781	1.166	10.602	55.781	1.247	11.333	54.662
4	1.089	9.899	65.681	1.089	9.899	65.681	1.212	11.019	65.681
5	.954	8.674	74.355						
6	.810	7.367	81.721						
7	.652	5.932	87.653						
8	.529	4.807	92.460						
9	.480	4.363	96.824						
10	.242	2.203	99.026						
11	.107	.974	100.000						

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component 1	2	3	4
Zscore(Sr)	-.106	-.533	.060	.640
Zscore(Pb)	.326	-.002	.594	-.056
Zscore(As)	.033	.394	-.356	.532
Zscore(Zn)	.203	.738	-.024	.213
Zscore(Cu)	.028	.359	.707	.297
Zscore(Fe)	.892	.126	-.103	-.072
Zscore(Mn)	.780	.007	-.186	-.291
Zscore(Ti)	.868	.169	-.161	.105
Zscore(Ca)	-.667	.119	-.330	.161
Zscore(K)	.730	-.429	-.036	.256
Zscore(S)	-.531	.190	.011	-.259

Extraction Method: Principal Component Analysis.

a. 4 components extracted.

APPENDIX 3: Raw Geochemical Data

Supplementary data file:

File name:

LESTER-Matthew-Appendix-3.xlsx

Description:

The accompanying Excel workbook shows the raw geochemical data from the wide-area surveys and context surveys. In the column headings of the "Dhaskalio survey" and "Kavos survey" sheets, "Reading No" represents the instrument's internal storage reading, and "Sample" represents the name of the survey. All elements analysed and their associated errors are given. In the "Trench data" sheet, "Reading No" represents the instrument's internal storage reading, "Trench" represents the name of the trench which the context belongs to, and "Context" represents the individual context numbers. All analyses were conducted in-line with the instrument settings outlined in "Chapter 4: methodology".