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Networks Of Knowledge: Metallurgical Technologies In Early Iron Age Cyprus And Crete

Olivia Eve Hayden

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Networks Of Knowledge: Metallurgical Technologies In Early Iron Age Cyprus And Crete

Abstract
The Early Iron Age (ca. 1200-800 BCE) in the eastern Mediterranean was an era of regeneration and innovation following a major economic and social collapse. During this period influential advancements in metalworking included the development of iron smelting, for which the period was named, as well as advancements in bronze casting. These practices were adopted by smiths around the Mediterranean. Previous scholarship has suggested that that in the Aegean, technological knowledge necessary for many aspects of complex craft production was forgotten and that techniques in metalworking were subsequently imported from Cyprus, which was a center of metallurgical innovation. In fact, the evidence for this claim is far from conclusive and many questions remain about the practical mechanisms by which these innovations could have been transmitted.

This dissertation widens the scope of the questions asked as well as the range of evidence used, looking at more mundane copper and iron objects found in larger numbers in both Cyprus and Crete. It combines an archaeometric analysis of copper-based objects from the Penn Museum's 20th century excavations at Kourion and Lapithos on Cyprus and Vrokastro on Crete with a social network analysis of bronze and iron objects from Cyprus and Crete using data gathered from published reports. Drawing on châine opératoire, this work reconstructs communities of practice active at the sites and investigates how metallurgical knowledge was shared among and between them. The results of these analyses indicate that the most frequent and significant interactions occurred on a local scale and that long-distance connections between Cyprus and Crete have been overstated.

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NETWORKS OF KNOWLEDGE: METALLURGICAL TECHNOLOGIES IN EARLY IRON AGE

CYPRUS AND CRETE

Olivia Hayden

A DISSERTATION

in

Art and Archaeology of the Mediterranean World

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NETWORKS OF KNOWLEDGE: METALLURGICAL TECHNOLOGIES IN EARLY IRON AGE
CYPRUS AND CRETE

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2020

Olivia Hayden
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ABSTRACT

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Olivia Hayden
Thomas Tartaron

The Early Iron Age (ca. 1200-800 BCE) in the eastern Mediterranean was an era of regeneration and innovation following a major economic and social collapse. During this period influential advancements in metalworking included the development of iron smelting, for which the period was named, as well as advancements in bronze casting. These practices were adopted by smiths around the Mediterranean. Previous scholarship has suggested that in the Aegean, technological knowledge necessary for many aspects of complex craft production was forgotten and that techniques in metalworking were subsequently imported from Cyprus, which was a center of metallurgical innovation. In fact, the evidence for this claim is far from conclusive and many questions remain about the practical mechanisms by which these innovations could have been transmitted.

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# Table of Contents

ACKNOWLEDGEMENTS........................................................................................................ iii

ABSTRACT .................................................................................................................................. vi

LIST OF TABLES AND FIGURES .................................................................................. xi

CHAPTER 1: INTRODUCTION ......................................................................................... 1
  HISTORICAL OVERVIEW ............................................................................................... 3
  Mobility .......................................................................................................................... 4
  Metallurgy ...................................................................................................................... 5

OVERVIEW OF DISSERTATION ................................................................................... 7
  Part I: Communities of Practice in Early Iron Age Kourion, Lapithos, and Vrokastro ... 8
  Part II: Networks of Knowledge in the Early Iron Age Eastern Mediterranean .......... 10

ROADMAP OF DISSERTATION ..................................................................................... 11

CHAPTER 2: METALLURGICAL KNOWLEDGE AND THE TRANSFER OF TECHNOLOGY IN THE EARLY IRON AGE EASTERN MEDITERRANEAN ...... 13
  HISTORY OF SCHOLARSHIP ....................................................................................... 13
  CYPRIOT INNOVATORS ............................................................................................... 15
    An Abundance of Copper ......................................................................................... 17
    Translatable Experience with Copper ..................................................................... 23
    Early Experimentation ............................................................................................. 26

  AEGEAN ADOPTERS ..................................................................................................... 29
    A “Dark Age” in the Aegean .................................................................................. 30
    Loss of Specialized Craft Knowledge .................................................................... 32

  CYPRO-AEGEAN CONNECTIONS ............................................................................ 33
    A Special Relationship? ......................................................................................... 34
    Trade in Finished Products ................................................................................... 35
    Mobile Craftsmen .................................................................................................. 40

  MOVING FORWARD ................................................................................................... 43

CHAPTER 3: INVESTIGATING METALLURGICAL TECHNOLOGY AT EARLY IRON AGE KOURION, LAPITHOS, AND VROKASTRO .............................................. 47
  MATERIALS .................................................................................................................. 48
    Kourion ................................................................................................................... 49
    Lapithos ................................................................................................................... 55
    Vrokastro ................................................................................................................ 61

  THEORY ....................................................................................................................... 66
    Technological Studies .............................................................................................. 67
    Technological Change and Transmission of Technological Knowledge ................. 74

  METHODS .................................................................................................................... 80
    Background ............................................................................................................. 82
LIST OF TABLES AND FIGURES

List of Tables

Table 1: Table of Results from Visual Analysis
Table 2: Table of Results from Microscopy

List of Figures

Figure 1: Map of the Eastern Mediterranean
Figure 2: Chronological Chart
Figure 3: Map of Cyprus with Kourion and Lapithos
Figure 4: Map of Crete with Vrokastro
Figure 5: Site Map of Kourion
Figure 6: Site Map of Episkopi-Kaloriziki
Figure 7: Site Map of Lapithos
Figure 8: Site Map of Lapithos, Upper Geometric and Kastros Tombs
Figure 9: Site Map of Lapithos, Upper Geometric Cemetery
Figure 10: Site Map of Vrokastro
Figure 11: Results of the SEM Analysis
Figure 12: Results of the LA-ICP-MS Analysis
Figure 13: Results of the LA-ICP-MS Analysis
Figure 14: Châine Opératoire Diagram
Figure 15: Images of front and back of 32-27-793
Figure 16: Images of front and back of 32-27-823
Figure 17: Images of front and back of 32-27-1047
Figure 18: Images of front and back of 32-27-1201
Figure 19: Images of front and back of 49-12-6
Figure 20: Images of front and back of 49-12-490
Figure 21: Images of front and back of 49-12-722
Figure 22: Images of front and back of 49-12-726
Figure 23: Images of front and back of 49-12-912
Figure 24: Images of front and back of 49-12-922
Figure 25: Images of front and back of 49-12-969
Figure 26: Images of front and back of 49-12-985
Figure 27: Images of front and back of 49-12-988
Figure 28: Images of front and back of 32-27-802
Figure 29: Images of front and back of 49-12-721
Figure 30: Images of front and back of VK4756
Figure 31: Images of front and back of VK4757
Figure 32: Images of front and back of VK4760
Figure 33: Images of front and back of VK4622
Figure 34: Images of front and back of VK4758
Figure 35: Images of front and back of VK4618
Figure 36: Location of sample VK4622
Figure 37: Microstructure of sample VK4622, polished
Figure 38: Microstructure of sample VK4622, etched
Figure 39: Location of sample VK4756
Figure 40: Microstructure of sample VK4756, polished
Figure 41: Microstructure of sample VK4756, polished
Figure 42: Microstructure of sample VK4756, etched
Figure 43: Location of sample VK4757
Figure 44: Microstructure of sample VK4757, polished
Figure 45: Microstructure of sample VK4757, etched
Figure 46: Location of sample VK4758
Figure 47: Microstructure of sample VK4758, polished
Figure 48: Microstructure of sample VK4758, etched
Figure 49: Location of sample VK4759
Figure 50: Microstructure of sample VK4759, polished
Figure 51: Microstructure of sample VK4759, etched
Figure 52: Location of sample VK4760
Figure 53: Microstructure of sample VK4760, polished
Figure 54: Microstructure of sample VK4760, etched
Figure 55: Microstructure of sample VK4760, etched
Figure 56: Location of sample 49-12-721
Figure 57: Microstructure of sample 49-12-721, polished
Figure 58: Microstructure of sample 49-12-721, polished
Figure 59: Microstructure of sample 49-12-721, etched
Figure 60: Location of sample 49-12-988
Figure 61: Microstructure of sample 49-12-988, polished
Figure 62: Microstructure of sample 49-12-988, polished
Figure 63: Location of sample 32-27-1201
Figure 64: Microstructure of sample 32-27-1201, polished
Figure 65: Microstructure of sample 32-27-1201, etched
Figure 66: SEM/BSE image of sample VK4622
Figure 67: SEM/BSE image of sample VK4756
Figure 68: SEM/BSE image of sample VK4757
Figure 69: SEM/BSE image of sample VK4758
Figure 70: SEM/BSE image of sample VK4759
Figure 71: SEM/BSE image of sample VK4760
Figure 72: SEM/BSE image of sample 32-27-1201
Figure 73: SEM/BSE image of sample 49-12-721
Figure 74: Images of front and back of 49-12-724
Figure 75: Images of front and back of 49-12-989
Figure 76: Images of front and back of 49-12-948
Figure 77: Images of front and back of VK4619
Figure 78: Images of front and back of VK4621
Figure 79: Images of front and back of VK4620
Figure 80: Images of front and back of 32-27-652
Figure 81: Images of front and back of 32-27-795
Figure 82: Images of front and back of 32-27-1184
Figure 83: Images of front and back of 49-12-853
Figure 84: Images of front and back of 49-12-545
Figure 85: Images of front and back of 49-12-773
Figure 86: Images of front and back of 49-12-982
Figure 87: Images of front and back of 49-12-986
Figure 88: Images of front and back of 32-27-651
Figure 89: Images of front and back of 32-27-721
Figure 90: Images of front and back of 32-27-734
Figure 91: Images of front and back of 32-27-735
Figure 92: Images of front and back of 32-27-744
Figure 93: Images of front and back of 32-27-780
Figure 94: Images of front and back of 32-27-792
Figure 95: Images of front and back of 32-27-1195
Figure 96: Images of front and back of 32-27-743
Figure 97: Images of front and back of 49-12-444
Figure 98: Images of front and back of 49-12-1058
Figure 99: Images of front and back of 32-27-661
Figure 100: Images of front and back of 32-27-611
Figure 101: Images of front and back of 32-27-635
Figure 102: Images of front and back of 32-27-741
Figure 103: Images of front and back of 32-27-742
Figure 104: Images of front and back of 32-27-745
Figure 105: Images of front and back of 32-27-796
Figure 106: Images of front and back of 32-27-820
Figure 107: Images of front and back of 32-27-1150
Figure 108: Images of front and back of 32-27-1196
Figure 109: Location of sample 32-27-745
Figure 110: Microstructure of sample 32-27-745, polished
Figure 111: Microstructure of sample 32-27-745
Figure 112: Microstructure of sample 32-27-745
Figure 113: Location of sample 32-27-1196
Figure 114: Microstructure of sample 32-27-1196, polished
Figure 115: Microstructure of sample 32-27-1196, polished
Figure 116: Microstructure of sample 32-27-1196, etched
Figure 117: Location of sample 49-12-792
Figure 118: Microstructure of sample 49-12-792
Figure 119: Location of sample 49-12-545
Figure 120: Microstructure of sample 49-12-545, polished
Figure 121: Location of sample 49-12-982
Figure 122: Microstructure of sample 49-12-982, polished
Figure 123: Location of sample 49-12-986
Figure 124: Microstructure of sample 49-12-986, polished
Figure 125: Location of sample 32-27-1195
Figure 126: Microstructure of sample 32-27-1195, polished
Figure 127: Microstructure of sample 32-27-1195, polished
Figure 128: Microstructure of sample 32-27-1195, etched
Figure 129: Location of sample 32-27-735
Figure 130: Microstructure of 32-27-735, polished
Figure 131: Microstructure of 32-27-735, polished
Figure 132: SEM/BSE image of sample 32-27-735
Figure 133: SEM/BSE image of sample 32-27-1195
Figure 134: SEM/BSE image of sample 32-27-1196
Figure 135: SEM/BSE image of sample 32-27-745
Figure 136: SEM/BSE image of sample 49-12-545
Figure 137: SEM/BSE image of sample 49-12-982
Figure 138: Images of front and back of 32-27-1202
Figure 139: Images of front and back of 32-27-1197A
Figure 140: Images of front and back of 32-27-1198
Figure 141: Images of front and back of 32-27-1200
Figure 142: Images of front and back of 32-27-797
Figure 143: Images of front and back of 32-27-798
Figure 144: Images of front and back of 32-27-799
Figure 145: Images of front and back of 32-27-1048
Figure 146: Images of front and back of 32-27-733A
Figure 147: Images of front and back of 49-12-719
Figure 148: Images of front and back of 49-12-720
Figure 149: Images of front and back of 49-12-723
Figure 150: Images of front and back of 49-12-1004
Figure 151: Images of front and back of 49-12-1005
Figure 152: Images of front and back of 49-12-1023
Figure 153: Images of front and back of 49-12-1024
Figure 154: Images of front and back of 49-12-544
Figure 155: Location of sample 32-27-733
Figure 156: Microstructure of sample 32-27-733, polished
Figure 157: Location of sample 49-12-544
Figure 158: Microstructure of sample 49-12-544, polished
Figure 159: Microstructure of sample 49-12-544, etched
Figure 160: Location of sample 49-12-1005
Figure 161: Microstructure of sample 49-12-1005, polished
Figure 162: Microstructure of sample 49-12-1005, polished
Figure 163: SEM/BSE image of sample 32-27-733
Figure 164: SEM/BSE image of sample 49-12-544
Figure 165: Images of front and back of 32-27-633
Figure 166: Images of front and back of 32-27-633
Figure 167: Images of front and back of 32-27-634
Figure 168: Images of front and back of 32-27-634
Figure 169: Images of front and back of 32-27-648
Figure 170: Images of front and back of 32-27-648
Figure 171: Images of front and back of 32-27-719
Figure 172: Images of front and back of 32-27-719
Figure 173: Images of front and back of 32-27-720
Figure 174: Images of front and back of 32-27-1045
Figure 175: Images of front and back of 32-27-1046
Figure 176: Images of front and back of 32-27-1046
Figure 177: Images of front and back of 49-12-1051
Figure 178: Images of front and back of 49-12-1051
Figure 179: Images of front and back of 49-12-1052
Figure 180: Images of front and back of 49-12-1052
Figure 181: Images of front and back of 32-27-789
Figure 182: Images of front and back of 49-12-1055
Figure 183: Images of front and back of 49-12-1055
Figure 184: Images of front and back of 49-12-1055
Figure 185: Images of front and back of 49-12-1029
Figure 186: Images of front and back of 49-12-1029
Figure 187: Images of front and back of 49-12-1029
Figure 188: Location of sample 32-27-789
Figure 189: Microstructure of sample 32-27-789, polished
Figure 190: Microstructure of sample 32-27-789, polished
Figure 191: Microstructure of 32-27-789, etched
Figure 192: Location of sample 32-27-1045
Figure 193: Microstructure of sample 32-27-1045, polished
Figure 194: SEM/BSE image of sample 32-27-789
Figure 195: SEM/BSE image of sample 32-27-1045
Figure 196: Images of front and back of VK4584.1
Figure 197: Images of front and back of VK4584.2
Figure 198: Images of front and back of VK4584.3
Figure 199: Images of front and back of VK4584.4
Figure 200: Images of front and back of VK4584.5
Figure 201: Images of front and back of VK4584.6
Figure 202: Location of sample VK4584.1
Figure 203: Microstructure of sample VK4584.1, polished
Figure 204: Microstructure of sample VK4584.1, etched
Figure 205: Location of sample VK4584.4
Figure 206: Microstructure of sample VK4584.4, polished
Figure 207: Microstructure of sample VK4584.4, etched
Figure 208: SEM/BSE image of sample VK4584.1
Figure 209: SEM/BSE image of sample VK4584.4
Figure 210: Images of front and back of 49-12-1053
Figure 211: Images of front and back of 49-12-1053
Figure 212: Images of front and back of 49-12-1053
Figure 213: Images of front and back of 32-27-791
Figure 214: Images of front and back of 49-12-491
Figure 215: Images of front and back of 49-12-1056
Figure 216: Images of front and back of 49-12-493
Figure 217: Images of front and back of 49-12-1050
Figure 218: Images of front and back of VK4764
Figure 219: Images of front and back of VK4766
Figure 220: Images of front and back of VK4763
Figure 221: Images of front and back of VK4765
Figure 222: Images of front and back of 49-12-1030
Figure 223: Antimony to Arsenic Ratio
Figure 224: Antimony vs Arsenic Graph with Trend Lines
Figure 225: Arsenic Content of Sampled Objects
Figure 226: Comparison of Results to Other Sites
Figure 227: Iron Content of Sampled Objects
Figure 228: Sampled Objects by Tin Content
Figure 229: Sampled Objects by Lead Content
Figure 230: Cobalt to Nickel Ratio
Figure 231: Cobalt to Nickel Ratio vs Antimony to Arsenic Ratio
Figure 232: Cobalt to Nickel Ratio vs Antimony to Arsenic Ratio
Figure 233: Objects in the Network Database and Their Attributes
Figure 234: Cypriot Bronze and Iron Objects in the Network Database
Figure 235: Cypriot Bronze and Iron Objects in the Network Database
Figure 236: Cretan Bronze and Iron Objects in the Network Database
Figure 237: Map of Cyprus with Selected Sites
Figure 238: Map of Crete with Selected Sites
Figure 239: Network Graph for Cypriot Fibulae by Site
Figure 240: Network Graph for Cypriot Fibulae by Date
Figure 241: Network Graph for Cypriot Fibulae with Clustering
Figure 242: Attributes Determining the Shape of the Cypriot Fibulae Network
Figure 243: Network Graph for Palaepaphos Fibulae by Date
Figure 244: Network Graph for Palaepaphos Fibulae with Clustering
Figure 245: Network Graph for Amathous Fibulae by Date
Figure 246: Network Graph for Amathous Fibulae with Clustering
Figure 247: Network Graph for Cypriot Fibulae by Period
Figure 248: Network Graph for Cypriot Fibulae by Period with Clustering
Figure 249: Network Graph for Cypriot Fibulae by Period
Figure 250: Network Graph for Cypriot Fibulae by Period with Clustering
Figure 251: Network Graph for Cypriot Fibulae by Period
Figure 252: Network Graph for Cypriot Fibulae by Period with Clustering
Figure 253: Network Graph for Cypriot Fibulae by Period
Figure 254: Network Graph for Cypriot Fibulae by Period with Clustering
Figure 255: Network Graph for Cypriot Bowls by Site
Figure 256: Network Graph for Cypriot Bowls by Date
Figure 257: Network Graph for Cypriot Bowls with Clustering
Figure 258: Network Graph for Palaepaphos Bowls by Date
Figure 259: Network Graph for Palaepaphos Bowls with Clustering
Figure 260: Network Graph for Amathous Bowls by Date
Figure 261: Network Graph for Amathous Bowls with Clustering
Figure 262: Network Graph for Amathous Bowls by Period
Figure 263: Network Graph for Amathous Bowls by Period with Clustering
Figure 264: Network Graph for Amathous Bowls by Period
Figure 265: Network Graph for Amathous Bowls by Period with Clustering
Figure 266: Network Graph for Amathous Bowls by Period
Figure 267: Network Graph for Amathous Bowls by Period with Clustering
Figure 268: Network Graph of Cypriot Knives by Site
Figure 269: Network Graph of Cypriot Knives by Date
Figure 270: Network Graph of Cypriot Knives with Clustering
Figure 271: Network Graph of Palaepaphos Knives by Date
Figure 272: Network Graph of Palaepaphos Knives with Clustering
Figure 273: Network Graph of Amathous Knives by Date
Figure 274: Network Graph of Amathous Knives with Clustering
Figure 275: Network Graph of Cypriot Knives by Period
Figure 276: Network Graph of Cypriot Knives by Period with Clustering
Figure 277: Network Graph of Cypriot Knives by Period
Figure 278: Network Graph of Cypriot Knives by Period with Clustering
Figure 279: Network Graph of Cypriot Knives by Period
Figure 280: Network Graph of Cypriot Knives by Period with Clustering
Figure 281: Network Graph of Cypriot Spearheads by Site
Figure 282: Network Graph of Cypriot Spearheads by Date
Figure 283: Network Graph of Cypriot Spearheads with Clustering
Figure 284: Cretan Fibulae Types by Site
Figure 285: Network Graph for Cretan Fibulae by Site
Figure 286: Network Graph for Cretan Fibulae with Clustering
CHAPTER 1: INTRODUCTION

This dissertation investigates how technological knowledge was transmitted among and between communities of bronze and iron smiths in Cyprus and the Aegean in the Early Iron Age (Fig. 1). The Early Iron Age in the eastern Mediterranean was an era of regeneration and innovation following a major economic and social collapse. Influential advancements were made in many fields, and it was a particularly fruitful period for metalworking with the development of iron smelting and forging as well as the development of other techniques in bronze and iron working. New metal working practices, once discovered, traveled around the Mediterranean and were adopted by smiths working within a number of different metalworking traditions.

A traditional perspective suggests that in the Aegean, technological knowledge necessary for many aspects of complex craft production was forgotten and that techniques in metalworking were subsequently imported from Cyprus, which was likely the center of innovation in metalworking, given its position as a major copper producer. In fact, the evidence for this claim is far from conclusive and leaves many questions unanswered regarding the practical mechanisms by which these innovations were transmitted cross-culturally. How were Aegean craftsmen introduced to new techniques? What factors influenced their willingness to adopt untested foreign methods? What type of contact (if any) between Cypriot and Aegean smiths was necessary to foster the types of relationships that would promote knowledge sharing and acquisition? How mobile were Cypriot and Aegean smiths and how mobile were their tools and their products?
I argue that before addressing the transfer of metallurgical knowledge across the Mediterranean, it is necessary to form more complete understanding of the technological systems in place in Cyprus and the Aegean. The traditional focus on long-distance exchanges has led to an imbalanced picture of innovation dynamics, which gives undue weight to infrequent interactions instigated by Cypriot innovators. I advocate for a shift in focus to how metallurgical knowledge and technological style traveled (or did not travel) on a local and regional scale. My research demonstrates that smiths were trained in locally specific traditions of metallurgy that differed by site. Most transfer of knowledge occurred on a local or regional level, with much less interaction on a pan-Mediterranean scale.

By investigating how forming practices were passed down within and spread between communities of practice, I am able to shed light on the likelihood of various modes of technological transfer at multiple geographic scales. I suggest that long-distance connections between Cyprus and Crete have been overstated. While there could have been limited contact that allowed for the introduction of new ideas, the kind of sustained, face-to-face interaction that is needed for a transformative and lasting impact on metallurgical systems does not seem to have occurred. Instead, I argue that the connections Cretan smiths had to other sites on Crete and other Aegean islands were more frequent and more significant to the development of their metallurgical systems. I hypothesize a framework under which innovation spreads as a series of local interactions rather than as one long-distance exchange.
HISTORICAL OVERVIEW

At the end of the Late Bronze Age, a system-wide collapse precipitated by the dissolution of several major political powers drastically altered life in the Mediterranean. The subsequent Early Iron Age was characterized by continuity in many areas of daily life that stood in contrast to the dramatic changes that were brought on by the collapse. The dynamic interplay of continuity and change can be seen, for example, in the ever-shifting networks of interaction in different regions. Although the collapse severed many previously active long-distance trade routes between the Aegean and the Near East, cross-cultural interaction persisted, albeit on a temporarily reduced scale and within entirely new circumstances.

The Early Iron Age in the Aegean has traditionally been considered a prolonged “Dark Age,” during which the major political centers of the Mycenaean world collapsed, palace-attached craft workshops were disbanded, writing fell out of use, and specialized technological knowledge lay dormant or disappeared altogether (Dickinson 2006; Coldstream 2003; Snodgrass 2017). Subsequent archaeological work has led an increasing number of scholars to argue, however, that this period was neither as isolated nor as long lasting as was previously believed (Lemos 2002; Papadopoulos 2016). While some regions of the Aegean were indeed fairly isolated, there were notable exceptions, especially in Euboea, Attica and Crete, where some communities continued to engage in long-distance trade with Cyprus and the Levant.

By contrast, Cyprus made it through the Late Bronze Age collapse relatively unscathed (Sherratt 2000; Iacovou 2008). Within the island there was a considerable amount of internal reorganization with some cities being destroyed or abandoned, but
with more cities moving to nearby locations. Taken as a whole, however, the island was able to successfully leverage its copper ore deposits and trade connections to become a major economic power. Cyprus maintained its centrality in Mediterranean trade routes, engaging not only with the Aegean and points further west (notably Sardinia), but also with Levantine city-states and with the rising power of Assyria (Sherratt and Sherratt 1993; Sherratt 1994; Broodbank 2015).

MOBILITY


While movements of whole populations are relatively well-understood, the movement of individuals, such as itinerant craftsmen, is notoriously difficult to establish. In particular, attempts to recognize itinerant craftsmen in the archaeological record of the Aegean, and especially Crete, have been met with skepticism (Hoffman 1997). With the return of writing to the Aegean in the 8th century, the movement of individuals including itinerant craftsmen, religious professionals, and mercenaries can be more easily established (Burkert 1992).
Although it is difficult to trace, the movement of people was instrumental to the dissemination of non-material goods and ideas. In the Early Iron Age, important innovations affecting many areas of life, including transportation, communication, and economics, spread throughout the Mediterranean. Many innovations had their roots in advances in crafting practices and technological knowledge. For example, new developments in mining and metalwork allowed for the production of new weapons and armor that spurred on changes in warfare, and also affected the development of coinage, the economic repercussions of which are still felt today (Ramage and Craddock 2000). Even relatively mundane changes in technology can provide insight into cross-cultural exchange, particularly because many technological changes require face-to-face interaction.

**Metallurgy**

Demand for metals drove much of the trade around the Mediterranean and it was therefore the ultimate cause of, as well as the context for, a great deal of cross-cultural interaction. For example, Assyrian demand for silver and tin may have encouraged Phoenicians to explore mining opportunities in the western Mediterranean and thus come into contact with Iberians, first as trading partners and later in the context of more intensive colonization (Sherratt and Sherratt 1993; Frankenstein 1979). As a result of this contact, Iberian smiths adopted some typically Phoenician metalworking techniques, particularly as colonization intensified in the 8th century (Valério et al. 2016; 2010). Innovations in metallurgy are therefore inextricably linked to trade patterns and mobility in the Iron Age Mediterranean.
The major role Cyprus played in copper production and exportation in the Late Bronze Age is well-understood based on both archaeological and textual evidence (Vasiliki Kassianidou and Papasavvas 2012; Stos-Gale et al. 1997; Jansen et al. 2018). Whether it continued in this role in the Iron Age, however, is less clear. Recent excavations of mines, slag heaps, and a few metallurgical workshops seem to confirm that the mining and smelting of copper continued (V. Kassianidou 2013). A temporary contraction in Cypriot copper production in the 11th-9th centuries, however, seems to coincide with an expansion in mining activity in the Arabah region of the southern Levant, which may have taken on a larger role in providing raw metal to the Aegean at that time (Yahalom-Mack et al. 2014; Kiderlen 2016; Kiderlen et al. 2017).

In part because of its reputation as a center of copper production, Cyprus is often thought to be an innovator in metallurgical technology and a disseminator of cutting-edge techniques, in both bronze and iron. For bronze, the conversation has focused on technologically complex bronze rod tripods and four-sided stands, both of which are thought to have been developed in Cyprus at the end of the Late Bronze Age and adopted by Cretan craftsmen in the Early Iron Age (Papasavvas 2014). Similarities in more utilitarian bronze objects in Cyprus and the Aegean, such as fibulae or pins, have not been as thoroughly explored as potential avenues for investigating connections in bronze working techniques. This dissertation will investigate some of these more utilitarian objects. For iron the conversation has focused primarily on bi-metallic and iron knives, also thought to have been developed in Cyprus and adopted by Aegean smiths.
OVERVIEW OF DISSERTATION

Previous scholarship on the transmission of metallurgical knowledge in Cyprus and Crete has focused on the relatively narrow question of the transmission of iron smelting and advanced bronze casting, using a limited range of artifacts (namely bronze stands and iron knives) to address it. My dissertation widens the scope of the questions asked as well as the range of evidence used, looking at more mundane copper and iron objects found in larger numbers in both Cyprus and Crete.

I draw on multiple lines of evidence to form a holistic picture of the state of metalworking knowledge and the mechanisms by which that knowledge was transmitted. I employ methods drawn from archaeological sciences as well as from network analysis to construct a picture of the communities of practice that were in operation and their relationships to each other. Although both methods of analysis address the same questions, they do so from different perspectives, making use of different data sets and methods.

In doing this, I present a view of metallurgical technology in the Early Iron Age that is both multi-scalar and dynamic. I employ a multi-scalar methodology that combines an in-depth investigation of local bronze and iron working techniques at three sites in Crete and Cyprus with a regional and supra-regional analysis of bronze and iron artifact assemblages throughout the eastern Mediterranean. I present a view of the Early Iron Age that includes all its complexities and contradictions and presents it as a highly dynamic period with ever-shifting networks of interaction that do not fit neatly into a single narrative of increasing connectivity.
PART I: COMMUNITIES OF PRACTICE IN EARLY IRON AGE KOURION, LAPITHOS, AND VROKASTRO

The first part of this dissertation presents a case study of bronze and iron objects from the Penn Museum’s excavations at Kourion and Lapithos on Cyprus and Vrokastro on Crete. The objects from Kourion were excavated from one LC III to Archaic period cemetery at the site of Episkopi-Kaloriziki (Benson 1973). The Lapithos material is drawn from the excavations of two Early Iron Age cemeteries at Lapithos, known as the Upper and Lower Geometric cemeteries (Diakou 2013; Donohoe 1992). Finally, the Vrokastro objects were excavated from burials as well as from a settlement dating from the LM IIIC through the Early Iron Age (Dohan 1914). The metal objects from these excavations that are housed at the Penn Museum include bronze pins, needles, fibulae, rings, bowls, and one bronze tripod along with several unique objects as well as iron knives, spearheads, and rods.

The larger theoretical framework of the project is informed by a number of related perspectives on technology and the transmission of technical knowledge. The two related approaches of *châine opératoire* and technological style form the basis of my approach, providing both a methodological structure and a larger theoretical perspective (Lemonnier 1992; Lechtman 1977). Both approaches hold that when producing an object, a craftsman makes a series of decisions and gestures and in doing so chooses among a number of available options. These choices are culturally determined and reflect larger cultural systems. Consequently, close analysis of specific moments of technological choice, or divergence in the operational sequences, can be used to differentiate between communities of practice (Lave and Wegner 1991; Gosselain 2000). Finally, drawing on
ethnographic analogy, I question the circumstances under which technical knowledge was shared among and between communities of practice and the mechanisms for that diffusion of information (David and Kramer 2001).

The analytic program involves a nested series of investigative techniques, which combine macroscopic and microscopic analysis, in order to provide a comprehensive overview of the entire operational sequence that led to the formation of the objects under study. Macroscopic analysis included visual analysis and x-radiography, which allowed for the investigation of forming techniques (Lang and Middleton 2006). A sub-group of sampled objects were then examined using optical microscopy (OM), Scanning Electron Microscopy-Energy Dispersive Spectroscopy (SEM-EDS), and Laser Ablation-Inductively Coupled Plasma- Multiple Spectrometer (LA-ICP-MS). SEM-EDS and LA-ICP-MS were carried out in order to determine the major, minor, and trace elements present in the samples. Determining the elemental composition of the objects allowed for a reconstruction of the early stages of production, including smelting and alloying. Optical microscopy revealed the internal structure of the samples, which sheds light on the later stages of production, including casting, working, and annealing.

The results of this scientific testing suggest that the majority of learning occurred on a local level. Unique communities of practice, characterized by their use of different techniques in the châine opératoire, can be identified at each of the sites under study. There is also evidence, however, for knowledge sharing among regional centers, in particular Kourion and Lapithos. I am able to show, for example, that one group of smiths at Lapithos combined some aspects of production common in Lapithos with others common in Kourion. In contrast, I find little evidence for the exchange of technological
knowledge between Cypriot and Cretan sites, suggesting that the narrative of technological export from Cyprus to Crete has been overstated.

**PART II: NETWORKS OF KNOWLEDGE IN THE EARLY IRON AGE EASTERN MEDITERRANEAN**

Using the above in-depth study as a foundation, the second section of the dissertation expands to present a wider view of the networks through which knowledge traveled around the eastern Mediterranean. I construct networks by analyzing bronze and iron objects found in Cyprus and Crete. I catalogue specific attributes and forming techniques for each object and use similarities in these features between pairs of objects to draw connections and quantify cross-cultural interactions. I first consider site-specific objects and look for communities of practice active at each location. I then construct networks for objects found within specific time periods across the sites, culminating in a regional perspective for Cyprus and Crete.

This study draws on network theory to address cross-cultural influence in the Early Iron Age Mediterranean and to assess the connectivity between sites on a local and regional level. Network analysis is employed in this study because networks are both multi-scalar and dynamic, making them very useful for this project which is diachronic and tacks between local and regional scales (Broodbank 2015; Horden and Purcell 2000; Malkin 2011; Tartaron 2013). In particular I draw on quantitative and qualitative network approaches which address the spread of innovation and knowledge (Östborn and Gerding 2015; Peeples 2018).

I created networks in which the connections are determined by threshold values of shared attributes in order to make the connections as representative as possible of actual
shared technology. I relied on standard network metrics to analyze the structure of each of the networks to determine the overall shape and to suggest potential paths for diffusion within it. In addition, I used the concept of clustering to identify groups of nodes that might have represented communities of practice and used the concept of centrality in order to identify connections between communities of practice.

The results of the network analysis largely corroborate the results of the scientific testing presented in Part I. The majority of connections were seen on a local level, with most graphs showing noticeable clusters of objects from a particular site. The pattern of clustering by site was even more noticeable in the iron objects (knives and spearheads) than it was for most of the bronze objects (especially bowls). This might suggest that initial experiments with iron were relatively isolated events. The network analysis also showed connections between regional sites, however. Especially close connections could be seen between sites in particular periods, such as Palaepaphos and Kourion in the Late Cypriot III – Cypro-Geometric I period. Again, echoing the results of the scientific testing, connections between Cypriot and Cretan networks were much less strong.

**ROADMAP OF DISSERTATION**

**Chapter 2** presents a historical overview of the Early Iron Age, with particular emphasis on the ways that cross-cultural interaction has been studied. It also contextualizes the research questions of the project by reviewing scholarship concerning metallurgical production and innovation in the Early Iron Age. The remainder of the dissertation is divided into two overarching sections. The first section presents a case study of the bronze and iron objects from three sites in Cyprus and the Aegean. This study seeks to identify communities of practice that were active at those sites and to
investigate how technological knowledge might have been transmitted between and among them. **Chapter 3** presents information about the objects under study and their archaeological contexts as well as the methodological and theoretical perspectives that are employed. The results and conclusions of that study follow in **Chapter 4**. The second section presents a network analysis of the networks through which knowledge was transmitted between metallurgical communities on multiple scales. The methodological and theoretical underpinnings of this study are laid out in **Chapter 5** and the results are presented in **Chapter 6**. The final chapter, **Chapter 7**, pulls together the various lines of evidence presented in the preceding chapters to construct a more holistic image of the spread of metallurgical knowledge in the Aegean and Cyprus in the Early Iron Age.
CHAPTER 2: METALLURGICAL KNOWLEDGE AND THE TRANSFER OF TECHNOLOGY IN THE EARLY IRON AGE EASTERN MEDITERRANEAN

Scholars frequently assume that advanced metal working techniques, especially iron working and complex bronze casting, have their origins in Cyprus and were exported from Cyprus to the Aegean. The goal of this chapter is to trace the lineage of that narrative and how it came to be widely accepted. I analyze the various pieces of evidence that are frequently stitched together to form the argument for Cypriot primacy in metallurgical production and for Aegean dependence on Cypriot intervention, noting the fragility of many of these claims. I question this narrative, calling attention to the incomplete nature of the current picture and highlighting the questions that remain. My objective is not to suggest that Cypriot smiths never traveled to the Aegean, but to shift the focus onto more local interactions that provided the context for more meaningful and frequent exchanges of knowledge. I end by suggesting new directions for further research.

HISTORY OF SCHOLARSHIP

In the nineteenth and early twentieth century, scholars argued that Cyprus was a metallurgical backwater at the close of the LBA and that Aegean influence was needed to kickstart Cypriot metallurgy. The metallurgical prominence of the Aegean was a long-held view. Some even argued that iron was discovered by the Greeks (Wilkinson 1837, 1:59). Advancements in Cypriot metallurgy were commonly attributed to Greeks
migrating to Cyprus during the turbulence of the LBA collapse. Snodgrass, for example, argued that LBA Cyprus’ bronzeworking traditions were “conservative and uninspiring until the arrival of a strong wave of Aegean influence about 1200 BCE” (Snodgrass 1980, 341). This argument paradoxically involved, “Greeks turning themselves into Cypriots and eventually back into Greeks in order to introduce an Iron Age into Greece” (Waldbaum 1982, 337).

In contrast, interest in Cypriot metallurgy has been relatively recent. Myres and Ohnefalsch-Richter first suggested that Cyprus might be the birthplace of iron working, but they based this theory on the false claim that Cyprus has abundant iron ore (Myres and Ohnefalsch-Richter 1899, 22–23). It was not until the publication of Lorimer’s *Homer and the Monuments* in 1950 that Cypriot metallurgy was approached with a serious scholarly interest (Lorimer 1950, 69, 115, 268). Subsequently, a number of scholars postulated Cypriot primacy in ironworking (Desborough 1972, 315–16; Snodgrass 1971, 229–31).

In the 1980s and 1990s, numerous investigations into Cypriot metallurgy seemed to confirm that Cyprus was indeed a metallurgical innovator. Scholarship on LBA Cypriot bronze metallurgy, including studies of Cypriot ore bodies (Constantinou 1982), slags and workshops (Koucky and Steinberg 1982; Stech 1982; Tylecote 1982), and attributions of oxhide ingots found around the Mediterranean to Cypriot ores (e.g. Stos-Gale et al. 1997) led to an expanded view of Cyprus as a metallurgical hub. Furthermore, scholars published wide ranging scholarship regarding Cypriot iron production, including studies suggesting the possibility of producing iron from copper byproducts (e.g. Gale et al. 1990; Tholander et al. 1982), archaeometric investigations of iron objects showing
advanced heating techniques (e.g. Maddin 1982), and analyses of the distribution and frequency of iron objects (e.g. Waldbaum 1978). These studies formed the backbone of a new, widely held opinion that Cyprus was an early innovator in iron production and that iron working spread from Cyprus to the Aegean (Stech-Wheeler et al. 1981, 266–67; 1994; Sherratt 1994; Crielaard 1998, 191; Maddin 1982, 311; Waldbaum 1978, 71–72; 1980, 69–98; 1982, 325–44). This has remained a standard scholarly view for some time (Pleiner 2000, 14; Dickinson 2006, 119; Andreyev 2013, 426). It remains the consensus view today, although some recent studies have begun to question the narrative (Palermo 2018).

The argument that advanced metallurgical techniques and skills were transferred from Cyprus to the Aegean during the Early Iron Age relies on a series of inferences. The basic assumptions are as follows: that Cyprus was a center of metallurgical innovation at the end of the second millennium BCE and beginning of the first millennium BCE, that the Aegean was a metallurgical backwater during that period, and that there was contact between the two regions of the kind that could foster a transfer of ideas and technological knowledge.

**Cypriot Innovators**

Scholars have highlighted both the “innovative spirit” of Cypriots generally and of Cypriot smiths specifically in the EIA. Perhaps the best example of this sentiment is Muhly’s assertion that Cyprus was the “…the proto-Silicon Valley of the Mediterranean world, a small area specializing in technological innovation…” (Muhly 1996, 53). Even Waldbaum, who generally argues against Cypriot priority in iron, states that Cyprus was in possession of certain preconditions for the development of iron, including an
“openness to new ideas and experimentation” (Waldbaum 1978, 337). The view of the entrepreneurial spirit of the Cypriot smith has persisted, even though this characterization is subjective, and the underlying evidence can be called into question.

Three basic arguments underlie the view that Cyprus was a metallurgical innovator. First, Cyprus was primed to be an early innovator in iron and in complex bronze casting because the foundations for complex metallurgy had already been laid in the LBA. It seems logical to assume that existing resources from a massive investment in the copper industry would have been put to use in the EIA in some way. Second, Cypriot smiths had access to resources and the considerable knowledge and expertise that were prerequisites for metallurgical innovation. Lastly, Cypriot iron objects display advanced heating treatments such as carburization and quenching that lend credence to the idea that Cyprus was instrumental in popularizing iron as a utilitarian metal.

While these claims seem logical, there is little hard evidence to support them. Evidence for copper production in the EIA is scant, especially in the 11th-10th centuries, and there may have been a dip in production when mines in the Levant were providing more copper to the Mediterranean. Although prior experience with copper may have given Cypriot smiths an advantage in working with other metals, many questions remain open about precisely which skills would be transferable, as well as about the relationship between the copper and iron industries. The traditional argument that iron smelting may have occurred by chance during copper processing remains unproven. Finally, the evidence for carburization and quenching of Cypriot objects has been called in question.
AN ABUNDANCE OF COPPER

Cyprus was famous in antiquity, as it is today, for its abundant copper deposits.¹ Most ancient mining on Cyprus exploited the rich copper-bearing ores in the geological stratum known as the Pillow Lava Unit, which is located around the periphery of the Troodos Mountains (Constantinou 2012, 5).² The Pillow Lavas contain massive copper sulfide deposits, which consist primarily of iron pyrite (FeS₂) and chalcopyrite (CuFeS₂) (Constantinou 2012, 5). The copper content of these ores varies between and within ore bodies, but it is generally between 0.5 and 4.5 percent (Constantinou 1982, 15). In the zone of secondary enrichment, however, copper yields could reach 10-15% or more.³ Cypriot miners were fortunate because the zone of secondary enrichment was easy to access. Counterbalancing these naturally favorable mining conditions was the fact that the vast majority of copper ores on Cyprus were sulfidic ores and smelting sulfidic ores is a more complicated process than smelting oxide ores. Before the ores can be smelted,

¹ For a full discussion of Cypriot geology and ore bodies see (Bruce 1937; 1948; Bear 1963; Constantinou 1982; 1992; Constantinou and Govett 1973).
² The Troodos Ophiolite Complex was formed by submarine volcanic activity 90 million years ago. It later rose to its current height of 1951m above sea level, due to the collision of the African and European tectonic plates and differential uplift by serpentine intrusion. Subsequent erosion exposed lower layers of the geological formation including its sulphide copper deposits (Constantinou 2012, 5). In addition to mining in the Pillow Lavas, there may have been some exploitation of the sheeted diabase (where there was widespread Fe-Cu sulfide mineralization in veins and disseminations) (Constantinou 1982, 13).
³ Cypriot copper ores underwent a process of “supergene enrichment,” which created this zone of secondary enrichment. Once the copper bearing ores were exposed to the atmosphere, surface water oxidized ore minerals near the surface of the orebody. The oxidized minerals formed acid metallic solutions, which leached the ore body as they percolated down towards the water table. These oxidized minerals form a “zone of oxidation” just above the water table, which contains oxidized copper ores. At the water table the solutions enter a reducing atmosphere, which causes copper to precipitate out as a variety of secondary copper sulphide and oxide minerals. This “zone of secondary copper sulphide enrichment” contains a substantially higher percentage of metal, so it would have been heavily exploited by ancient miners.
they require the additional step of being “dead roasted” in order to turn the sulfides into oxides.⁴

Although the mining and smelting of cupriferous ores on Cyprus began in the Middle Chalcolithic, the Cypriot copper industry reached an unprecedented scale in the Late Bronze Age, when Cyprus became a major producer of copper for export around the Mediterranean. Exchange of metal and other luxury goods was occurring at an enormous scale in the Late Bronze Age Mediterranean. The size of diplomatic exchanges between palaces can be approximated by the 14th century BCE Uluburun shipwreck, which contained 354 oxhide ingots along with other types of ingots totaling 10 tons of copper (Pulak 1998; 2008).

The evidence for Cyprus’ prominent role in this copper trade comes from both textual and archaeological sources. Eight letters in the Amarna archives (EA 33-40) record 897 copper ingots (between 24 and 27 tons of copper) being sent to Egypt from Alashiya in a period of no more than 30 years (Muhly 1972, 21). Most scholars accept that “Alashiya” refers to Cyprus (Knapp 2011; Kitchen 2009; Goren et al. 2003). Furthermore, Lead Isotope Analysis (LIA) links copper oxhide ingots, which are characteristic of Late Bronze Age metal trade, to Cypriot ore bodies (Stos-Gale et al. 1997). Despite considerable controversy over the validity of this method, the basic outline of this argument is now generally accepted (Pollard 2009). Further chemical testing has also strengthened the Cypriot attribution (Jansen et al. 2018). There is still some debate, however, over the attribution of all post-1400 BCE copper to a single mine

⁴ An alternative process is suggested by Koucky and Steinberg involving hydrometallurgical treatment of the ore (Koucky and Steinberg 1982).

The exportation of copper on this scale would have required a substantial copper industry at home, but the details of this industry and its organization are far from clear. Our understanding of the metallurgical landscape is hindered by the lack of consensus about the political organization of the island in the LBA, which has obvious implications for the control of metallurgical resources and the organization of labor.

Given the circumstantial evidence, it is likely that large scale mining and smelting occurred in the LBA. Evidence of mining, however, is notoriously difficult to find, and even harder to date. Fortunately, recent projects that focus on the mining region of Cyprus such as the Sydney Cyprus Survey Project have yielded some information about the mining and smelting that were taking place in LBA Cyprus (Given and Knapp 2003). The 16th-15th century BCE site of Politiko-Phorades was a specialized site used exclusively for the primary smelting of ores that has yielded fragments of smelting furnaces, broken tuyères, large quantities of slag, and matte (Knapp and Kassianidou 2008). The 13-12th century BCE site of Apliki-Karamallos, which is located about two miles from the ore body at Apliki, has been interpreted as a mining settlement (Plat Taylor 1952; Muhly 1989; Kling and Muhly 2007). The presence of tuyères, crucible fragments, stone hammers, and abundant slag seems to confirm the link to mining.

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5 Many of the ore bodies that were exploited in antiquity have been the sites of ongoing mining activity in recent times. Modern open-cast mining in Cyprus has often destroyed any evidence of ancient exploitation. Mining tools (such as axes and grinding stones) and mining shafts and adits are very conservative in form and do not change significantly over time. In the absence of datable cultural material, mining activity can be very difficult to pinpoint. Studies of mining landscapes often rely on radiocarbon dating of wooden beams used to support shafts and adits, or of charcoal found in slag heaps.
although metallurgical activities may not have been carried out in the village itself (Knapp 2012).

Almost every LBA urban center that has been excavated on Cyprus has produced some evidence for the subsequent stages of metal production (such as refining, alloying, and object formation) including slag, furnace conglomerate, and metallurgical installations. The most extensive evidence of copper production has been excavated at Enkomi (Muhly et al. 1982; Tylecote 1982; Kassianidou 2012a) and Kition (Tylecote 1982; Karageorghis and Kassianidou 1999). 6 Debris from copper production has also been found at Maroni-Vournes (Doonan, Cadogan, and Sewell 2012), Kalavassos-Ayios Dhimitrios (South 2012), Alassa-Pano Mantilares (Hadjisavvas 2011), and elsewhere (Stech 1982).

Despite massive disruptions across the Mediterranean in the 12th century, industrial activity, including metalworking, continued at some Cypriot sites. Metallurgical workshops were often relocated or rebuilt, however, perhaps reflecting some shift in site organization. At Enkomi, for example, the centralized workshops in Area 3 were abandoned, but others continued to operate throughout the city (Muhly et al. 1982, 160–62). At Kition, the newly constructed LC IIIA Temple 1 is associated with metallurgical workshops, which continue in use into the 11th century (Karageorghis and Demas 1985, 81–85; Karageorghis and Kassianidou 1999, 174–75).

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6 There is some debate over whether primary smelting was occurring in the urban centers. Tylecote argued that the installations in Area III at Enkomi were used for primary smelting (Tylecote 1982), but others have argued that they were only used for secondary smelting and refining (Hauptmann 2011; Kassianidou 2012a). At Kition slags from both primary smelting and refining have been studied, but the samples which were found in the area of the Temple workshops were all refining slags (Tylecote 1982; Stech, Maddin, and Muhly 1985; Karageorghis and Kassianidou 1999; Hauptmann 2011).
Cyprus also continued to produce oxhide ingots into the 12th century BCE. Although copper ingots may not have been exported to the eastern Mediterranean after the LBA collapse, Cypriots were forging connections with the West, where demand for copper remained high (Kassianidou 2014). Large numbers of oxhide ingots have been found in 12th and 11th century contexts in Sicily and Sardinia (Lo Schiavo 1995; 2009; Lo Schiavo, Albanese Procelli, and Giumlia-Mair 2009). LIA has confirmed a Cypriot source for the Sardinian ingots (Hauptmann 2009).

The 11th century was a time of dramatic change in Cyprus, and evidence of copper metallurgy begins to dwindle. Many sites were abandoned (Hala Sultan Tekke, Pyla Kokkinokremos and Maa Palaeokastro) or moved to new locations (Enkomi), leaving only a few sites that were occupied for the entire duration of the century (Palaepaphos and Kition) (Iacovou 2005, 32–34). Furthermore, most of the newly established cities were occupied until the Roman period and beyond. Consequently, the early levels of those settlements are buried under the later occupation, making it difficult to investigate crafting workshops in these periods. Given the dearth of archaeological evidence from settlements during this period of Cyprus’ history, it is unsurprising that no metallurgical workshops have been uncovered.

Direct evidence for mining and smelting is scant in the 11th – 10th centuries but begins to increase in the 9th and especially the 8th century. There are no smelting sites, but the Sydney Cyprus Survey Project has reported a few radiocarbon dates from the 11th-10th centuries from spoil heaps at Agrokipia and Skouriotissa (Kassianidou 2003; 2014). This is noticeably less than other periods, but less evidence does not necessarily imply less mining. There is somewhat more radiocarbon evidence from the 9th and especially 8th
centuries, including timbers from mining shafts at Skouriotissa and Kambia, ropes from Mavrovouni or Skouriotissa (Vasiliki Kassianidou 2013).

The evidence for large-scale exportation of Cypriot copper in the 11th and 10th centuries BCE is also sparse. Some scholars have argued that Levantine mines replaced Cypriot ones as major suppliers of copper to the eastern Mediterranean in the IA I (Finkelstein and Piasetzky 2008, 89; Gilboa 2014, 626). The dip in Cypriot copper production seems to correspond with the peak of smelting operations at Faynan and Timna (Levy et al. 2004; Levy, Najjar, and Ben-Yosef 2014). Others have maintained that this apparent dip in trade was the result of a shift in strategy, rather than a decline in copper production. Kassianidou suggests that Cyprus focused on supplying western markets including the Aegean and Sardinia, while the Arabah mines filled the needs of the eastern Mediterranean (Kassianidou 2014). Recent Lead Isotope Analysis (LIA) of bronze cauldrons and tripod stands from Olympia suggests, however, that the Aegean was importing at least some of its copper from the Levant between 950 and 750 BCE (Kiderlen 2016; Kiderlen et al. 2017). It is also possible that Cyprus shifted its focus from raw copper to finished bronze and iron objects as well as of the metallurgical techniques and skills needed to produce those objects (Muhly and Kassianidou 2012).

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7 An in-depth discussion of copper and iron metallurgy in the Levant is outside the scope of this dissertation. Nevertheless, it is worth noting that a recent surge in research and publications on bronze and iron working in the Southern Levant has vastly increased our knowledge about metallurgy in the EIA. This work has included wide-ranging research on mining and smelting of copper (Ben-Yosef et al. 2010; 2012; Hauptmann 2007; Levy, Ben-Yosef, and Najjar 2012) and iron (Levy, Ben-Yosef, and Najjar 2012; Veldhuijzen and Rehren 2007; Veldhuijzen 2009; 2012), as well as workshop production (Eliyahu-Behar et al. 2013; Eliyahu-Behar and Yahalom-Mack 2018; Erb-Satullo and Walton 2017; Yahalom-Mack et al. 02/01; Yahalom-Mack and Eliyahu-Behar 2015; Yahalom-Mack et al. 2017) and trade (Yahalom-Mack et al. 2014).
In the 9th and 8th centuries there is growing evidence for exports of Cypriot copper to the Levant and Assyria. Assyrian historical sources, including an inscription of Tukulti-Ninurta II (889-884 BC), state that the Assyrians were obtaining copper from Cyprus (Zaccagnini 1990). Additionally, a plano-convex ingot dating to the 9th century from Hazor was analyzed by Yahalom-Mack and was consistent with a Cypriot provenance (Yahalom-Mack et al. 2014, 171).

**TRANSLATABLE EXPERIENCE WITH COPPER**

Cyprus is often identified as an area where early iron production might have occurred, since it possesses a combination of factors conducive to the discovery of iron. First, most Cypriot ores are sulfide ores, which require more complex smelting, and contain high levels of iron, which may have been extracted to form metallic iron. The potential of producing iron from byproducts of copper smelting has been the focus of scholarly attention (Tholander et al. 1982; Craddock and Meeks 1987; Pickles and Peltenburg 1998, 79; Pleiner 2000, 212–13; Gale et al. 1990). In addition, Cypriot smiths had the copper-working expertise required to potentially extract this iron. While it now seems unlikely that iron was extracted in this manner, the experience of the Cypriot smiths remains relevant.

Iron is a common impurity in copper ores. Furthermore, iron oxides (such as hematite or limonite) were often included in copper smelting furnaces, either unintentionally as gangue or intentionally as flux, since they are often found in association with copper ores as gossans (Erb-Satullo 2019). Under certain conditions, such as a reducing smelting atmosphere, metallic iron can be formed during the smelt. There is evidence for efficient smelting furnaces with tuyères and bellows from Enkomi...
and Politico Phorades in the LC period, indicating that creating reducing smelting atmospheres was possible (Knapp and Kassianidou 2008, 144).

Iron is sometimes found in amounts of 20wt% or more in copper ingots and slags (Cooke and Aschenbrenner 1975; Craddock and Meeks 1987; Pleiner 2000, 12). A number of archaeometric studies in the 1980s found high iron content in slags from Iran, Israel, Oman, and Cyprus (Palermo 2018, 20–21). Furthermore, experimental smelting has shown that the reduction of iron is a common byproduct of copper smelting (1990).

A better indicator of whether iron was actually being produced using this method is to test whether there is any copper in the iron, which may suggest that it was formed from a mixed ore. Gale found small amounts of copper in 12 iron artifacts from Timna (Gale et al. 1990). Subsequent reexamination of those objects, however, found that the copper was the result of contamination from nearby objects (Craddock 1995, 255–56; Merkel and Barrett 2000). A somewhat more convincing example may come from Akanuma’s investigation of objects from Kaman-Kalehöyük, which showed higher copper concentrations near the center of the objects (2006). These examples, however, are from the later Iron Age and they are not always consistent (Erb-Satullo 2019).

This theory has since come under some scrutiny for its technological improbability. Whereas it is quite easy to remove iron impurities from copper, their chemistry makes it very difficult to remove copper impurities from iron (Maddin 1982, 303). The sulfur from copper sulfide ores can also make iron brittle and easily corroded if it exceeds 0.015% (Schrama et al. 2017, 333). Palermo also notes that relying exclusively on smelting copper to produce useable iron is an inefficient way to scale a new industry, noting “such interdependence between both metal industries increases risk; should an
issue like supply disruptions or decreased demand arise in one, then it will inevitably affect the other” (Palermo 2018, 24).

If obtaining iron from copper byproducts was not a realistic possibility, then the question of an iron source would remain. Kassianidou has argued that ochre and umber deposits, which are commonly found in the Troodos foothills, would have qualified as good iron ores in antiquity (Kassianidou 2012b, 238). No evidence of Cypriot iron extraction or iron smelting, such as smelting furnaces or iron slag, has been excavated to date. Kassianidou argues, however, that since evidence of mining and smelting activity in general is very scarce in Cyprus due to modern mining activities, this is not so unexpected (Kassianidou 2012b, 239). Furthermore, if iron was extracted from ochre and umber ores located near copper ores, and if the same smelting facilities were used to process iron and copper ore, the iron slag could be mixed in with large heaps of copper slag and the only way to identify it would be to do extensive microscopic analysis.

Attempts to determine the likelihood of reducing iron through the smelting of copper, however thorough, have not substantially advanced our understanding of the invention of iron smelting. Erb-Satullo has suggested that a more productive way to approach this issue would be to look for the skills that copper smiths would have already possessed that might have helped them in the development of early iron smelting (Erb-Satullo 2019). Smiths would possess the necessary experience working with heated materials, so they are the most likely candidates for iron invention. Nevertheless, copper and iron production have many fundamental differences in the way ore is smelted as well as the way metal is worked and shaped. Studies focusing on transferable skills and the
relationship between copper and iron industries may be a more fruitful approach to this topic in the future.

In the southern Levant, where more workshops have been excavated, the relationship of copper and iron production is complex. Iron working installations have been found in close association with copper production in several sites, suggesting that bronze smiths were the ones working on iron (see below). On the other hand, Gottlieb’s distribution study of iron objects in Israel showed that sites without a strong bronzeworking tradition were actually quicker to adopt iron (Gottlieb 2010). In this case, more robust evidence only complicates our understanding of the relationship between bronze and iron working. The question of whether bronzeworking experience necessarily leads to experimentation with iron in Cyprus is therefore a matter of pure speculation at this point.

**EARLY EXPERIMENTATION**

Although the earliest iron objects are found not in Cyprus, but in second millennium Anatolia (Erb-Satullo 2019), scholars have argued that Cyprus and the Levant played an important role in developing advanced heating techniques that made iron a viable alternative to bronze. Cyprus and Levant are seen as the first to use iron for utilitarian objects such as weapons. This in turn led to the widespread adoption of iron across the Mediterranean.

Early studies often assumed that iron was adopted because it was technologically superior to bronze and could be made into harder weapons and tools (Richardson 1934). Archeometallurgical studies beginning in the 1960s and 1970s, however, have
demonstrated that iron was not significantly harder than 10% tin bronze unless it was carburized, quenched, and tempered (Smith 1967). Evidence of carburization and quenching can be recognized in the microstructure of a metal object. Unfortunately, it can be difficult to identify martensite microstructures which are indicative of quenching, because they are most noticeable on the surfaces and edges of the object, which are highly susceptible to corrosion and rarely survive for analysis. Furthermore, even when pearlite and cementite microstructures indicative of carburization are visible, it is often impossible to say whether smiths were employing it intentionally or not.

Carburization can be performed intentionally by placing a formed object, such as a blade, in close contact with charcoal, which leads to the diffusion of carbon in the material (Maddin 1982, 304). In this case, metallographic investigation of the microstructure of an iron object will display a gradient of carbon, with more carbon present at the surface of the object, where it was in contact with charcoal, and less carbon present in the core of the object (Maddin 1982, 304). Unfortunately, most iron objects from this period are so heavily corroded that the exterior layers of the object cannot be examined. It is also possible for carburization to occur spontaneously during the bloomery smelting process when the iron is in close contact with the charcoal used to heat the furnace (Notis et al. 1986, 276). For example, recent analysis of bloomery

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8 Carburization takes place when metal is deliberately heated in a carbon-rich environment in order to increase the carbon content of the iron and produce steel. This would form a much stronger metal than iron alone, but in order to produce a metal that was considerably harder than tin-bronze, the object would also need to be quenched. Quenching occurs when an object is rapidly cooled from a high temperature (over 723°C) by immersing it in water or some other cold liquid (Maddin 1982, 304–5). Quenching results in a much harder but more brittle metal. In order to combat the brittleness of the metal, it must be tempered through reheating (Maddin 1982, 305; Notis et al. 1986, 278).

9 Yahalom-Mack and Eliyahu-Behar argue that although they found that most objects were carburized there was little evidence for gradients of carbon, but the authors concluded that the objects were intentionally carburized anyway (2015).
fragments from Hazor and Beer-Sheba showed carbon content as high as 0.6-0.7 wt% carbon, indicating that the carburization occurred spontaneously before objects were worked (Eliyahu- Behar et al. 2013). Intentionality is crucial to the argument that iron was adopted because of its superior hardness, but it is very difficult to prove given the possibility of spontaneous carburization (Erb-Satullo 2019).

An archaeometric study of several well-preserved 12th/11th century knives from Idalion concluded that carburization and quenching were in use on Cyprus at this early date (Tholander 1971). Maddin subsequently conducted a metallographic study of 51 Cypriot iron objects and he concluded that advancements in heat treatments were a key element in the rise of iron technology in Cyprus in the 11th century BCE (Maddin 1982). However, the results of his study were not very uniform and heat treatments seem to have been uneven, even within individual sites. Recent studies have reevaluated these publications and take a more skeptical view. In particular, McConchie has questioned the evidence of quenching on the knives from Idalion (McConchie 2004, 31–35). Yahalom-Mack and Eliyahu- Beyar also call into question the date of the Idalion knives since they are so well-preserved (Yahalom-Mack and Eliyahu-Behar 2015, 297).

Stech-Wheeler and colleagues carried out a similar study of iron artifacts from the southern Levant (1981). They concluded that while some objects showed consistent carburization, others did not, and there was no evidence of quenching and tempering. Subsequently, one exceptionally well-preserved pick from Mt. Adir that was thought to date to the 12th century showed evidence of carburization, quenching, and tempering (Davis et al. 1985), but new analysis has called the date of the pick into question (Yahalom-Mack and Eliyahu-Behar 2015, 297 fn.). More recent analysis of 60 iron
objects from major Iron Age sites in Israel carried out by Eliyahu-Behar and Yahalom-Mack determined that although almost all of the objects were carburized, there was not sufficient evidence to say that the carburization was intentional and none of the objects showed signs of quenching and tempering (Yahalom-Mack and Eliyahu-Behar 2015). As a result, they argue that there was no universal technological breakthrough which led to iron’s adoption for its mechanical advantage.

The evidence for advanced heat treatments in Cyprus and the Levant is therefore not as robust as believed in the 1980s. It should also be noted that other regions, such as the Aegean, have not received the same amount of metallographic study, so the focus on Cyprus and the Levant may be more reflective on the studies done rather than actual patterns in the data. Until similar studies have been performed on Aegean material, it is difficult to speculate how the Aegean might contribute to this narrative.

AEGEAN ADOPTERS

Whereas Cyprus is seen as a hub of metallurgical activity and the origin of innovative ideas and techniques in the EIA, the Aegean is often described as traditional and conservative. For example, Stech-Wheeler and colleagues argued, “The difference between Cyprus and Palestine and the Aegean may have been that the cultural predisposition toward metallurgy and the interest in experimentation did not exist in the Aegean, at least to the extent which they did in the eastern Mediterranean” (1981, 267).

This view of the Aegean as a technological backwater is predicated on the following narrative. After the collapse of the Mycenaean palaces in the 12th century, craftsmen who had been previously attached to those palaces, including bronze smiths, lost their commissions. Along with other crafts, metallurgy generally is believed to have
stagnated, with many luxury objects falling out of production. Smiths are thought to have practiced metallurgy part-time to supply essential utilitarian objects to fill local needs. They are not credited with major innovations (such as iron smelting) or with the creation of complex luxury objects (such as elaborately decorated bronze shields or stands). Inspiration is thought to come from contact with the Near East, specifically from mobile craftsmen from Cyprus or Phoenicia, rather than from local development.

Recent scholarship has emphasized continuity between the Bronze and Iron ages in many areas of life including craft production. Revised understanding of the Mycenaean economy has opened the possibility of smiths working outside the palaces and being more embedded in communities that in turn allowed them to continue operating during and after the collapse. Furthermore, recent approaches have focused more on local dynamics instead of external stimuli.

A “DARK AGE” IN THE AEGEAN

There has been a long tradition of scholarship that argues that the Aegean was undergoing a “Dark Age” following the Late Bronze Age collapse (Snodgrass 1971; Desborough 1972; Coldstream 1977). A growing body of evidence from both settlement sites (such as Lefkandi and Kavousi) and sanctuaries (such as Isthmia and Kalapodi) suggests that it was not as isolated or as long lasting as scholars initially believed (Lemos 2002; Papadopoulos 1996). The EIA was characterized by strong regionalism, and while some sites were certainly flourishing and continuing to import luxury goods from the Near East, others remained fairly isolated. The likely reality was a scenario in between the two extremes, a significant break with the world of the Bronze Age while relative continuity was maintained in certain locations.
Although many sites remained occupied for some or all of the period, there were shifts in settlement hierarchies in many regions. Coincident with the collapse of the palaces was a significant disruption of administrative practices, including the loss of the Linear B syllabary. When writing reemerged in the 8th century, it was written with an alphabet adapted from Phoenician (Papadopoulos 2016; Sass 2005; Naveh 1982; Powell 1996). There were significant changes in burial practices in many regions, as individual burials and cremations became more common (Morris 1987; Whitley 1991). Although many of the gods worshiped in Archaic and Classical Greece are known from Linear B tablets, it is uncertain whether they were worshiped in a similar way. There was a considerable changeover of religious sites between the BA and IA, but many of the important EIA sanctuaries can now be said to date back to the post-palatial period, including Olympia, Isthmia, and Kalapodi (Morgan 2007; Sourvinou-Inwood 1990; 1993).

Crete followed a somewhat different trajectory from other Aegean regions. On Crete there has traditionally been more emphasis on continuity with the Minoan and Mycenaean past. Settlement patterns differ from those in the rest of the Aegean and they differ regionally within Crete. In the 12th and 11th century a number of “refuge settlements” were founded in easily defensible locations away from the coast (Nowicki 2000; Wallace 2010). Local nucleation occurred gradually beginning in the 9th century (Wallace 2003). Some important sites like Knossos remained occupied throughout the period. Burial practices did not undergo as radical a change as they did on the mainland. Communal inhumations persisted and often reused LBA tombs (Cavanagh 1996; Eaby 2011). Evidence of continued cult activity has long been known from sites like Kato
Symi, although recent research has focused on how that cult activity might change along with shifting socio-political frameworks on the island (D’Agata 2006; Prent 2005).

**LOSS OF SPECIALIZED CRAFT KNOWLEDGE**

One posited consequence of the collapse is the loss of specialized craft knowledge (Dickinson 2006, 82; Osborne 2009, 46). Scholars have argued that after the fall of the Mycenaean palaces, specialized craftsmen would have lost their employment and the systems that had been in place for apprenticeship and passing down knowledge would have ceased to exist (Dickinson 2006, 116). After this loss of knowledge, as the theory holds, crafting techniques were reintroduced by contact with eastern craftsmen – either by them coming to the Aegean, or by Greeks traveling east (Dickinson 2006, 118; Hoffman 1997; Burkert 1992).

This argument rests on a number of assumptions about the organization of labor in Mycenaean palaces. A traditional understanding of the Mycenaean economy holds that the palaces were centralized redistributive centers that controlled almost every aspect of the economy. Accordingly, craftspeople were thought to have been “attached” specialists, whose raw materials and wages would have been supplied by the palace administration (Parkinson, Nakassis, and Galaty 2013, 414). Adhering to this narrative, it naturally follows that with the collapse of the palace system, metallurgical specialists would have lost their access to the raw materials needed to practice their craft, as well as the consumer base for their products, and the administrative stability required for specialization.
A more current view holds that only some craftspeople worked entirely within the palace system while others supplied some goods to the palace but were also able to work for other patrons (Galaty and Parkinson 2007). Metallurgists are among the specialists thought to be operating at least partially outside the palace, along with potters (Parkinson, Nakassis, and Galaty 2013, 419). Gillis looks specifically at the role of smiths in the Pylos tablets and argues that although they had to send an established amount of finished products to the palaces, they operated largely independently (Gillis 1997). Gillis reasons that they would have already been established in villages and it would not have been practical or desirable to move them to palatial centers. In addition, the amount of metal listed as being sent to the palaces is very small, presumably indicating that the smiths had other patrons (Gillis 1997, 512). The implication of smiths operating independently is that a palatial collapse would not completely disrupt the smiths if they had connections to other patrons (Palermo 2018). It should force a reevaluation of the idea that crafting knowledge was lost after the collapse of the palaces.

CYPRO-AEGEAN CONNECTIONS

In order to uphold the argument that Aegean smiths adopted metallurgical techniques from Cypriots, it must be established that these two areas were in contact. Scholars have proposed populations movements between the two regions, as well as close trade relations that set the stage for technological transfer. Ultimately, however, trade in finished products does not account for the spread in technology. Some face-to-face interaction is necessary in order to learn new techniques. To this end, mobile craftsmen traveling from Cyprus to the Aegean are usually considered a key part of this equation.
A SPECIAL RELATIONSHIP?

A traditional view holds that migrants fleeing the unstable Aegean after the collapse of the palaces arrived on Cyprus in the 11th century and founded many of the Cypriot kingdoms that are attested in literary sources such as the inscription of Sargon II (Coldstream 1989; 2012; Catling 1994; Karageorghis 1994; 2000a; 2000b; Iacovou 1994). These groups are often portrayed as having a profound “Hellenizing” effect on Cypriot culture. They are credited with a number of cultural influences including new mortuary practices, forms of political power (Iacovou 2006), language (Coldstream 1989), and material culture ranging from architectural forms (Hitchcock 2008) to bathtubs (Karageorghis 2000a). Scholars have also argued that this same population moved back to the Aegean later in the EIA and that these journeys are reflected in Homeric epic (Catling 1995).

While it seems clear that there must be a strong Greek connection to Cyprus given the cultural and artistic similarities, the nature of that relationship is debated. The “colonization narrative” assumes that the movement of objects implies the movement of people. It also relies on linguistic evidence from later periods, since the only text from this period is a much-cited obelos from an 11th century burial at Palaepaphos-Skales, inscribed with the Greek name “Opheltas” and written in a local syllabic script (Karageorghis 1983, 370; Masson, Masson, and Karageorghis 1983). Moreover, it has been pointed out that 19th and 20th century scholars working within a colonialist framework on Cyprus and serving various nationalist agendas had reason to exaggerate the importance of Aegean colonizers (Leriou 2002, 169–70).
Recently, scholars have started to critique this preoccupation with ethnicity. Iacovou, one of the biggest proponents of Aegean colonization, now advocates a movement away from questions of ethnicity and a stronger focus on internal socio-political and cultural change (Iacovou 2005; 2006). Voskos and Knapp have similarly cautioned against focusing on questions of ethnicity and have argued instead for hybridity (Voskos and Knapp 2008).

TRADE IN FINISHED PRODUCTS

Another point in favor of Cyprus and the Aegean having a close connection is that Cypriot imports are frequently found in Aegean contexts. Cypriot imports have been found throughout the Aegean, but they are found in great quantity in Crete (Karageorghis et al. 2014). Imports consist primarily of pottery (especially Red-on-Black ware and Black-Slip ware) but include metal objects such as iron weapons and bronze stands as well (discussed below). These bronze stands and iron weapons often co-occur in the same wealthy tombs (Muhly and Kassianidou 2012).

While imported objects suggests some connections between Cyprus and Crete, they do not account for the transfer of technology on their own. Cretan metallurgists would need to have adopted the imported objects, creating a local form in imitation. This process depends on the Cypriot objects being earlier in date than the Aegean ones. In many instances the objects are close in date. There is the possibility of new archaeological evidence predating the known examples. The absolute dating of Cypriot and Aegean chronologies in the first millennium remains in flux and is a matter of some

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10 For Cypriot pottery imported to Crete and imitation Cypriot pottery produced on Crete see Kotsonas (2012) and Boileau and Whitley (2010).
debate (Fig. 2).\textsuperscript{11} New information from radiocarbon dates or from redating pottery sequences is liable to change our understanding of the way various chronologies fit together and alter the evidence for priority arguments.

\textit{Four-Sided Stands and Tripods}

More so than other bronze objects, four-sided stands and tripods have been considered a marker of Cypriot innovation. Tripod stands have three feet that support a ring which can be simply or elaborately decorated.\textsuperscript{12} Four-sided stands comprise a rectangular box with struts supporting a ring on top and are mounted on feet or wheels. The sides of the rectangle can be elaborately decorated and often depict complex scenes such as processions or fights, or isolated, standing animals.\textsuperscript{13} Unfortunately, many of the stands were not scientifically excavated and very little is known about their archaeological contexts. As a consequence, the function of the objects is difficult to determine. The highly decorated nature of the stands suggests that they may have had a ceremonial function of some kind (Papasavvas 2004, 33).

The technology for constructing bronze rod tripods and four-sided stands is thought to have been developed in Cyprus at the end of the Late Bronze Age, while Aegean craftsmen (particularly Cretan craftsmen) learned it in the Early Iron Age (Papasavvas 2014). Papasavvas argues that Cyprus was instrumental in spreading the technology needed to make the stands, not only to the Aegean, but also to the Levant and

\textsuperscript{11} This debate has been primarily focused on radiocarbon dates from the Levant, where there has been a longstanding divide between proponents of the low chronology (Finkelstein 2005; Finkelstein and Piasetzky 2010; 2011; Sharon et al. 2007) and the modified middle chronology (Mazar 2005; 2011), with implications for the Aegean (Coldstream 2003; Fantalkin 2001; Toffolo et al. 2013).

\textsuperscript{12} The tripod stand has some precursors in the Near East including 19\textsuperscript{th} century clay tripods from Karum Kanesh and Hattusha and a 16\textsuperscript{th} – 14\textsuperscript{th} century bronze tripod from Alalakh (Papasavvas 2004, 33).

\textsuperscript{13} They are often associated with motifs seen on ivories, and their construction also has some similarities to furniture construction (Papasavvas 2004, 33).
to Sardinia, arguing that the stands “document the role of the Cypriot smiths in the dissemination of metalworking traditions outside the island through the transmission of their form and technique to the East and the West” (Papasavvas 2014, 31).

Scholars have asserted that the technology used to make the stands was complex. Catling asserts that they are the “…greatest technical masterpieces of bronzework of any period during the Late Bronze Age in the East Mediterranean” (Catling 1984, 88). Muhly similarly opines that they “…represent some of the most impressive bronzes produced in the ancient world during the second half of the second millennium BC” (Muhly 1996, 54).

There is no question that the stands were constructed using the lost-wax casting method, but the precise way that the objects were fabricated using various wax models is still debated. First, models of each individual part of the stands were constructed in wax. Catling and Matthäus have argued that the stands were constructed from individually cast components that were metallurgically joined through soft soldering, hard soldering, or fusion welding (Catling 1964, 190–92; Matthäus 1985, 300). Papasavvas, on the other hand, argues that the whole stand was constructed in wax and then cast in one piece, arguing that piece casting would actually have been far more difficult and time consuming (Papasavvas 2014, 37). There have been several scientific studies have been conducted on bronze tripods from the British Museum and the Metropolitan Museum of Art (Macnamara and Meeks 1987; Schorsch and Hendrix 2003). Schorsch and Hendrix’s X-radiography shows that the tripods under study were constructed from a single wax model. They also note flaws in the casting, however, and point to the carelessness of the construction.
The complexity of the casting lends credence to the idea that Aegean smiths had to learn to make bronze stands through face-to-face interactions and could not have learned the process from seeing a finished example. The transmission of casting technology can be investigated through the casting moulds for tripod legs, which have been found in Cyprus and the Aegean. Casting moulds for rod tripods have been found at Lefkandi in Euboea and at Palaikastro on Crete (Stampolidis 1998; Benson 1960). The presence of these moulds suggests that Cretan metalworkers were learning new techniques from Cypriots or that Cypriot craftsmen were traveling to Crete and bringing their tools with them.

The argument that the stands were invented on Cyprus and exported to the Aegean rather than the other way around rests primarily on the earlier date of the Cypriot stands. On the whole the Cypriot examples are often found with pottery dated to the end of the 13th century BCE, whereas the examples from the Aegean come from EIA contexts. Complicating the date of the stands is the likely proposition that many of them were kept as heirlooms for hundreds of years (Catling 1984). The stands were likely valued possessions and they may have been deposited in the ground hundreds of years after their manufacture. The pottery associated with them at the moment of deposition can serve at best as a terminus ante quem.

Iron Knives

The earliest iron objects to become widespread were iron knives with bronze rivetted hilts made of bone or ivory. These knives are the most commonly found iron object in the 12th-11th centuries in both Cyprus and the Aegean, and they figure prominently in discussions of how iron working was transferred. Many scholars have
argued that bimetallic knives originated in Cyprus and either the knives themselves, the technology to make them, or both were exported by Cypriots to the Aegean and the Levant (Sherratt 1994, 68–69; Hoffman 1997, 140–41; cf. Waldbaum 1982, 330–32). Although a greater number of the knives come from Cyprus than from the Aegean or the Levant, there is no direct evidence of their production on the island.

The argument for Cypriot origin rests on the earlier date and greater number of examples found on Cyprus. A number of the Cypriot examples can be attributed to 12th century contexts, with the earliest example usually stated to be from the Kouklia-Elionymilia Tomb 113 dated to the transitional LC IIC-III A (Karageorghis 1990, 80, 84–87; Sherratt 1994). Although there are far fewer Aegean examples that can be dated to this early a period, recent finds from the Kentria and Tsiganadika cemeteries on Thasos date even earlier than the Kouklia example (LH IIIB and LH IIIB-C transition phases) (Koukoulē-Chrysanthakē 1992). Ultimately, the dating is in flux and with the ever-present possibility of finding earlier examples, earliest date is not a secure metric.

Furthermore, the parallels between the knives have been called into question (Palermo 2018). Cypriot and Aegean iron knives display important differences. For example, the most common form of Cypriot knife has a convex spine, whereas most Aegean examples have a straight spine. Cypriot examples often use many rivets, whereas Aegean ones typically have only a few spaced far apart. Although bi-metallic knives are typically treated as a cohesive group there are also significant variations in types, and there need not be a single point of origin (Waldbaum 1980, 85). Some scholars have argued therefore that iron knives in the Aegean should be seen as an extension of a robust tradition of local bronze knife production (Sandars 1955).
MOBILE CRAFTSMEN

Although bronze and iron objects in Cypriot styles are commonly found in EIA Aegean contexts, it can be very difficult to determine whether the importation consisted of objects themselves or the technology needed to make them. Scholars have argued that Cyprus sent both the finished products and the technology required for their manufacture. For example, Muhly states, “I would argue that what was being exported was not just a product but also a process. As in the case of the bronze stands, the Cypriot smiths were also exporting an iron technology. The two often were sent abroad together: bronze stands and iron weapons, finished products, the fruit of the newly developed Cypriot technology” (Muhly 2012, 126).

To explain how technological knowledge travelled, many scholars postulate some form of mobile craftsperson. It is difficult to imagine that something as complex as iron working could have been learned without face-to-face instruction of some kind. Desborough writes, “I am sure that [the initiative] came from Cyprus and that it was not a matter of casual trading visits. Even if no potters came, there must have been technicians in the new metal, iron – otherwise how could the Athenians and other communities of the central mainland have learnt the process?” (1972, 340). Similarly, Dickinson argues, “the spread of iron-working is likely to have been a lengthy process, if only because it would require movement by experts who could recognise ore sources and work the metal” (2006, 146).

While this argument seems perfectly logical, the textual and archaeological evidence for mobile craftsmen has proven elusive. The textual evidence does not support the idea of itinerant craftsmen, who travelled routinely and of their own volition.
Zaccagnini’s study of LBA texts demonstrates that craftsmen were much more likely to be attached to palaces, although they may have been dispatched either to more remote regions or to other palaces upon request as part of the elite gift exchange network active in the LBA (Zaccagnini 1983). In Homer, craftsmen are considered people of status and appear to have the autonomy to travel on their own, attested by the oft-cited line “Who will personally invite a foreigner, unless he is a craftsman, a diviner, a healer, a carpenter, a divine singer who delights with his songs? These are the ones among men who are sought on the broad earth” (Odyssey 17.382-386). It is important not to selectively excerpt a poetic text or to retroject this image into an earlier past.

Itinerant or mobile craftsmen are notoriously difficult to identify in the archaeological record, since they are unlikely to leave archaeologically visible evidence. Attributions of specific objects to particular craftsmen or “workshops” on the basis of style has been widely critiqued (Hoffman 1997). Archaeological evidence has been used to make a number of arguments about itinerant, Near Eastern (primarily Phoenician) craftsmen on Crete, although many of these arguments have come under scrutiny. The elaborately decorated bronze shields (Dunbabin 1957, 40–41; Coldstream 1982, 272; cf. Kunze 1931; cf. Hoffman 1997, 160–65) and ivory plaques (Barnett 1948, 1–25; cf. Hoffman 1997, 156–60) from the Idean Cave have often been taken as evidence that Phoenician craftsmen lived and worked on the island. Boardman also famously proposed that the Teke cemetery at Knossos contained a burial of a Syrian gold worker (Boardman 1967; cf. Hoffman 1997, 191–246). The presence of Phoenician craftsmen on

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14 More recently Sakellarakis has argued that the ivories could have been carved in the Levant, but would have required the presence of some skilled Phoenician craftsmen on Crete to complete their assembly at their final destination (1993, 360–61).
Crete has been convincingly refuted by Hoffman in each of these cases (Hoffman 1997). Somewhat more plausible arguments have been made for the presence of non-specialist Phoenicians on the basis of religious practices, in particular a late ninth – mid 7th century tri-pillar shrine at Kommos (Shaw 1989; cf. Hoffman 1997, 172–76), and burial practices, such as Phoenician gravestones found at Knossos and Eleutherna (Kourou and Karetsou 1998; Stampolidis 2003).

It is important to draw a distinction between itinerant craftsmen and mobile craftsmen. Some “mobile” craftsmen may have moved together with their families to cities that continued to thrive after the collapse in pursuit of better employment opportunities. They likely would have tried to minimize how often they moved, particularly since so much of their occupation relies on large systems that take a long time to put in place. These would not be “itinerant” craftsmen but migrants who happen to be smiths. Although this is a likely reality, it would be difficult to identify such craftsmen in the archaeological record. This type of movement would primarily have the effect of centralizing metallurgical knowledge in the most populous cities.

On the other hand, there is the notion of the “itinerant” craftsmen who habitually travelled the Mediterranean plying their wares. The best archaeological evidence of truly itinerant smiths comes from the Cape Gelidonya shipwreck, which yielded a “tinker’s kit” containing scrap metal and tools (Bass 1961). This kit has been used to support the idea of metal smiths travelling aboard ships on long-distance journeys and stopping at ports throughout the Mediterranean to perform small scale metallurgical tasks, which could have included mending or reworking broken objects. An itinerant tinker of this sort
was likely to have used metal supplied by a patron and was probably not involved in the smelting and refining stages of production.

There could have been several different types of metallurgical specialists involved in a range of operations within the production sequence, some of whom were more mobile than others. Introducing major innovations or implementing entirely new industries around the exploitation of a new metal, such as iron, necessarily involves a complex operation much larger than a few itinerant craftsmen. A new industry would need to leverage a huge workforce and organize production from prospecting and mining to smelting and transportation to workshops. The organizing body would be taking on considerable risk, which limits the mobility of its participants.

MOVING FORWARD

As discussed in this chapter, the primary concern of scholarship on metallurgical technology in the Aegean EIA has been how iron smelting and, to a lesser extent, advanced bronze casting, were introduced. The explanation given by most scholars has been that mobile Cypriot smiths travelled to the Aegean and instructed Aegean smiths. Recent work has eroded many of the pillars supporting this narrative of technological exchange from Cyprus to the Aegean. In my dissertation I challenge the model of straight-forward, unidirectional flow of metallurgical information from Cyprus to the Aegean. While it is possible that Cypriot smiths did travel to the Aegean, bringing their technology and tools with them, I do not believe that the current evidence is strong enough to uphold this conclusion and my research suggests that their role has been overstated.
My research did not display significant influence of Cypriot metallurgical Cretan smiths. The copper ore on Crete, as elsewhere in the Aegean, was imported from multiple sources. Only a small percentage of the ore appears to have been imported from Cyprus. More importantly, the way the imported raw metal was handled during refining, casting, and working does not show particular affinities to Cypriot practices as might be expected if Cypriot smiths were a major presence on Crete. Furthermore, finished copper and iron objects often show important differences from Cypriot types. For example, the most common form of iron knife on Crete had a different spine shape as well as different trends in how the handle was rivetted to the knife from the most common Cypriot form.

While this dissertation represents a preliminary study, and a much more robust body of data would be needed to draw definite conclusions, my research sheds light on the types of interactions that are more or less likely to have occurred between Cypriot and Cretan smiths and the context in which these exchanges of knowledge might have occurred. If Cypriot smiths did come to the Aegean, their interaction with Aegean smiths does not seem to have had a deep or long-standing impact on Aegean copper or iron metallurgy, since the most commonly produced objects in the Aegean were of local and not Cypriot types, and they were made using techniques that were not similar to Cypriot ones. It is therefore unlikely that Cypriot smiths set up workshops on Crete and trained a new generation of Aegean smiths who would go on to produce Cypriot-style bronze and iron artifacts.

An alternate possibility is that Cypriot smiths sparked innovations through limited contact. In this scenario, the Cretan adopters would already be trained smiths, acquiring a few new techniques from visiting Cypriot smiths. This seems more likely than a model
based on prolonged instruction based on the lack of similarities between Cretan and Cypriot formation practices. Significant changes in methods of manufacture typically require more prolonged face-to-face interaction with trusted sources, however.

A third possibility is that iron smelting technology could have been passed along between neighboring communities, rather than making one large leap across the Mediterranean. In this scenario, ideas would be shared between communities that had already built a foundation of mutual trust. Smiths at Vrokastro could, in this scenario, have learned some new techniques from smiths at Knossos, or from other Aegean islands, who in turn could have learned from smiths on the Anatolian coast, and so forth. In order to test this model, further scientific testing of far more metal objects from the Aegean islands would be needed.

The question of where iron smelting was developed and how it spread across the Mediterranean is very broad in its geographic scope, but the majority of metallurgical training took place in face-to-face interactions. My research focuses in on the local scale, where most transfer of technology occurred. My research suggests that both in Crete and in Cyprus, smiths were primarily entwined in local networks. Smiths at Vrokastro, for example, made use of varied metallurgical practices, showing the influence of multiple communities of practice, within Crete or among Aegean islands. These practices had little in common with Cypriot ones, which were much more uniform across the island.

The remainder of my dissertation is split into two sections. Chapters 3 and 4 present a scientific analysis of copper-based objects from Kourion and Lapithos on Cyprus and Vrokastro on Crete. This portion of my research offers an example of how collecting more detailed data on how objects were made allows us to reconstruct local
communities of practice and trace how knowledge is shared between these communities. Chapters 5 and 6 present a network analysis of bronze and iron objects from cemeteries located around a number of Cypriot and Cretan sites. This section shows how networks which reflect associations of metal smiths can be built based on similarities between objects.
CHAPTER 3: INVESTIGATING METALLURGICAL TECHNOLOGY AT EARLY IRON AGE KOURION, LAPITHOS, AND VROKASTRO

The following two chapters of this dissertation present a case study of the bronze, copper and iron objects from two sites in Cyprus, Kourion and Lapithos, and one site on Crete, Vrokastro. This chapter (Chapter 3) lays out the materials under study as well as the methodology applied to them and the theoretical framework in which this work was conducted. The following chapter (Chapter 4) details the results and conclusions of this study and situates it in the context of regional metalworking practices. The primary goals of this study are (1) to identify the technological signature of metalsmiths working at the sites of Kourion, Lapithos, and Vrokastro in the Early Iron Age and (2) to investigate the possibility of the transfer of technological knowledge between Cypriot and Aegean metalworking traditions.

The first section of this chapter presents the materials studied. It includes a survey of the sites of Kourion, Lapithos, and Vrokastro, including a historical outline, an account of the excavations conducted, and a description of the EIA phase of occupation. It also includes an overview of the metal objects found at those sites.

The second section places this study in its larger theoretical framework. My perspective is informed by a number of related theoretical perspectives on technology and the transmission of technical knowledge. Châine opératoire and technological style form the basis of my approach, structuring my understanding of the sequences of operations employed to fabricate the objects under study. Close analysis of key moments of
technological choice, or divergence in the operational sequences, are used to differentiate between communities of practice. Finally, drawing on ethnographic analogy, I question the circumstances under which technical knowledge was shared among and between communities of practice and the mechanisms for that diffusion of information.

The final section of this chapter lays out the analytical program. This study applies a nested series of investigative techniques, beginning with a macroscale survey of all the objects, which included both visual analysis and X-radiography. Based on the results of the macroscopic analysis, a sub-sample of the objects were subjected to destructive sampling. Those samples were tested using an integrated approach, which made use of both microscopic and chemical methods.

**MATERIALS**

This section of my dissertation focuses on copper-based objects from three important EIA sites: Kourion, Lapithos, and Vrokastro. Kourion and Lapithos are both located in Cyprus: Kourion in the southwest and Lapithos on the northern coast (Fig. 3). Vrokastro is located on the northern coast of eastern Crete (Fig. 4). The Penn Museum conducted extensive excavations at Early Iron Age cemeteries and settlements at all three of these sites in the early 20th century. Material from all three sites was subsequently divided between local museums and the Penn Museum. Consequently, many of the copper-based objects from these sites are currently housed at the Penn Museum.

This section provides background information on the archaeological contexts of the objects and explains how the objects were selected for testing. To that end, this section begins with a review of each of the three archaeological sites, which includes an overview of its history of occupation and excavation as well as a more detailed
description of the EIA contexts from that site. A brief summary of the EIA metal objects from Kourion, Lapithos, and Vrokastro that are currently housed at the Penn Museum follows. Finally, the criteria used to determine which of these objects should be selected for scientific testing are laid out.

In this section I have attempted to create a cohesive narrative for each site, which is similar in scope and in the information provided. It should be noted, however, that the excavation of these sites differed in several important respects. First, they were excavated at different times and consequently different questions occupied the minds of the excavators. For example, the publications of the Kourion material make extensive reference to the “Coming of the Greeks” to Cyprus (Benson 1973, 22–24). Furthermore, the landscapes around the sites and the amount of survey and excavation that has been done in the region is drastically different for each site. A number of large-scale, intensive pedestrian surveys have been conducted around the area of Vrokastro, whereas very little survey has been done around Lapithos due to the current political situation. Comparing data across these three sites therefore presents some of the challenges that are often faced when working with legacy data.

KOURION

Kourion is located in southwestern Cyprus, near the modern town of Episkopi. It sits on the southern coast of the island overlooking Episkopi Bay, which forms the western edge of what is today the Akrotiri peninsula (Fig. 5). The peninsula was initially a group of small islands and it was not until the Roman period that eroded sediment from the Kouris and Garyllis rivers gradually formed a land bridge between the coast and the island (Swiny 1982, 1-2). The topography of Kourion is largely defined by its
relationship to the Kouris river as well as by its relationship to the coast. In the pre-Roman period, the mouth of the Kouris river was probably a navigable lagoon (Swiny 1982, 2).

The Kouris river and the smaller streams that feed into it have been a focus of human activity throughout the history of the region. The river both provided a source of water and served as a corridor to the mountainous interior of the island, facilitating access to the mining region of the lower foothills of the Troodos mountains. From there, copper could be easily transported to the coast and be shipped abroad (Swiny 1982, 2). Kourion is one of several sites in southwestern Cyprus whose position on the coast near the mouth of a river allowed them to access inland territory as well as maritime networks. For example, Amathous to the east is associated with the Garyllis river that forms the eastern side of Akrotiri peninsula and Palaepaphos-Kouklia to the west is situated at the mouth of the Diarizos river.\(^\text{15}\)

The region of Kourion was inhabited more or less continuously from as early as the 10\(^{th}\) millennium BCE, with sites such as Aetokremnos cave. In the Late Bronze Age, the sites along the Kouris river expanded, probably at the expense of the sites located on the smaller western rivers. Alassa-Paliotaverna, which was located near the copper sources of the lower Troodos mountains grew dramatically in importance. Alassa has been put forward as a candidate for the administrative center of the entire island (Goren et al. 2003). Near Kourion, the smaller site of Episkopi-Bamboula, which was located on

\(^{15}\) The names of Cypriot archaeological sites are given according to the convention in Cyprus, which is to combine the name of the nearest town (here, “Palaepaphos”) and then the name of the archaeological site in italics (here, “Kouklia”), separated by a hyphen.
a small hill near the coast, also gained importance. It may have functioned as harbor town under the control of a larger local power like Alassa. At the end of the Late Bronze Age, Episkopi-\textit{Bamboula} was abandoned and the population moved to a new settlement that has not been located. The fact that there was an EIA population living in the area, however, is not in doubt, since an EIA cemetery has been located at Episkopi-\textit{Kaloriziki}.

The location of the site of Kourion was known to early western travelers and amateur excavators in the 19\textsuperscript{th} century, who were familiar with Kourion’s association with the Temple of Apollo Hylates from literary sources.\footnote{Herodotus 5.113, Arrian \textit{Anabasis} 2.22, and Strabo 14.683.} Many travelers visited Kourion, but undoubtedly the most famous was the Italian-American consul, Luigi Palma di Cesnola. Although he recorded the results of his excavations, the veracity of his report is in doubt (Cesnola 1878). Almost certainly influenced by Heinrich Schliemann’s recent publication of the “Treasure of Priam” at Troy, Cesnola released an account of the “Curium Treasure,” which consisted of objects taken from a number of different tombs at Kourion that spanned many time periods (Karageorghis, Mertens, and Rose 2000, 5). The next large-scale project to be undertaken at Kourion was organized by the British Museum in 1895 with funds from the Turner Bequest. It was overseen by Henry Beauchamp Walters and excavated 118 tombs in five cemeteries (A-E) as well as a small rural sanctuary (Murray, Smith, and Walters 1900).

The early twentieth century ushered in a new era of scientific excavations. In 1933 Porphyrios Dikaios excavated a group of Early Iron Age tombs in the Episkopi-
Kaloriziki cemetery on behalf of the Department of Antiquities. One year later the University Museum (now the Penn Museum) sent a team to excavate at Kourion, beginning a project that would continue until 1954. The project was led by Bert Hodge Hill, John Franklin Daniel, and George McFadden. Over the years the University Museum team excavated extensively at a number of different sites at Kourion including the sanctuary of Apollo Hylates, the stadium, the Classical acropolis, and the Late Bronze Age settlement at Episkopi-Bamboula. They also excavated a number of cemeteries including the Iron Age necropolis at Episkopi-Kaloriziki and the Cypro-Classical, Hellenistic, and Roman burial grounds around the church of Ayios Ermoyenis.

After the University Museum expedition, work continued at Kourion on a number of projects. From 1978 to 1984, a University of Arizona and Walters Art Gallery project led by David Soren and Diana Buitron-Oliver reinvestigated the Sanctuary of Apollo Hylates (Soren 1987; 1988; Buitron-Oliver 1996; 1997). Danielle Parks excavated the Roman cemeteries in the Amathus Gate Project (Parks 1995). Gisela Walberg renewed excavations at Bamboula for the University of Cincinnati. Concurrently, the Department of Antiquities has continued its own excavations (Swiny 1982; Christou 1996).

Early Iron Age Kourion
The topography of EIA Kourion is still not very well understood. Although 44 EIA tombs have been excavated, the location of the corresponding settlement site remain unknown. One suggestion is that the settlement might have moved to the Kourion bluff and is now buried beneath the later acropolis of the city. This argument is supported by

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17 These excavations were never fully published. Benson includes some treatment of them in his Kaloriziki volume (1973).
Proto-Geometric sherds, which were found in deep soundings on the acropolis (Young and Young 1955, 224). On the other hand, Benson argues that the settlement might be located on the Kaloriziki plain adjacent to the cemetery. He cites comparisons with Kition-Bamboula and Enkomi where the necropoleis were situated inside the towns, as well as a ridge-like formation in the Kaloriziki plain that might be part of a city wall (Benson 1973, 18).

Episkopi-Kaloriziki

The EIA cemetery at Episkopi-Kaloriziki is situated west of the modern village of Episkopi on a low, flat coastal plain below and to the east of the bluff of Kourion (Swiny 1982, 51) (Fig. 6). The full extent of the cemetery was never determined during excavation. Episkopi-Kaloriziki was excavated by two separate teams. First, in 1933, Dikaios working for the Cyprus Museum excavated Tombs 1-17, which are located in the center of the Kaloriziki plain. Then, from 1937-1939, J.F Daniel and G.H. McFadden excavated Tombs 18-29 and 32-44 in the Kaloriziki plain as well as Tombs 30 and 31 in the adjoining Mersinoudhia field (Benson 1973, 17). The cemetery was in use from the very end of the Late Bronze Age (LC IIIB) until the very beginning of the Cypro-Classical period. When the earliest LC IIIB burials were interred, there was still a settlement on Bamboula hill, so there is some continuity between the two sites. The primary period of use is the Cypro-Geometric period. Burials begin to taper off after the CA I, at which point burials shift further west to Area B of the British Museum.

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18 Two tombs were found in the neighboring Mersinoudhia field (200m south of Kaloriziki), but test pits in the area did not reveal any more tombs (Benson 1973, 17). British Museum excavations in Area B on the other site of a stream contained Cypro-Archaic burials (Benson 1973, 17).
excavations. Many of the tombs were reused for multiple burials over a long period of time so they span multiple periods.

All of the tombs at Kaloriziki are chamber tombs, featuring dromoi, stomia, and chambers. Many of the burials had been disturbed prior to their excavation by natural processes, such as flooding, or by looting, so it is difficult to draw definite conclusions about the burial practices. The majority of the burials were inhumations, although there were several instances of cremation, especially in the LC IIIB period. Cremation was very unusual in EIA Cyprus and the ones from Kaloriziki along with several from Palaepaphos-Skales (T.83 and T.89) are the primary examples of cremations from this period. Secondary burial was also very common. When a new burial was introduced the first burial might be left in place, pushed to the side, covered with a layer of earth, or placed inside a vessel (Benson 1973, 21).

The most spectacular and well-known finds from the Kaloriziki cemetery come from Tomb 40, which was looted in 1903. The looters were apprehended quickly, and the finds brought to the Cyprus Museum. This tomb contained, among other things, a gold scepter which was thought to belong to an Argive prince who immigrated to Cyprus (McFadden and Sjöqvist 1954). This tomb was thought to hold the bodies of the rulers of Kourion because of the caliber of the finds. In 1952 McFadden returned to Kourion to investigate the looted tomb. He was assisted by locals, some of whom had participated in the original looting, in relocating the tomb.

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19 Tomb 19 contains a cremation in an amphora. Tomb 40 contained one or two cremations in bronze urns. Tomb 39 yielded a cremation in an amphora. Burnt material in the dromos of Tomb 39 suggests that the funeral pyre was nearby (Benson 1973, 21).
Objects Included in Study

The University Museum expedition to Kourion included the excavation of 27 tombs at the EIA cemetery of Episkopi-Kaloriziki. The finds were divided between the Cyprus Museum in Nicosia and the University Museum in Philadelphia. 38 bronze and iron objects from this cemetery were brought back to the University Museum (Table 1). The majority of these were copper-based objects, including ten fibulae, four pins, five needles, and eight rings, as well as a couple more unusual objects: a strainer and a tripod. Five of the remaining objects were made of iron. They included three knives, one blade, one spear, and one knob. The final object was a lead fragment.

Lapithos

The site of ancient Lapethos is located near the modern town of Lapithos / Lapta on the coast of Northern Cyprus. It sits on the northern slopes of the Pentadaktylos mountains, overlooking a narrow alluvial plain that is bounded by the Mediterranean to the north and is separated from the rest of the island by the mountains to the south. The site is positioned to take advantage of the natural resources in the region. It is located near one of the springs which dot the lower slopes of the Pentadaktylos mountains. Lapithos is situated between two important mountain passes (Panagra to the east and Agirta to the west) that give access to the interior of the island and important resources there, such as copper ore (Diakou 2013, 72).

The location of these springs and mountain passes have impacted the pattern of human activity in the region since the Chalcolithic period in the 6th millennium BCE (Webb and Frankel 2013). In the Philia culture period, during the transition from the
Chalcolithic to the Early Bronze Age, the nearby site of Vasilia-Evremann flourished in part because of its location at the terminus of a copper trading route. In the Early and Middle Cypriot periods, a proliferation of sites along the northern coast has also been associated with a growing demand for copper (Webb and Frankel 2013, 71, 76). In particular, the Early and Middle Cypriot cemetery at Lapithos-Vrysin tou Barba displays large-scale consumption of metal that probably reflects Lapithos’ involvement in the copper trade (Keswani 2004, 67–71).

The entire north coast seems to have declined in importance in the Late Bronze Age when trade networks shifted towards growing centers to the south and east. The only evidence of the Late Bronze Age in Lapithos are a few burials near the center of Lapithos village (Diakou 2013, 74). In the following Cypro-Geometric period, however, the northern coast grew in importance again. A proliferation of Cypro-Geometric sites cluster around the foothills of the Pentadaktylos mountains (Diakou 2013, 75). The historical kingdom of Lapethos emerged at some point during the first millennium BCE, but its origins are not well understood due to a paucity of archaeological evidence. The exact location of the settlement is unknown, but is often assumed to be located beneath the modern village of Lampousa on the coast.

Early western travelers in the 19th century were familiar with Lapithos. The archaeological remains were first mentioned by Sir John Linton Myres and Max Ohnefalsch-Richter in 1899 (Myres 1899). In 1913, Myres and Menelaos Markides began

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20 Strabo asserts that the kingdom was founded by a group of Laconian settlers led by Praxander (Strabo 14.682).
21 This is based on the identification of Myres, but Diakou points out the lack of evidence and suggests some alternate locations (Diakou 2013, 77).
excavations on behalf of the Cyprus Museum Committee (Diakou 2013, 12). The Swedish Cyprus Expedition (SCE) was the first to conduct systematic work at Lapithos with the aim of establishing good chronological sequences. In 1927 the SCE excavated 23 Early and Middle Cypriot tombs (T.301-323) at Vrysin tou Barba and two Middle and Late Cypriot tombs (T.701-702) at Kylistra (Gjerstad et al. 1934, 1:33–162). From 1927-1928 the SCE excavated 28 rock-cut tombs (T.401-429) at Kastros (Gjerstad et al. 1934, 1:172–264). The SCE also excavated three Early Iron Age tombs (T.601-603) at Plakes (also called Alonia ton Plakon) (Gjerstad et al. 1934, 1:13).

In 1931, Bert Hodge Hill agreed to begin excavations in Cyprus on behalf of the University Museum. Hill brought with him an impressive team of women from the American School of Classical Studies in Athens including Dorothy Cox, Virginia Grace, and Lucy Talcott. Ida Thallon Hill and Elizabeth Pierce Blegen also assisted in cataloguing (Diakou 2013, 16). They began by excavating 38 Early and Middle Cypriot tombs (T.801-838) at Vrysin tou Barba. Next, they excavated 20 Early Iron Age tombs (T.451-470) at the Lower Geometric cemetery. Finally, they excavated sixteen Early Iron Age tombs (T.471-486) at the Upper Geometric / Kato Kastros cemetery. Unfortunately, the University Museum was unable to provide further financial support for the project so there was no funding to prepare the publication of any of these excavations. A preliminary report was prepared by Virginia Grace when she studied the finds in 1937. Her preliminary report remained the only publication of the site, with the exception of a
few publications of individual tombs, until the material from these excavations was eventually studied as part of three doctoral dissertations.\textsuperscript{22} 

The University Museum excavations were the last large-scale, foreign excavations at Lapithos, but ongoing work by the Department of Antiquities has increased our knowledge of the region. The Department of Antiquities of Cyprus formed the Cyprus Survey Branch in 1955 and between 1955 and 1959 they surveyed the Lapithos region. Department of Antiquities also undertook various rescue excavations, which were sporadically published.\textsuperscript{23} Since the occupation of Northern Cyprus in 1974 no legal excavation has taken place. The lack of recent excavations using modern methods in Northern Cyprus makes it all the more important to return to legacy data from early excavations.

\textit{Early Iron Age Lapithos}

As part of her dissertation Diakou undertook much of the work of reconstructing the topography of Early Iron Age Lapithos (Fig. 7). As is the case at Kourion, there is no conclusive evidence for the location of the settlement site in the Early Iron Age. The Cyprus Survey identified two potential sites, one at \textit{Ayia Marina} to the west and one at \textit{Sphinarin} to the east (Diakou 2013, 76) Another candidate is the coastal city of Lampousa. The coastal plain has very little evidence of occupation, but it is not clear whether this is a genuine absence or a result of archaeological visibility (Diakou 2013, 77). Diakou suggests that the settlement may have been located on the prominent plateau

\textsuperscript{22} Grace published T.806A from \textit{Vrysin tou Barba} (Grace 1940). Pieridou published T.474 from the \textit{Upper Geometric} cemetery (Pieridou 1965). \textit{Vrysin tou Barba} was studied by Ellen Herscher (Herscher 1978), the \textit{Lower Geometric} cemetery was studied by Jean Donohoe (Donohoe 1992), and the \textit{Upper Geometric} cemetery was studied by Stella Diakou (Diakou 2013).

\textsuperscript{23} Four tombs were excavated in the area between Karavas and Lapithos (Pieridou 1964). Work undertaken from 1969-1976 in the region is covered in (Nicolaou 1975).
of *Ayia Anastasia*, citing a concentration of Bronze and Iron Age tombs in the surrounding area (Diakou 2013, 78).

Diakou also argues that the Cypro-Geometric cemetery at *Kastros* and the *Upper Geometric* cemetery should be considered part of the same necropolis (Diakou 2013, 717). The survey results also indicate the existence of more tombs to the west at *Kylistra, Mersineron, Troulia* and *Mandra tis Zos* and to the north at *Plakes, Ayia Marina* and *Loures tous Agades* (Diakou 2013, 75). The Cypro-Geometric cemeteries, therefore, seem to form a semi-circular area around the village in the Pentadaktylos foothills (Diakou 2013, 75). The *Lower Geometric* cemetery, on the other hand, is located near the coast and is quite distinct from the other two in terms of the wealth of its assemblages. It should be considered a separate cemetery, which served the needs of a distinct community (Donohoe 1992, 403–6).

*The Upper Geometric / Kato Kastros Cemetery*

Sixteen EIA tombs (T.471-486) were excavated by the University Museum team in the Upper Geometric cemetery (Figs. 8-9). Diakou suggests that the tombs at the top of the plateau, which are the largest and which contain the more prestigious goods, should perhaps be considered the primary part of the necropolis, with the cemetery expanding from the top of the plateau to the slopes in CG II (Diakou 2013, 717).

All the tombs in the Upper Geometric cemetery are rock-cut chamber tombs, consisting of *dromoi, stomia*, and chambers of varying size and shape. Several typologies have been created with the aim of putting the tombs in chronological groupings, but their
usefulness has been called into question. All the burials are inhumations. In three instances, bodies were found buried in the dromos of the tomb. The majority of the tombs contain multiple burials and older burials might be pushed to the side, covered with a layer of earth, or placed in a vessel to accommodate new burials (Diakou 2013, 620).

The Lower Geometric Cemetery

The University Museum team excavated 20 EIA tombs (T.451-470) at the Lower Geometric cemetery. The earliest use of the cemetery dates to the Cypro-Geometric IB or II period and it remained in use throughout the CG period.

All the tombs in the Lower Geometric cemetery are rock-cut chamber tombs. The typology of these tombs is the same as those in the Upper Geometric cemetery. All of the burials are inhumations (Donohoe 1992, 35). Of the 21 tombs in the Lower Geometric cemetery, eight contained only one burial and the rest contained between two

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24 Gjerstad developed one typology of EIA chamber tombs, which was based largely on his excavations at Lapithos (Gjerstad 1948, 29–33). Grace developed a separate typology for the Lapithos tombs around the same time before Gjerstad’s typology was published. These two typologies are remarkably similar. Both distinguish three types. Type I has a longer dromos, Type II has a shorter and wider dromos, and Type III is something of a hybrid. At the time that these typologies were developed scholarship on EIA Cyprus was preoccupied with the question of the “Coming of the Greeks” to Cyprus. Type I was seen as a Greek form, brought to Cyprus by displaced Mycenaeans. Since this form of chamber tomb was not in fact current in mainland Greece, this theory posited that the Mycenaeans in question were actually coming from Rhodes, where the chamber tomb tradition persisted into the EIA. Type II, in contrast, was seen as a local Cypriot type and Type III was understood as a hybrid form developed once Greek and Cypriot populations started to live together. More recent treatments have called this interpretation into question, arguing, “the choice of a particular type of tomb from among those in vogue at any given time might reflect individual, family or community preference rather than ethnic affiliation.” (Donohoe 1992, 29).

25 T.474, T.480 and T.482. These were interpreted by the excavators as the burials of slaves who were sacrificed at the time of their owner’s death, but the evidence for this hypothesis is not conclusive.

26 The dromoi vary in length and shape. The stomia are irregular in shape but are typically not very thick. They were usually blocked with stone rubble or with a large slab with rubble packed around it. The chambers vary in shape from ovular to rectangular. Some tombs have a pebble pavement covering some or all of the interior of the chamber. Often the pebbled area formed a bed for an inhumed body (Donohoe 1992, 53).

27 Many of the inhumed bodies were laid out so that their heads faced the direction of the dromos, but this was not a strict rule. Burial placement was probably determined by practical spatial considerations (Donohoe 1992, 36).
and five (Donohoe 1992, 36). In the tombs that contained multiple burials, the first burial was left in place, moved to the side, or placed in an amphora (Donohoe 1992, 38).

**Objects Included in Study**

The University Museum project at Lapithos included the excavation of 16 EIA tombs from the *Upper Geometric* cemetery and 20 EIA tombs from the *Lower Geometric* cemetery. The finds from these excavations were divided between the Cyprus Museum in Nicosia and the University Museum in Philadelphia. All of the finds from the *Upper Geometric* cemetery were given to the University Museum except for the contents of T.474 and one bronze strainer from T.480 (Diakou 2013, 39). A total of 53 bronze and iron objects were brought back to the University Museum (Table 1). These included mostly fibulae, bowls, needles, and pins. There were also some more unusual objects, such as a unique pendant, a set of tweezers, and a hook. There was also one bronze knife and one iron knife with bronze rivets. Finally, there were several sets of gold earrings as well as some gold ornaments, gold leaf, and two silver rings.

**Vrokastro**

The site of Vrokastro is located on the northern coast of East Crete. It sits atop a 313m high peak overlooking Mirabello Bay (Hayden 2003, 1:1). Mirabello Bay offers a protected place for ships to harbor and it sits at a crossroads for land travel within Crete, so it has been a center of trade throughout Crete’s history. Mirabello Bay forms the northern edge of the Isthmus of Hierapetra, which is the narrowest point along the island, providing an easy crossing to the southern coast. It is also located on an important east-west land route that links central Crete with far eastern Crete. Below the peak of Vrokastro, towards the north, are the lower hills of Kopranes. Behind and above
Vrokastro to the south is the Karakolilia Ridge, which extends west to Mazikhortia and Amighetli (Fig. 10).

The region around Mirabello Bay has a long history of occupation. This stands in contrast to the peak of Vrokastro, which has been only sporadically occupied, usually in times of unrest, when a defensible position was desirable. There is evidence of habitation of the Mirabello Bay region beginning in the Final Neolithic period, but not on the summit of Vrokastro until the MM I–III periods. The abandonment of the summit in the early Neopalatial period (MM IIIA) was consistent with larger regional patterns of settlement contraction in the region (Haggis 1992, 280; Watrous et al. 2012, 55). The Postpalatial period (LM IIIA-B) is marked by depopulation and in particular by the appearance of small settlements inside larger abandoned towns (Hayden 2004b, 235). At the end of the LM IIIB period, disruptions across the entire Aegean caused a dramatic shift in settlement patterns. Responses to these disruptions were regionally specific and in the Mirabello Bay region, one response was to retreat to defensible mountainous locations or “high sites.” The summit of Vrokastro served as a “high site” in the LM IIIC period, but notably, when most high sites were abandoned in the SM / PG period, Vrokastro remained inhabited down to the 6th century BCE. By the Archaic period settlement in Mirabello Bay focused around the sites of Prophetes Elias, Azoria, and Istron (Watrous et al. 2012, 77). In this period the inhabitants of Vrokastro descended to the coast to join the polis of Istron on Nisi Pandeleimon promontory.

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28 The occupation of Vrokastro in the MM period is postulated based on the presence of Kamares Ware vessels (Hayden 2004b, 235).
29 Besides Vrokastro, Elias to Nisi on the coast was one of the only sites to remain inhabited in the Vrokastro survey area.
The site of Vrokastro was first visited by Richard Seager and Harriet Boyd in 1903. They noted the abundance of pottery at the site as well as a few visible walls, which led them to believe it would be a profitable location for excavation. Edith Hall subsequently undertook excavations at the site during two short seasons in 1910 and 1912. These excavations were centered around the settlement site on the summit of Vrokastro, but also included a number of dispersed tombs along Karakovilia ridge, as well as south of the ridge, in Amigthali, and west of the ridge in Mazikhortia (Dohan 1914). In 1986 Barbara Hayden initiated the Vrokastro Survey Project. As a part of that project she restudied the exposed architecture and published the pottery from Hall’s excavations (Hayden 2003). She also conducted a pedestrian survey of a 10km² area around the site in order to situate Vrokastro in its regional context (Hayden 2004a; 2005).

Although no other work has been done at Vrokastro, the Mirabello Bay area is very well studied. There have been several important survey projects in this area including L. Vance Watrous’ survey of the Gournia Valley and Donald Haggis’ survey of the Kavousi-Thripiti region (Watrous et al. 2012; Haggis 1992; 2005). Furthermore, excavation at the contemporary sites of Kastro Kavousi and Vronda Kavousi adds to our understanding of this region (Boyd 1901; Day 2009; 2012; 2016).

Settlement

The settlement site, located on the peak of Vrokastro, offers a commanding view of the coast from a defensible position, as well as easy access to water from the river in the Kalo Chorio (or Istron) valley and fertile lands in the plain below. The settlement was inhabited from the LM IIIC period to the 6th century BCE. The LM IIIC occupation of the site is known only from the ceramic finds, but it appears to have been a phase of dense
habitation. During the following SM – PG period, occupation of the settlement continued, but at a lower rate. Hayden has suggested that this change represents a dispersed living pattern, with families living close to their farms, rather than a period of depopulation (Hayden 2003, 1:13). In the 9th and 8th centuries the settlement became more densely populated again and most of the architecture dates to this period.

Tombs
Although the settlement at Vrokastro is evidenced as early as LM IIIC, there are no tombs around Vrokastro until the very end of the LM IIIC period. The dominant tomb type at Vrokastro from the end of the LM IIIC period down to the 9th century was the “tholos tomb” or “corbel-vaulted tomb,” which is a specific type of chamber tomb featuring a corbel-vaulted roof. Most have dromoi and their chambers can be either rectangular, square, or ovular. Tholos tombs contained both cremations and inhumations, although inhumations were far more numerous. This tomb type is very common around the Mirabello Bay and West Sitia region. The earliest tholos tombs dating to the late LM IIIC / SM period are located at Kopranes and at Istron. In the SM / PG period the form becomes much more widespread and there are examples from Kopranes,

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30 There is some confusion in the pottery sequences from this period in eastern Crete. For example, pottery with “Subminoan” decoration persists during this period only in eastern Crete and only in burials. The contemporary pottery from settlement contexts is not well understood, so it is difficult to assess the density of habitation using only ceramic evidence from survey. See Hayden (2003, 1:3) for further discussion of the Subminoan style in the Vrokastro area.
31 Hayden suggests that the inhabitants of the high site may have continued burying their dead at the coastal, LBA site of Phanourios (2004b, 236).
32 This term is potentially confusing, since these are not “tholos tombs” in the Bronze Age sense of the term.
33 Hall claims to have found cremations in Tombs 1, 4, and 5 (Dohan 1914, 175).
34 See Eaby’s dissertation (2007) for a comprehensive review of regional burial practices in Early Iron Age Crete, which were regionally dependent and extremely varied.
35 Tombs V-VII at Kopranes were excavated by Hall. At Istron two small LM IIIC-SM tholos tombs were excavated in 1991 on the land of K. Arnaoutaki (Eaby 2007, 45).
Karakovilia, Amigthali, and Mazikhortia. The geographical expansion of the tholos tomb area in this period has been associated with the more dispersed settlement pattern of this period mentioned above (Hayden 2003, 1:13). Many of these tombs were used for multiple burials, so they remained in use into the Geometric period.

In the 9th-8th centuries BCE there was a dramatic shift in burial practices across the region. A new form of burial building known as a “bone enclosure” became popular. “Bone enclosures” were constructed of a series of small and irregularly shaped rooms with low walls between them. The introduction of this new form of tomb was accompanied by a shift in burial practices, from inhumation to cremation. Often bone enclosures were built in the vicinity of earlier tholos tombs. Although these were the two most common means of burial in this period, they were by no means the only ones. There are also a few examples of burials in pithoi or under ridges.

It should be noted that not all of the tombs in the Vrokastro area need be associated directly with the population living at the settlement on Vrokastro peak. Hall notes that during her excavations, tholos tombs and burial enclosures were often interspersed with settlements (Dohan 1914, 83–84). It is quite possible, therefore, that the tombs should be associated with individual families or kinship groups living dispersed throughout the landscape.

*Objects Included in Study*

36 Recent treatments point out that there is no reason to believe that a significant socio-cultural change accompanied this new burial practice: “The introduction of new burial practices does not in and of itself necessarily indicate a changing sociopolitical structure or the presence of new people…the presence of multiple burials in most tombs, as well as the frequent association with earlier tholos tombs, implies that no significant change in ideology has yet taken place; the basic unit of social organization still seems to have been the household or extended family” (Eaby 2007, 351–52).

37 As is the case at Amigdali (VK 12 near Tomb IV), Karakovilia (BE I-V near Tomb I), Kopranes (BE VII-XII near Tombs V-VII), and Mazikhortia (BE VI near Tombs II and III).
Hall’s excavation at Vrokastro included a settlement site as well as seven tholos tombs and 12 bone enclosures. Her excavations were undertaken under the auspices of the University Museum. The finds from Hall’s excavations in Vrokastro were divided between the University Museum in Philadelphia and the Heraklion Museum in Crete. The objects that came to the Penn Museum included only 22 bronze and iron finds. The majority of these were bronzes, predominantly fibulae and nails, as well as a few pins, one saw and one fishhook. Four iron objects were also brought to the Penn Museum: two knives, one dagger and one spear (Table 1).

THEORY

This study draws on a number of theoretical perspectives on technology, technological change, and the transmission of technological knowledge. Rather than situating this study within a single theoretical tradition, I bring together threads from several related approaches. This section outlines some ongoing theoretical discussions about technology, addresses how these perspectives complement (or contradict) each other and lays out the ways I will apply them to this project.

*Châine opératoire* and technological style form the starting point of my approach. Both approaches highlight the importance of considering every step in the operational sequence used to produce a finished object. They demand a rigorous attention to detail and they formalize a straightforward means of organizing and interpreting data. Both are frequently applied to studies of technology and to metallurgical material in particular, because they are well suited to the study of systemic processes and because they draw attention to each step of production.
Building on this, my approach to the transmission of technological knowledge incorporates models of learning based in sociological and ethnographic research. Communities of practice has become a core concept in many technological studies because it provides a framework for understanding the social setting in which craft learning was embedded and technological knowledge was shared. Extensive ethnographic research on the transmission of craft knowledge and technological skill is frequently used to augment studies based in a communities of practice framework. The long history of ethnographic research on this topic can both deepen and broaden archaeological perspectives on the many and varied ways in which learning takes place.

I employ *châine opératoire* to reconstruct the operational sequences used to manufacture a variety of objects types from Kourion, Lapithos, and Vrokastro. Moments of technological choice in these operational sequences, when the craftsman had a number of options open to him and chose to pursue one over another, are investigated and used to form an understanding of the prevailing technological style. By distinguishing these technological styles, I attempt to identify the communities of practice that were active at Kourion, Lapithos, and Vrokastro throughout the course of the Early Iron Age. Ethnographic analogy is also drawn upon to model how these groups might have functioned and how they might have interacted with one another. Ultimately, I seek to model how technical knowledge flowed within communities of practice and between them.

**Technological Studies**

Archaeologists from different theoretical schools have approached technology in various ways. Culture-historical studies of technology were primarily descriptive, and
their objectives were centered around composing chronologies and identifying cultures. With the advent of processualism in the 1960s, earlier approaches to technological studies were rejected as overly normative and untheoretical. They were critiqued for using levels of technological sophistication to demarcate cultural groups (Stark 1998, 3). Processualists developed their own views on technology, typically operating on the premise that ancient peoples adopted various technologies simply because they were adaptive and unquestionably useful. For example, Binford famously defined technology as “man’s extrasomatic means of adaptation” (L. R. Binford 1965, 205).

The processualist approach has since been heavily critiqued as positivist and functionalist (Dobres and Hoffman 1994, 227). Pfaffenberger traces how this “Standard View” developed and points to the ways in which it is inextricably linked to modernism and the growth of Western capitalism (Pfaffenberger 1992, 495). Whereas processualists viewed technology as man’s means of mediating between nature and culture, post-processualists suggest that technology is itself culturally mediated (Dobres 2010, 106).

Studies of technology today draw on a variety of different theoretical traditions, but most scholars would agree that that humans create technology for a wide variety of reasons, many of which are cultural and entirely unrelated to adaptation or economic efficiency. Three basic premises of modern technological studies can be established:

(1) There are many different ways to accomplish any task. For example, there are many ways to provide oxygen to a furnace. This can be accomplished for example with tuyères and bellows or with blow pipes. Some techniques may be more economically “efficient” (e.g. bellows instead of blow pipes), but they are not always preferred.
The specific way a person chooses to accomplish a task is always informed, consciously or unconsciously, by the cultural context in which they are operating. Within all the possible ways of accomplishing a task, there are always constraints that limit the available option. First, the environment plays an active role in restricting a variety of factors - for example, the availability of raw materials. Second, technological choices are always influenced by what is perceived to be the culturally appropriate way of doing things. A complex set of social, economic, and ideological variables shape cultural perception of what options are available. Consequently, technological choice is embedded in worldviews and beliefs. Finally, technological choice is often constrained by the prior choices of the society under study (Killick 2004; Pfaffenberger 1992).

The element of technological choice within these environmental and cultural constraints can reveal important elements of the relationship between technology and society. Technological choice can be understood as a decision that preferences one method of forming the object over another equally adaptive option. From these choices we hope to infer something about larger worldviews and cultural norms of the society in question. So, with reference to the earlier example, one group might choose to continue using lung powered blow pipes to provide oxygen to a furnace, because they believe that by doing so, they are imbuing the molten metal in the furnace with the breath of life (Epstein 1993).

Two very influential concepts in technological studies in the past 30 years are châine opératoire and technological style. Although they originate from two parallel intellectual traditions, the concepts have much in common and are mutually compatible. Each
provides a means of reconstructing a fine-grained technological sequence of operations based on the archaeologically visible finished product and of locating the points of technological choice in that sequence. Furthermore, each seeks to relate those technological choices to larger culturally held beliefs. Although they have their roots in earlier studies, both concepts became very popular in the 1990s. An increase in English language publications about *châine opératoire* at that time also led to cross-pollination between the two schools of thought (Stark 1998, 1).

*Châine Opératoire and the Techniques et Cultures School*

The *châine opératoire* can be understood as “a series of technological operations which transform a raw material into a usable product” (Cresswell 1990, 46). These technological operations typically involve raw materials, tools, energy sources, and techniques which are all applied in a particular sequence to form the final product. For example, a potter will choose their clay, add temper to it, shape a vessel, and then decorate and fire it. Based on analysis of the final product and the debris produced during the manufacturing process, archaeologists should (in theory) be able to recover the details of this production sequence. The ultimate goal of *châine opératoire* research is not only to reconstructing a detailed *châine opératoire*, but also to reconstruct the social systems within which the production occurred and to understand how the social background informed the production techniques. As Schlanger explains, use of *châine opératoire* “implies a rigorous methodological framework for reconstructing processes of manufacture and use, and also, as importantly, a theoretically informed commitment to understanding the nature and role of technical activities in past human societies” (Schlanger 2005, 19).
The underpinnings of *châine opératoire* can be traced back to the work of Marcel Mauss, a sociologist who was interested in bodily movements and gestures. In his seminal study, *Les Techniques du Corps*, he put forward the idea that gestures were culturally informed (Mauss 1935). This interest in gesture extended to the connection between gestures and the physical objects those gestures created. He therefore was interested in the idea of techniques and in unfinished objects. André Leroi-Gourhan drew heavily on Mauss’ theories about gesture as he developed the concept of the *châine opératoire* (Leroi-Gourhan 1943; 1945). Leroi-Gourhan was an anthropologist who developed the *châine opératoire* in order to study lithic technology, to which it is very well suited. Leroi-Gourhan believed that these operational sequences were deep-seated and that they influenced all types of material culture.

The concept of the *châine opératoire* was popularized in the 1990s by social anthropologist Pierre Lemonnier. Lemonnier is particularly interested in defining the entire technological system, which he sees as having five components: (1) matter, (2) energy, (3) objects or tools, (4) gestures in sequence, and (5) specialized knowledge (Lemonnier 1992). He also focuses specifically on the “strategic moments” when a specific choice that defines the technological system is made (Lemonnier 1992). His most famous study on the Anga of New Guinea indicates that various social groups are often aware of how their technological choices differ from those of their neighbors, but they choose not to adopt their practices, because the differences are a mark of social differentiation (Lemonnier 1986, 161).

*Technological Style and the Anthropology of Technology*
Technological style is similar to *châine opératoire*, but it grew independently out of a renewed interest in studying technology and technological change in American scholarship.

Heather Lechtman coined the term “technological style” and laid out her conceptual framework for its use in a fundamental introduction to a collected volume entitled “Technological style – some early thoughts.” (Lechtman 1977). Her fundamental hypothesis is that “style” resides in every stage of a technological process.

Lechtman argues that the process of producing an object is as full of cultural meaning as the object itself. Because she views technologies as “integrated systems that manifest cultural choices and values,” she believes that they are the starting point from which to learn about the “emic” mindset (Lechtman 1977, 5). In other words, by investigating moments of technological choice something can be inferred about the values and beliefs of the person who made the choice. For example, in a famous study, Lechtman found that Andean metalworkers chose to produce objects of a bronze-gold alloy and remove the bronze from the surface to give them a gold appearance, rather than to gild the objects with gold foil. She argued that they did this because they believed the gold should be diffused throughout the objects so that its appearance would reflect their interior essence (Lechtman 1984). She was also able to show that textile production was accomplished in accordance with similar worldviews.

Lechtman’s understanding of technological style is firmly grounded in structuralist theory. She argues that styles are shaped by unconscious cultural patterning. Lechtman also believes that technological choices are not only informed by cultural
beliefs, but they also affirm and uphold those beliefs in a recursive process. In this way technology is actively engaged in reproducing culture.

Technological style and an anthropology of technology more broadly were adopted by several generations of American scholars, especially those working at the Massachusetts Institute of Technology (MIT). Many, including Lechtman, were influenced by the work of physicist and historian of technology Cyril Stanley Smith (Smith 1986; 1981). Smith’s work on materiality and the patterning of material objects was grounded in a structuralist framework, which became an underlying pillar of much of the work done on technological style. Smith’s students at MIT included Lechtman, Kingery, Vandiver, Pigott, and others. They in turn trained a second generation of archaeologists in interdisciplinary methods including archaeological sciences (Childs 1991; Childs and Killick 1993; Epstein 1993; Hosler 1994). In the 1990s the MIT school produced an outpouring of interdisciplinary scholarship on technology that drew on theory from a diverse range of subjects including materiality, archaeological science (Martínón-Torres and Killick 2015; Jones 2001; Sillar and Tite 2000), Science and Technology Studies (STS), and ethnoarchaeology (David and Kramer 2001).

The interdisciplinary nature of the method is one of its primary benefits. In particular it has a long history of being used in conjunction with archaeological sciences. Lechtman’s work on Andean metallurgy was one in a long line of metallurgical studies to draw on technological style and anthropology of technology (Childs 1991; Epstein 1993; Hosler 1994). On the other hand, technological style has been critiqued for its structuralist underpinnings and for not incorporating agency or diachronic change over
time (Dobres and Hoffman 1994). These critiques have much in common with the critiques of châine opératoire.

Although Lechtman and Lemonnier were both concerned with the relationship of technology and society, they focused on slightly different aspects of this question. Lechtman was more interested in the ideology and worldview of Andean culture as a whole. Lemonnier, by contrast, was interested primarily in the interplay between technology and various social groups. Hegmon proposes that this may be due to their various fields of interest (archaeology vs ethnography) and the types of objects they studied (metals controlled by craftsmen vs everyday objects made by everyone) (Hegmon 1998).

TECHNOLOGICAL CHANGE AND TRANSMISSION OF TECHNOLOGICAL KNOWLEDGE

Many early studies viewed technological change as a teleological evolution towards more and more adaptive technologies, in which increasingly adaptive technologies clearly signified increasing complexity and civilization (Childe 1930). More recent studies of technological change and the transmission of technology include a wide range of approaches including evolutionary, behavioralist, and cognitive models.38 These approaches have been critiqued for failing to adequately account for the culturally embedded nature of learning.39 In this study I will rely instead on models of learning that

38 More recent evolutionary models for the spread of technology have relied more on neo-Darwinian or “non-directional” evolution. For examples of evolutionary approaches see (Kuhn 2004; 2004; Roux 2013; Stark, Bowser, and Horne 2008; Eerkens and Lipo 2005; Jelmer W. Eerkens and Lipo 2007; O’Brien 2008; 2011). For behavioralist approaches see (Schiffer 2001; 2004; 2005).
39 Evolutionary approaches have been critiqued by some scholars for being overly functionalist or for failing to take into account the cultural embeddedness of learning (Dobres 2010). Other scholars have pointed out, however, that evolutionary models are well-suited to some questions and should not be dismissed out of hand (Killick 2004). For example, evolutionary models have often been applied to
draw on sociological and ethnographic research, since they place more emphasis on the social setting of learning.

*Communities of Practice*

The concepts of situated learning and communities of practice, which have their origins in the sociological work of Lave and Wenger, have been highly influential in archaeology (Lave and Wegner 1991; Wenger 1998). The foundational premise of situated learning is that learning is a socially embedded process and that knowledge derives from participation in everyday life. Definitions of learning should not be restricted to formal instruction. Instead, learning takes place while working and performing daily activities.

Lave and Wenger argued that learning is achieved through “legitimate peripheral participation.” It is through this practice that newcomers or children learn a set of techniques by observing more experienced practitioners and by participating in increasingly difficult tasks as their abilities allow. It is essential that newcomers contribute something to the group in order to be considered “legitimate.” As they become involved in more difficult tasks, they move toward the center of the group and begin to identify more with the community.40

For Lave and Wenger, learning takes place inside “communities of practice.” Their definition of “communities” has been left quite nebulous, leaving the door open for technological adoption over very long periods of time (Kuhn 2004). They are less useful for thinking about change in the short-term and especially for thinking about imperfect datasets.

40 Interest in “legitimate peripheral participation” has coincided with an increase in archaeological studies of apprenticeship, particularly in studies of ceramics (Crown 2001; Minar and Crown 2001; Wallaert-Pêtre 2001; Wendrich 2013). This topic has not been as extensively studied by metallurgists, in part because of practical constraints. For example, whereas sub-standard or failed pottery made by apprentices may survive in the archaeological record, failed metal objects would have been melted down and reworked.
a number of different interpretations (Cox 2005). The most widely accepted definition could be stated as a small learning network with members that are characterized by their use of similar practices. Communities of practice are not stable groups with well-defined boundaries, and they may not even self-identify as a group. Community of practice theory has been criticized for being too open-ended. On the other hand, its flexibility has been in part what has made it such a popular method.

Communities of practice can vary widely in scale. In their original publication, Lave and Wenger see them as small, close-knit groups, working in close physical proximity, but in later publications they expanded their definition to include larger, physically dispersed groups as well (Wenger 1998). Their work is situated in the context of the modern world, however, where geographically dispersed groups can still be in frequent contact. Most applications of communities of practice to the ancient world understand the community as a small, face-to-face learning network. The related concept of “constellations of practice,” can be used to study more geographically dispersed groups, however, since it is concerned with more diffuse configurations, held together by “brokers” and “boundary objects” (Roddick and Stahl 2016).

Communities of practice have been widely applied to the study of technology and craft production in archaeology (Arnold 2018; Cordell and Habicht-Mauche 2012; Dorland 2018; Eckert, Schleher, and James 2015; Hensler 2020; Kelly 2016; Mills 2016; Peeples 2018; Sassaman and Rudolphi 2001; Wendrich 2013). This presents the issue of trying to identify communities of practice based only on the materials they leave behind. Often scholars attempt to reconstruct the chaine opératoire in order to identify groups that may have existed.
Ethnographic Analogy and Ethnoarchaeology

While the application of ethnographic data to archaeological questions is a notoriously tricky task, it is nevertheless foundational to the entire discipline of archaeology. Every attempt to make sense of the archaeological record makes use of analogy in some way, whether or not that analogy is made explicit (David and Kramer 2001; Lane 2006; Johnson 2010). Ethnoarchaeological theorists advocate the transparent use of analogy, which clearly states the reasons for employing one analogy over another and which acknowledges the limitations of the analogy used.

Archaeological studies of technological transmission have relied heavily on information culled from extensive ethnographic and ethnoarchaeological research about learning and craft production. Many ethnographic studies have taken craft-production and specifically the transfer of technological knowledge and skill as their subject (Gosselain 1992; 2000; Sassaman and Rudolphi 2001). These studies suggest patterns or trends in the way people learn and the way knowledge is imparted to learners. Those patterns are frequently applied to archaeological materials through ethnographic analogy. Although a complete review of ethnographic research concerning learning and transmission of technological knowledge is too extensive to be covered in depth here, the following discussion is meant to highlight some topics that are most relevant to this study.

Many ethnographic studies are primarily concerned with learning that takes place within a community and focuses on the instruction of children. Although specific mechanisms of learning vary widely between cultures, certain aspects of learning remain fairly constant. For example, complex crafts are usually learned through vertical transmission (from a parent) or occasionally oblique transmission (from an older relative)
but are very rarely learned by horizontal transmission (from a peer). Complex crafts can take a very long time to master and it is often a parent or close relative who is willing to invest the time to teach a child (Stark, Bowser, and Horne 2008, 7). Furthermore, once a certain set of motor skills or gestures is learned, a craftsperson is unlikely to deviate from them. Therefore, elements of production that rely heavily on motor skills are far less malleable than those that do not. In ceramic production, for example, the method of shaping a vessel is often more conservative than the decoration (Gosselain 1992; 2000).

As these examples highlight, people often begin their instruction in complex crafts and technological skills at a young age and once learned, physical gestures and techniques are unlikely to be altered. Consequently, learning new techniques as an adult from craftsmen working in other cultural traditions is relatively rare. Furthermore, the types of techniques that are adopted are often restricted to specific elements of production (e.g. vase decoration, rather than vase forming techniques). Furthermore, styles that already have some cultural currency in the culture that is adopting them may be more likely to be adopted.

Many ethnographic studies are concerned with the social boundaries between craft communities that prevent the sharing of information. For example, in a well-known study conducted in southwestern Niger, Gosselain concluded that there was intentional non-borrowing between groups living in close proximity, because of the perceived distinction between social groups (Gosselain 2008).

Ethnography in Metallurgical Studies
Historically, archeometallurgical studies have tended to emphasize the technological and functional properties of metals, ignoring their more socio-cultural and
ideological roles. Scholars have pointed out a “lack of integration between metallurgical research and anthropologically informed archaeology” (Budd and Taylor 1995, 134). This omission extends to the use of ethnographic analogy, which has been underutilized in metallurgical studies, despite its extensive use in ceramic and lithic studies.41 Recently, however, there has been a push for more integrated methodologies.

The most well-known metallurgical project to use ethnographic methods is the extended study of iron production in sub-Saharan Africa (Childs and Killick 1993; Childs 1991; Iles 2018). Through interviews with smiths and observations of activities surrounding the smelt, archaeologists were able to learn about the cultural context in which iron production was embedded.42 Although these studies have since been critiqued for failing to account for multiple perspectives (such as the perspective of women or of a younger generation), they have had an enormous impact on the field of archaeometallurgy (Iles 2018).

While there are some communities in Asia and the Americas still using “traditional” metalworking techniques, they have received far less scholarly attention than those in Africa.43 Furthermore, iron predominates in the field, while studies of silver and lead, gold, and bronze are less common. In the Mediterranean, similar living communities using pre-industrial metallurgical methods are extremely rare. Furthermore,

41 See Costin (2000) for an overview of ethnographic methods in archaeological studies of ceramics.
42 In ethnographic studies of many cultures in sub-Saharan Africa, the process of smelting iron was paralleled to the process of reproduction. Often the smelters were bound to strict rules of sexual abstinence during the smelt. The Chisinga of Zambia considered the head smelter the husband of the impregnated furnace. Smelting equipment was often endowed with gendered names and attributes. Restrictions against women being present during the smelt are also attested in some cases. An overview is given in Iles (2018). For a discussion of the application of these ethnographic models to Greek context see Blakely (2006).
43 See Iles and Childs (2014, 196) for a more extensive discussion of the ethnographic work being done in Asia and the Americas.
any claims to continuity of practice between the Iron Age Aegean and the modern day cannot be sustained, and direct analogy is thus impossible. Instead, archaeologists must rely on “relational analogy,” which uses ethnographic data to form cross-cultural generalizations. Relational analogies are very challenging and Iles and Childs rightly note that, “a wider range of caveats needs to be taken into consideration when applying these types of data to archaeological interpretations, along with increased interpretative caution” (Iles and Childs 2014, 200).

In addition to ethnographic parallels, metallurgical studies have drawn heavily on analogy from related fields such as historical texts and experimental archaeology. Historical and ethnohistorical texts describing pre-industrial metalworking have been used both to form a picture of metalworking at the specific time when they were written and, more generally, to broaden understanding of the variety of possible metal working techniques.44 In particular Agricola’s De re Metallica (1556), which features wood block prints of contemporary, 16th century mining and smelting processes, is very widely cited (Craddock 1994). Proponents of experimental archaeology have advocated for working with metals in order to gain hands-on experience that can guide and improve research questions. These questions can then be tested by controlled experiments that expand knowledge about metallurgical properties and metalworking possibilities (Heeb and Ottaway 2014, 163).

METHODS

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44 See Iles and Childs (2014, 197) for a more extensive discussion of historic texts on metallurgy.
This study applies a multi-pronged approach to the question of technological transfer. A combination of macroscopic and microscopic analysis was employed in order to provide a comprehensive overview of the technological system used to construct the objects. Macroscopic analysis was undertaken first in order to establish a typology of the objects and investigate the forming techniques. It included formal visual analysis and X-radiography of the entire sample (24 objects, Table 2). This dual step macroscale analysis also served as a survey of all the objects, which informed the sampling strategy for microscopic analysis. Twenty-four objects were sampled and subjected to scientific testing. Microscopic methods included both optical microscopy and chemical analysis. Optical microscopy revealed the internal structure of the samples, which reflects the stages of an object’s formation. It was also used to identify areas of interest for chemical testing and to refine research questions. Next, chemical analysis was carried out to determine the major, minor, and trace elements present in the samples, which reflect alloying practices and smelting conditions. Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM-EDS) was used to determine the major and minor elements present in the samples as well as to locate and identify inclusions through micro-analysis. Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) was then used for the analysis of bulk composition and trace elements.

The objects used in this study all came from the Penn Museum’s collection. The macroscopic analysis was carried out in the object handling room of the Penn Museum. The X-radiography was carried out in the laboratory of the Conservation Department at the Penn Museum. The microscopy and the SEM-EDS analysis were carried out in the Center for the Analysis of Archaeological Materials labs at the Penn Museum. Finally,
the LA-ICP-MS was carried out in the Elemental Analysis Facility at the Field Museum in Chicago.

**BACKGROUND**

Archaeometallurgists working in many different parts of the world are engaged in a debate about the technological transfer of metallurgical techniques. For example, scholars working in Southeast Asia have produced a robust and impressive body of literature regarding technological transfer with a specific focus on the origins of metallurgy.45 Scholars working on metallurgy during the contact-period in many different regions of the Americas have extensively discussed the interaction of Native and European metal working practices (Ehrhardt 2007; Lattanzi 2008; Dussubieux et al. 2008). Although similar scientific techniques have not been extensively applied in the eastern Mediterranean, they have been applied by scholars working in the western Mediterranean. In particular, there is a team of metallurgists investigating the adoption of Phoenician metalworking practices by the indigenous communities of Iberia in the 8th – 6th centuries BCE (Valério et al. 2010; Figueiredo et al. 2011; Valério et al. 2016; Farci, Martinón-Torres, and Álvarez 2017).

Projects on technological transfer of metallurgical techniques vary significantly in their scope, in the materials available for use, and in which scientific methods are employed. The scope may range from large scale reviews of entire technological systems of whole regions that draw on many different sources to smaller scale research conducted

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45 Much of this discussion centers on whether metallurgy in Thailand was imported from the Huanghe Central Plain of China (Higham 1996; Higham et al. 2011) or from the Eurasian steppe (White and Hamilton 2009). See also (Pryce et al. 2011; 2014).
at one or several sites, which focus on a smaller portion of the production sequence. In many cases the available material involves tools and debris from metal working sites, such as technical ceramics and slag. While this is of course preferable and allows for a more complete examination of the technological system as a whole, many other studies must rely solely on the finished objects and what can be learned from them. Finally, projects use a variety of scientific methods, depending on what is best suited to their research questions, but also what is widely used in their particular field of study, and what is available and cost effective.\textsuperscript{46}

Nevertheless, some common methodological approaches can be discerned. Most studies include some macroscopic analysis in order to develop a typological system and to inform their scientific analysis, along with a combination of optical microscopy and one of more methods of elemental analysis. They are often used in combination since some methods are better suited to answering questions about the bulk composition and others are specifically targeted to understand trace elements (as discussed below).

This project draws on a range of scientific methods and aims to bring an integrated approach to the question of metallurgical connections between Cyprus and the Aegean in the Early Iron Age. It employs methods suitable for studying finished objects, since no tools or byproducts of metalworking are available for this dataset.

**Macroscopic Analysis**

*Visual Analysis*

\textsuperscript{46} There are many techniques for elemental analysis available, each with particular own pros and cons. For example, NAA has been very popular in the past and provides reliable quantitative data but is not a widely used method anymore as facilities have phased it out. XRF is fast and easy, but only provides surface information and has limited sensitivity.
Formal descriptive analysis and typological categorization was performed for the entire sample of 105 objects. The first goal of this examination was to describe the objects formally and functionally. This allowed for the typological categorization of the objects, and, importantly, for the examination of forming practices. Particular attention was paid to attributes that reflected technical manipulation. A second goal of macroscopic analysis was to document the state of preservation of the objects with an eye toward establishing which objects might be profitably sampled for further scientific testing (see below for further discussion).

The investigation of the objects began with a basic formal and functional description of each object. When possible, objects were identified in accordance with established typologies (e.g. Blinkenberg’s typology for fibulae). Hypotheses about the formation practices were also made wherever possible. Any elements that suggested an unusual method of production were noted, along with any aspects of similarity within objects types. Hypotheses about formation practices made based on visual analysis were later tested using microscopy. Basic metric analysis aided in the description and classification. The measurements taken depended on the object type, which included fibulae, pins, rings, bowls, knives, and some unique objects. Weights were not taken because significant amounts of the original metal were lost over time either by corrosion or by outdated conservation methods.

The state of preservation was also recorded, including the level of corrosion, the fragmentary or complete nature of the objects, and any previous conservation efforts. Macroscopic, optical analysis can shed light on two preservation concerns that are particularly relevant to this study. The first is whether the objects had been chemically
treated in early conservation efforts. Chemical treatment of objects not only removes layers of corrosion and creates a false “surface”, but also alters the chemical composition of the surface of the object. For this reason, any suspected chemical treatment was noted so that it could be kept in mind when interpreting the results of further scientific tests. The second preservation concern is whether the object has any intact metal remaining or whether corrosion has eaten through the entire object. This concern can often be assessed using the naked eye or a low magnification lens, particularly for fragmentary objects, which offer a glimpse into the interior. For intact objects the corrosion level can be addressed using X-radiography (see below). Fortunately, the conservation department of the Penn Museum conducted a survey of the Lapithos and Kourion material in 2013 to 2014, and I was given access to the records of that survey. The expertise of the conservation team greatly benefitted to my study.

Photographs were taken of every object from multiple viewpoints. Special attention was paid to documenting evidence of object formation and the state of preservation. Samples had already been taken of 13 of the objects from Vrokastro (see Table 2). The position of these samples was also documented with photographs. In addition, some objects were chosen for microphotography to document small details.

*X-Radiography*

X-Radiography is a useful method for studying fabrication techniques. By examining radiographs, it is possible to determine whether an object has been manufactured by casting, working, or by some combination of the two. Furthermore, specific ways of casting, working, and joining can often be determined or at least
suggested by X-radiography. Hypotheses formed on the basis of radiographs can then be tested by optical microscopy and chemical tests.

Cast objects are made by pouring molten metal into stone, ceramic, or sand moulds or by using the process of lost wax casting. They can be identified by a number of features visible in radiographs such as porosity, variations in thickness, or a coarse granular appearance. In some cases, cast objects can also be identified by the presence of casting faults, internal cores and chaplets, or cast-on sections (Lang and Middleton 2006, 52). Hammered objects, on the other hand, are formed by hammering the object into the desired shape. Often radiographs will display an uneven thickness following a regular pattern where the metal has been thinned by hammer blows. A clear example is swords made from rods or strips of ferrous metal that are forge-welded together. Repeated unidirectional hammering produces elongated and fibrous microstructure (Lang and Middleton 2006, 58). Many objects are composites of several components that have been joined together using mechanical joins, soldering, or welding. X-radiography can be used to locate these joins and to identify the type of join that was used.

X-radiography also serves a secondary role in guiding sample selection for the destructive testing that makes up the second portion of this study. Since X-radiography provides a window into the internal structure of the objects, it can be used to identify areas that are likely to be fruitful for scientific analyses. In some cases, radiographs can

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47 Sometimes bowls with uneven casting are turned on a lathe to remove uneven surfaces and even out the thickness (Lang and Middleton 2006, 52). The granular appearance is the result of the dendrites that form when the object is cooling. The distinctive dendritic structure of cast objects is always apparent in the microstructure, but it can only be seen in a radiograph if the object cooled especially slowly, allowing for the formation of large dendrites as it cooled (Lang and Middleton 2006). Dendritic structure can be seen in the microstructure of cast objects, but if it cooled especially slowly, you can see in in the radiograph.
be used to highlight specific areas of interest. In this study, however, the primary utility of radiographs was in identifying areas that retained intact metal. Many of the objects were so heavily corroded that no metal remained. Sampling these objects is unproductive, since they cannot be used for chemical analysis and are less useful in microscopy. Areas of low density, where the objects were heavily corroded, were identified by X-ray were therefore avoided in destructive sampling.

**Procedures**

The majority of the objects were investigated using X-radiography. Since the objects are small and many are also flat, they were able to be tested in batches. This allowed for the investigation of many objects in a relatively short period of time. The tests were completed using a GE Eresco 65MF4 with a GE-DXR 250V digital capture plate at the Penn Museum with the help of Marie-Claude Boileau, the director of the CAAM labs at Penn Museum. This machine takes digital radiographs which were processed using Rhythm Radiography X-Ray Software Suite software from GE.

**Selection of Objects for Destructive Sampling**

When deciding which objects to sample, it was important that the objects come from comparable archaeological contexts that could be closely defined in terms of space and time.

Fortunately, all of the copper-based objects from Kourion, Lapithos, and Vrokastro objects come from well-recorded, datable contexts. They are all from mortuary contexts, which assures that there is not variation in the metalworking process that might be attributable to different functional contexts. On the other hand, they come from chamber tombs, which were reused over the course of many generations. Also due to post-
depositional disturbances, such as secondary treatment of bodies and natural processes like flooding, the objects cannot always be confidently associated with the individual burials.

Within this assemblage, the decision to sample destructively was based on a number of factors. Objects were chosen so that comparisons could be made across sites for the same object types. Fibulae were sampled from all three sites. Samples were also taken from pins, needles, rings, and bowls, from the Cypriot sites, but not from Vrokastro. Due to the destructive nature of the testing, broken objects were preferred to whole ones, because they were less likely to be put in a museum display. Furthermore, no unique objects were tested, since these add diversity to the collection. Preservation was also a major concern when choosing the objects. Some of the objects were so heavily corroded that there was nothing remaining of the original structure of the metal, in which case they were excluded from the sample list. Six fibulae and two nails from Vrokastro had already been sampled. In addition, three fibulae, eight pins and needles, 3 rings, and 2 bowls from the Cypriot sites were sampled (Table 2).

MICROSCOPIC ANALYSIS

All of the microscopic analysis performed in this study involved destructive sampling, in part due to the effect that corrosion can have on surface testing. Copper-based objects are highly susceptible to surface corrosion. When a copper-based object corrodes, copper is leached out of the interior and deposited on the surface of the objects. As a result, chemical analysis performed on the surface does not produce results which are reflective of original composition of the artifact. The methods of chemical analysis employed in this study (SEM-EDS and LA-ICP-MS) can in some cases be done in a
minimally destructive way, but the sample would then be taken from the corrosion layer on the surface of the object. Since mounted samples were already prepared for optical microscopy, performing the SEM-EDS and LA-ICP-MS on the polished cross sections provided much more accurate results.

Optical Microscopy

Optical microscopy (or “metallography”) is an essential part of any study that is concerned with the formation processes of metal objects. Microscopy involves the examination of the microstructure of metal objects under a reflected light microscope. The microstructure of an object provides insight into its manufacturing and thermal history. For example, it can indicate whether the object has been hot or cold worked (cast or wrought) and whether it has gone through a process of hammering and annealing (heated to below the melting point to make it more malleable). It also reflects the conditions under which the metal object was quenched and tempered. Finally, the microstructure can in some cases reveal a multi-phase structure or inclusions in the metal. All of these components in the manufacturing process reflect the technological choices made by the craftsman during the object’s formation and they can be used to reconstruct larger technological systems.

Although optical microscopy is one of the most important tools for studying fabrication technology, there are several drawbacks and limitations. It requires destructive sampling of objects. Since corrosion, which occurs on the surface of a copper-based object, changes the metal’s structure, the sample must be taken from the interior of the object. Because this sampling process is quite destructive, the potential value of the study must be carefully weighed against the likelihood of the object being displayed in a
museum and the value of keeping the object intact for future generations. There are also limitations to the types of questions that optical microscopy can answer. Any results obtained from microscopy are applicable only to the specific area of the sample. The results cannot necessarily be extrapolated to the entire object. This can sometimes be combatted by taking more than one sample from different parts of the object that may have been formed using different techniques.

The primary goal of microscopy was to investigate the manufacturing history of individual objects as the basis for a larger study of technological systems in EIA Cyprus and Crete. A secondary goal of the microscopy was to guide the elemental analysis that formed the next portion of this project. By examining the internal structure of the samples, I was able to identify areas of interest, which were then prioritized as areas to investigate further using more elemental analysis such as SEM-EDS and LA-ICP-MS.

**Procedures**

The samples from Vrokastro had already been taken and mounted in epoxy resin. Samples from the Cypriot objects were taken for this study. The decision about where to sample the objects was made in collaboration with Lynn Makowsky, the Keeper of the Mediterranean section of the Penn Museum. The samples were cut by Moritz Jansen, Teaching Specialist for Archaeometallurgy at the CAAM labs of the Penn Museum, using a rotating blade tool (Dremel). They were then mounted with phenolic mounting powder using a Struers LaboPress-3 in the metals lab of the Laboratory for Research on the Structure of Matter at the University of Pennsylvania. They were heated at 180 °C and compressed at 20kN for 6 minutes, followed by cooling period for 3 minutes. Grinding and polishing were done using a Buehler EcoMet 3000 in the CAAM labs of
the Penn Museum. They were ground using silicon carbide papers (Carbimet) with progressively finer grit sizes (600, 320, 240) and polished using alumina oxide particles of 1 and subsequent 0.3 \( \mu m \) (MicroPolish) on a polishing cloth (MicroCloth).

Once the samples were prepared, they were examined in both their polished and etched state under a digital microscope (Keyence VHX-5000) using a zoom lens (100-1000x) in the CAAM labs of the Penn Museum. One of several standard etching agents was used following recipes published by Scott (1991, 72). All samples were etched initially in ammonia hydrogen peroxide. This did not produce desirable results with some of the samples, so they were subsequently etched in aqueous ferric chloride, which usually produced better results. Microphotographs were taken of areas of interest, both on polished and etched samples. While samples were in the non-etched condition, inclusions and areas of corrosion were noted. In the etched condition observations were made concerning the range, type, and size of grains, presence and shape of twin lines within the grains, presence of strain lines within the grains, heterogeneity in the sample, presence and distribution of inclusions, the presence of different phases, and pseudomorphic remnants of grain structure in the corrosion layers. This was all done in the manner recommended by Scott (1991, 67).

*Scanning Electron Microscopy - Electron Dispersing Spectroscopy (SEM-EDS)*

Analysis of major and minor elements is an undeniable necessity in a study of manufacturing techniques. Although there are many techniques that could have been used for this purpose, SEM-EDS was chosen for its sensitivity and spatial capabilities.\(^{48}\)

\(^{48}\) For more comprehensive reviews of the capabilities and setbacks of SEM-EDS and its applications in archaeology see Olsen (1988) and Meeks (2012).
Electron microscopy is a powerful tool because it combines high quality imaging with fully quantitative elemental analysis. In other words, it produces a high-magnification X-ray image of the sampled area and the elemental composition of the sample can be tested at various points on that sample. It can therefore be used not only to determine the bulk composition of the object, but also to investigate specific areas of heterogeneity, such as inclusions or high tin phases. This tool is therefore especially useful for investigating the spatial variation in the composition of a sample. For archaeological metals, this allows for the investigation of the elemental composition of inclusions (e.g. oxide, sulfide, or lead inclusions). In samples with multi-phase structures, it also allows for the investigation of different phases. Potential setbacks to using SEM-EDS include the fact that many machines require small samples that are perfectly flat. Fortunately, the samples used in this study were already mounted for microscopy, so this was not a concern.

SEM-EDS also complements the microscopy and LA-ICP-MS used in this study and forms a bridge between them. I was able to identify areas of interest and hone research questions based on optical microscopy that formed a strong foundation for the SEM work. In turn, SEM analysis located areas that would be well-suited to the LA-ICP-MS analysis in order to avoid issues of heterogeneity. The data on the major and minor elements was also used to confirm the results of the LA-ICP-MS. In fact, several studies have noted the compatibility of SEM and ICP-MS for these reasons (Frahm 2014; Resano, García-Ruiz, and Vanhaecke 2010, 74).

*Scientific Background*

A brief explanation of SEM is given here, but a more in depth discussion can be found in (Pollard 2007, 109–13; Frahm 2014). Electron microscopes operate by focusing
the beam of a conventional electron gun on a specific area of a sample and hitting it with a beam of high energy electrons. When the beam hits the sample, two processes occur. First, secondary electrons (SEs) are knocked out of the outer electron orbitals of surface atoms. Since these SEs have low energies, only the ones emitted from very near the surface can escape. Therefore, they reflect the surface topography of the sample and they can be used to image surface details. Second, the beam knocks backscattered electrons (BSEs) out of the inner orbitals of the atom and these electrons have a higher energy. Rather than producing an image, these elections display an intensity which is proportional to the atomic weigh of the atom, known as the backscattered electron image. These images show compositional contrast rather than topographic features. Brighter areas have higher atomic numbers and darker areas have a lower atomic number. These images only show relative differences in composition.

In order to quantitatively measure the elements present, their X-ray emissions must be analyzed with an X-ray analyzer. X-rays have wavelengths and energies that are unique to the elements that emit them. Therefore, an X-ray analyzer can measure either wavelength or energy. SEMs are usually paired with energy-dispersive spectrometers (EDS or EDX), which measure the intensity of characteristic X-rays at energies which correspond to elements within a spectrum. In a similar process, an electron microprobe analysis (EMPA) is often outfitted with several wavelength-dispersive spectrometers (WDS) which differentiate X-rays by wavelength rather than energy. Both methods are comparable in their accuracy and precision, but EMPA-WDS has considerably lower Limits of Detection (LODs) than SEM-EDS. In this study, more precise measurements
were given by LA-ICP-MS, so the disparity between SEM and EMPA was not deemed a significant obstacle.

**Procedures**

The SEM analysis was conducted on mounted samples that had already been prepared for microscopy. The samples were coated in carbon in the Nanoscale Characterization laboratory at the Singh Center for Nanotechnology at UPenn. They were then investigated using a benchtop SEM-EDS (Jeol JCM-6000 NeoScope) in the CAAM labs at the Penn Museum. Analyses were performed at 15kV. The data produced by SEM testing consists of both images and numerical data that is processed by Smile View Lab software. The results of the SEM analysis can be found in Figure 11.

*Laser Ablation – Inductively Coupled Plasma – Mass Spectrometry (LA-ICP-MS)*

LA-ICP-MS allows for fast, multi-element, trace-level elemental analysis. This is important for understanding the conditions under which an object was formed. For example, arsenic behaves differently in an oxidizing or a reducing atmosphere. The arsenic present in the sample, might therefore provide information about the conditions under which the metal was heated and cast.

ICP-MS has been gradually gaining in popularity relative to other methods of elemental analysis since its commercialization in 1983 (Pollard 2007, 195; Resano, García-Ruiz, and Vanhaecke 2010, 55–56). Many studies have been conducted to test the accuracy and precision of ICP-MS relative to more traditional methods of elemental analysis like XRF (Dussubieux et al. 2008; Walaszek et al. 2014) and INAA (James, Dahlin, and Carlson 2005). They have produced generally favorable results, leading to
increased adoption of this technique. ICP-MS has been useful for the study of many archaeological materials including ceramics, glass, metals, and biological remains.

There are two subcategories of ICP-MS, which are differentiated by the way in which the sample is introduced into the plasma (as a solution or by laser ablation of a solid sample). The more traditional method of dissolving the sample in a liquid has lower limits of detection, but it is more destructive. Laser ablation (LA-ICP-MS) was found to be considerably less sensitive than ICP-MS when it was initially applied to archaeological materials but is becoming more and more popular as innovations in the instruments used and careful refining of best practices have increased the precisions and accuracy of the method. For this study LA-ICP-MS will be used, so the advantages and limitations of the method give below will reflect those of LA-ICP-MS specifically.

The primary advantages of LA-ICP-MS are that it provides simultaneous multi-elemental data for major, minor, and trace quantities of elements.\[^{49}\] It is a highly sensitive method, with limits of detection usually below parts per billion.\[^{50}\] It can provide spatially resolved data. It is minimally invasive, leaving behind an “ablation scar” of between 5 and 200 microns. Finally, a sample can be processed in only a few minutes, making it one of the faster methods available.

Many initial concerns about LA-ICP-MS are being resolved now with the development of new instruments and the implementation of proper procedures (Resano, García-Ruiz, and Vanhaecke 2010). There are still some limitations that should be kept in

\[^{49}\] It cannot detect lighter elements like H, He, C, N, O, F, Ne, Cl, Ar, but those are not relevant for metals.  
\[^{50}\] They typically range from \(\mu g \, g^{-1}\) to \(ng \, g^{-1}\) levels, although this depends on the machine and the conditions (Hattendorf, Latkoczy, and Günther 2003).
mind, however. The biggest concern with LA-ICP-MS is that it is essential that the machine be well calibrated in order to produce quantifiable data and this is often quite difficult to accomplish (Pollard 2007, 207). The most common method of calibration involves using solid standards of a (bulk) composition as similar as possible to that of the target samples. This is known as a matrix-matched standard. Luckily, for metals there are many commercially available reference materials that can be used for this purpose. Another limitation, which should be kept in mind when interpreting data, is sample heterogeneity. Samples taken using laser ablation come from a very small area of the object and the results obtained from the test can only be considered applicable to that area. When dealing with heterogenous objects, this can be a serious concern.51

LA-ICP-MS was chosen to round out the analytical program of this study for several reasons. When the correct parameters are set, LA-ICP-MS produces very sensitive, accurate, and precise quantifiable data. The fact that it is fully quantifiable means it can be compared with data from other studies. LA-ICP-MS was also chosen over other methods of elemental analysis because of its relative ease and practicality. Since samples had already been taken, LA-ICP-MS required no additional sample preparation.

Scientific Background

The sample is placed on a stage in the ablation chamber, which can be moved in all three spatial directions. The chamber is connected to a video camera so that the area of the sample can be visually selected. A laser beam is then focused on the desired area and

51 Line profiling can cover a wider area to produce more representative results, but drilling is still a much more common method, because it is smaller and less visible.
used to ablate a portion of the solid surface by irradiation. The sample is then moved into the ICP by a gas flow (usually Ar, He, or both). The high temperature inside the ICP causes the sample to undergo vaporization, atomization, and eventually ionization. The ions are then extracted and guided into a mass analyzer, where detection and quantification of those ions takes place.

The analytical performance of LA-ICP-MS is expected to vary significantly depending on (1) the type of laser used, (2) the ICP-MS instrument used, and (3) the parameters selected. This is a brief overview, see (Resano, García-Ruiz, and Vanhaecke 2010) for a more detailed discussion. The laser used to perform the ablation can impact the sensitivity of the results in several ways. The wavelength of the laser is specific to the instrument itself and it cannot be changed. Wavelength is particularly important, because a shorter wavelength will yield a lower rate of fractionation. The settings to which the laser is set are also important. These include (1) the frequency (usually 1 to 50 Hz) (2) the irradiance (≤100 nm per pulse) (3) the beam diameter (anywhere from 5 µm to 200 – 300 µm). Standard conditions about 10 Hz, 100 nm per pulse, and 40 µm spot size (Hattendorf, Latkoczy, and Günther 2003). ICP-MS instruments vary based on the type of magnetic separation that is applied to the ions. “Single collectors” contain a single rod that receives the beams of ions of various mass-to-charge ratios in a sequential mode. The most common single collector is the quadrupole filter as mass analyzer (ICP-Q-MS).

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52 Fractionation occurs when the composition of the ion beam that arrives at the mass analyzer does not represent the composition of the sample. Fractionation can occur during the ablation of the sample, during the transportation of the particles, or within the ICPMS itself. For more discussion of fractionation see (Russo 2002; H.-R. Kuhn and Günther 2004; Koch and Günther 2011). Recent studies have also looked into the potential for femtosecond lasers to minimize fractionation (Velásquez et al. 2018; Pisonero and Günther 2008).
Although this method suffers from some issues of spectral interference, there have been many solutions proposed to combat this issue (Tanner, Baranov, and Bandura 2002). In contrast, a “multi-collector” (MC-ICP-MS) uses multiple collectors, each set to monitor the ion beam intensity at a specific mass-to-charge ratio. This method benefits from the simultaneous measurement of isotopes of specific elements allowing very precise determination of isotope ratios such as lead isotopes used in archaeometallurgy. Finally, many different parameters must be set in order to conduct testing and all of them have some impact on the sensitivity of the results. These include the atmosphere used in the cell, among other things.

**Procedures**

For this study the samples for ICP-MS were taken from the mounted samples, which had already been prepared for metallographic and SEM analysis. As mentioned above, the use of laser ablation makes LA-ICP-MS minimally destructive, but for most copper-based objects high levels of surface corrosion mean that it is always preferable to sample metal from the interior of the object, which retains its original structure. Another benefit of performing the laser ablation on a prepared, resin-embedded sample is that the surface of the sample is already microscopically flat, which is necessary for the laser to remain focused.

Testing was conducted at the Elemental Analysis Facility (EAF) at the Field Museum of Natural History in Chicago, using a Thermo ICAP Q Inductively Coupled Plasma Quadrupole Mass Spectrometer (ICP-Q-MS) connected to a New Wave UP213 laser for direct introduction of solid samples. Helium was used as the gas carrier for better sensitivity. The laser with a wavelength of 213 nm was set to operate with a laser
beam diameter of 100 μm, operating at 80% of the laser energy (0.2 mJ) and at a pulse frequency of 20 Hz. A pre-ablation time of 20s was set to eliminate the transient part of the signal and to avoid any possible surface contamination. For each sample the calculation of concentrations was taken as the average of 10 measurements corrected from the blank.

The use of an internal standard with known concentrations of the analyzed elements is necessary for quantification, to control signal stability, and to correct possible instrumental drifts. The element chosen should be present in large quantities for the most accurate results, in this case, Cu65. The specific isotopes analyzed to quantify the element concentrations are given with the results in Figures 12 and 13. The concentrations were calculated assuming that the sum of all elements in weight percent is equal to 100%. Seven CRMs were used for quantitative analysis: B10 and B12 from the Centre de Développement des Industries de Mise en Forme des Matériaux, France, 71.32–4 and 51.13–4 from the Bureau of Analyzed Samples Ltd., England and 500, C1123 and 1275 from National Institute for Standards and Technology (NIST). These CRMs are the ones used by the EAF and they were selected in order to be suitable for a range of projects with very different compositions of copper alloys. The limits of detections were calculated as three times the relative deviation of ten measured blanks (Fig. 12). For a more detailed description of the methodology used see Dussubieux (2019).

**RELATING THEORY TO METHOD**

Each of the methods described above sheds light on one or more steps in the process of forming a copper object. By combining the methods together, I am able to
reconstruct the entire *châine opératoire* used to create the objects under study. The *châine opératoire* used to create a finished bronze object from copper ore is complex and it involves many steps, but it can be roughly broken down into mining, smelting, working, use, and deposition (Fig. 14). In the section that follows I outline which methods pertain to which steps of production, focusing on mining, smelting and working, which I further break down into refining, alloying, casting, and working.

**MINING AND ORE PREPARATION**

The metallurgical *châine opératoire* begins with prospecting and mining to extract metal ore. Mining was not a major focus of this study, since, as mentioned in Chapter 2, evidence for EIA mining in Cyprus is very scant, and there is no copper ore on Crete. Because the provenance of the ore was not a major research question of this study, Lead Isotope Analysis was not included in the methodology. It is therefore impossible to attribute the metal samples to a specific ore.

Nevertheless, the results of the SEM-EDS and the LA-ICP-MS can shed some light on characteristics of the ore bodies used. By identifying chemical composition of inclusions in the metal, SEM-EDS analysis can indicate whether sulfide or oxide ores were used. While this cannot be taken as a definite indication of source, Cyprus, for example, contains predominantly sulfide ores. Furthermore, the relative amounts of trace elements detected in LA-ICP-MS, such as the ratio of arsenic to antimony, can be used as indications of the specific ore body used. Since the two elements have similar properties.

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53 This is only a brief overview of the copper production process, for a more thorough review see Craddock (1995), Hauptmann (2007), and Tylecote (1992).
and are lost in proportional amounts during smelting and reheating, the ratio stays the same in metals from the same ore body.

Once the ore has been mined, it is typically beneficiated through a process of crushing and sorting in order to remove as much of the gangue (unwanted minerals in the ore) as possible and prepare a fairly standard ore charge. At this stage, roasting is sometimes carried out in order to make the ore more friable, to drive off water molecules from the crystal structures, or to chemically convert sulfides, chlorides, and carbonates to oxides.

SMELTING AND REFINING

The ore was then smelted in order to extract raw metal from the ore. Smelting operations were quite variable, but typically included placing the beneficiated ore, fuel (charcoal), and flux (materials used to lower the melting point and increase viscosity) in a furnace. The exact shape and dimensions of furnaces were highly variable and often they are difficult to reconstruct, since furnaces were often destroyed in the smelting process (Craddock 1995, 169). As the ore heated up and liquified, the metal sunk to the bottom of the furnace, and the unwanted minerals from the ore were removed as slag. Air was supplied to the furnace through tuyères, clay tubes that ran through the furnace wall.

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54 Crushing is usually carried out near the mines, using handheld stone hammers. Sorting can be done in many different ways, from sorting by hand to more complex washing operations (Craddock 1995, 156–66).

55 The reactions that occurred inside the furnace can be considered in four zones. In the upper zone the charge was dried and heated. It then sank to the combustion zone directly in front of the tuyère, where two primary reactions occurred. First, the combustion of the fuel provided the thermal energy required for smelting and generated carbon monoxide which pervaded the mineral and reduced oxides to metal. Second, the reaction of silica and metal oxides created liquid slag, which contained gangue minerals, flux, fuel ash, and parts of the furnace wall. Slag could either be tapped out of the furnace or it could remain inside. Below the reaction zone, the metal coalesced into droplets which sank through the slag to the bottom of the furnace. After the process was complete and the furnace had cooled it was possible to retrieve the irregular lumps of metal from the bottom of the furnace (Craddock 1995, 199–201).
connecting the interior to bellows on the outside.\textsuperscript{56} The amount of oxygen that entered the furnace determined how oxidizing or reducing the smelting atmosphere was - the more oxygen there was, greater the loss of more volatile elements such as arsenic and antimony.

Metal fragments produced from initial smelting still had to undergo a process of refining. These fragments were typically remelted to combine the pieces and to remove impurities (Craddock 1995, 202–4). Because an open crucible is a very oxidizing atmosphere more reactive elements such as arsenic, antimony, and iron would oxidize and either evaporate or form a layer on the surface, which could then be removed.

By looking at the levels of trace elements such as arsenic, antimony, or iron in the results of the LA-ICP-MS, it is possible to reconstruct some characteristics of the smelting and refining process. Higher levels of these elements could indicate a more reducing smelting atmosphere, in which volatile elements are retained or a less thorough refining stage to remove impurities.

ALLOYING

After the copper was refined it could be mixed with other metals to form an alloy. In this study, copper was either left unalloyed or it was combined with tin to make bronze. The amount of tin included in the alloy could vary considerably. A “classic” tin bronze has around 8–10% tin, because metal containing this proportion of tin can be easily cast and also work hardened. Using higher amounts of tin can make the metal more

\textsuperscript{56} There are other ways to supply air to the furnace, but in the EIA eastern Mediterranean tuyères were the most common. Tuyères could vary in shape depending on what type of bellows they were connected to or what type of metal they were used for. In most cases it is difficult to know how many tuyères might have been attached to a single furnace. For a basic overview of tuyères see (Craddock 1995, 185–89).
brittle and difficult to work. Both the SEM-EDS and the LA-ICP-MS both provide percentages of the alloy components.

CASTING AND WORKING

Once the desired alloy was obtained, the bronze was formed into the desired shape by some combination of casting, hammering, and annealing. The liquid metal could be poured into a mold made of sand, clay, or stone. By investigating the microstructure of the samples through microscopy, observations can be made about the frequency and size of porosities. Many large porosities reflect a less careful refining process.

Finally, the objects could be hammered or “worked” into the desired shape. Once the metal had been heavily worked it would become brittle and would have to be “annealed” through a process of reheating so that the metal would regain its ductility. The microstructure of a metal, particularly in its etched state, reflects this stage in the forming process. The presence of straight annealing twins in the grains indicates that annealing was the last stage in the process, whereas bent annealing twins and slip lines indicate that hammering was the final stage.

CONCLUSION

I combine a theoretical perspective, which incorporates châine opératoire, technological style, and communities of practice, with a methodology that is firmly grounded in archaeological science. Such an approach is not unusual in African, Asian, and American archaeology, but it is rarely applied to Mediterranean archaeology. Although the adoption of Cypriot bronze and iron working techniques in the Aegean
during the Early Iron Age has been the subject of much scholarly attention, it has not been approached from this angle.

The purpose of this chapter has been to lay out the materials, methods, and theory, which form the basis of my study of the Early Iron Age bronze and iron objects from the sites of Kourion, Lapithos, and Vrokastro. These objects were investigated by means of an integrated analytical program, which included both macroscopic and microscopic analysis. The results of both optical and chemical analyses were used to form a detailed sequence of operations for each object, utilizing the framework of châine opératoire. For example, chemical testing (SEM and ICP-MS) provided information about the smelting and alloying process, and optical microscopy and X-radiography gave insight into the formation of the objects through casting or hammering. These sequences of operation are used to identify key moments of technological choice, where various communities of practice diverge in their preferred techniques. Similarities and differences in technological styles are used to investigate the relationships between communities of practice.

The study ultimately seeks to understand how technological knowledge is transmitted within and between communities of practice, by asking questions such as: (1) which elements of production are particularly mobile or static and why, (2) in which physical and temporal spaces is information shared between craftsmen from different communities, (3) what factors influence the decision to adopt or reject a foreign trait or a new innovation, (4) what are the specific mechanisms for imparting knowledge and teaching skills and how do those mechanisms differ when the learning takes place within or between communities, and (5) what manner of contact (direct, indirect, momentary,
sustained) is necessary to foster the cross-cultural sharing of crafting techniques. Chapter 4 addresses these questions using the case of Cypriot and Aegean metallurgical practices as its starting point. In it, I apply the methodological and theoretical frameworks put forth in Chapter 3 to the dataset in question and present the results and conclusions of that undertaking.
CHAPTER 4: RESULTS AND DISCUSSION OF INVESTIGATING
METALLURGICAL TECHNOLOGY AT EARLY IRON AGE KOURION,
LAPITHOS, AND VROKASTRO

This chapter details the results of the scientific testing of artifacts from Kourion (Episkopi-Kaloriziki) and Lapithos (Upper and Lower Geometric cemeteries) on Cyprus and Vrokastro on Crete held in the collection of the Penn Museum and discusses their implications. The purpose of this study is to identify communities of metal smiths active at EIA Kourion, Lapithos, and Vrokastro based on their technological signature and to investigate the possibility of sharing technological knowledge between Cypriot and Aegean metalworking communities.

I begin with an overview of the testing results by object type (fibulae, pins, needles, rings, bowls, nails, tripods, knives, daggers, and spearheads). The results of the visual analysis, x-radiography, metallography, SEM-EDS, and LA-ICP-MS testing are recorded for each of these object types and are used to draw conclusions about the production of the objects. The second section of the chapter presents an overview of chaîne opératoire used to construct the objects and a consideration of the communities of practice and technological systems in operation in the three sites under study.

RESULTS
FIBULAE
Many typologies of Cypriot and Greek fibulae have been proposed over the years (Myres and Ohnefalsch-Richter 1899; Blinkenberg 1926; Stronach 1959; Birmingham 1963; Sapouna-Sakellarakē 1978; Giesen 2000). Recounting them in detail is outside the scope of this dissertation, but I will refer to the typological categorization of objects where relevant. I have found these typologies valuable in grouping objects for initial assessment, but I mainly focus on the more minute differences between objects of the same type that might reflect local or individual working techniques.

The bulk of the scholarship has focused on typological categorization, dating, and function of fibulae, but in some discussions working techniques are also present (in particular see Giesen 2000). Although there is some variation based on the type of fibulae, it is usually agreed that most fibulae would have been initially cast and then worked into shape. The initial casting was likely done in closed molds made of sand, ceramic, or stone. Unfortunately, not many molds have been found that might shed light on this aspect of the formation process. This is in large part because the majority of our evidence for the EIA comes from burials, rather than settlement contexts. Giesen suggests that sand molds are the most likely, pointing to a clay model of a fibula, from which a sand mold might have been formed (Giesen 2000).

The fibulae were then worked into their final shape. The bows of the fibulae, especially the more elaborately decorated ones, were probably minimally worked, whereas the arms would have been hammered to form a wide, flat bottom and then turned.

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57 For a more comprehensive discussion of molds in the ancient Mediterranean, see also Craddock et al. (1997). For a discussion of the impact of sand, clay, and bronze molds on the microstructure of copper alloys see Ottaway and Wang (2004).
up to form the clasp. The needles would also have been hammered around a dowel or rod to form a spring and hammered to a point. In some examples the pin is attached separately, which would have required a significant amount of planning and skill (Giesen 2000). In addition, many fibulae featured decorated beads on either side of the bow and sometimes on the arm. The incisions and decorative markings on and around the beads would often have been added after casting, likely using a chisel. Giesen points out that some of the incised lines form a continuous loop, suggesting the use of a lathe, while others appear to have been done by hand (Giesen 2000).

Visual Analysis (Figs. 15-35)
Most of the Cypriot fibulae included in this study fall into a very common Cypriot type: the asymmetrical, D-shaped fibula (32-27-793, 32-27-823, 32-27-1047, 32-27-1201, 49-12-6, 49-12-490, 49-12-722, 49-12-726, 49-12-912, 49-12-922, 49-12-969, 49-12-985, and 49-12-988, Figs. 15-27). This type is classified as SCE Type II and Giesen type VII. This is by far the most commonly found fibula type across Cyprus. They can be found with two or three beads. The two-bead variant has a swollen bow surrounded by a bead on either side and a plain arm that reaches down to the clasp. The three-bead variant has an additional bead on the arm.

It can be difficult to determine the number of beads on each fibula due to heavy corrosion or partial preservation of the fibula. X-radiography can, in some cases, reveal a third bead that is hidden by corrosion. Fibulae 32-27-823, 32-27-1047, and 32-27-1201 from Lapithos as well as 49-12-969, 49-12-985, and 49-12-988 from Kourion can all be identified as three-bead variants. 49-12-490 and 49-12-6 from Kourion can be identified as two-bead variants. The remaining fibulae, including 32-27-793 from Lapithos and 49-
12-722, 49-12-726, 49-12-912, 49-12-922 from Kourion, cannot be assigned to a subtype since they are only partially preserved.

These D-shaped, asymmetrical fibulae can also be analyzed in relation to the decoration on their beads. Many of the fibulae are too corroded to determine anything about the surface decoration. Of the remaining fibulae, however, all of the fibulae from Kourion have incised lines running along the height of the beads (49-12-6, 49-12-922, 49-12-969, 49-12-985, and 49-12-912). 49-12-969 and 49-12-985 are particularly similar since the beads are similar in size and the incisions run the entire length of the bead. The fibulae from Lapithos, on the other hand, are more likely to be decorated with bands running around the diameter of the fibula on either side of the beads. 32-27-793 has raised bands on either side of the beads, but no decoration on the beads themselves. 32-27-1047 and 32-27-1201 also have bands on either side of the beads, although they are too corroded to determine if the beads were also decorated, and they are more easily seen on the x-rays. 32-27-823 has many shallow incised bands on either side of the beads along with shallow incised line decoration on the beads themselves. All of this decoration was likely done with chisels after the fibula was cast. These variations in decorative technique may reflect regional workshop styles.

One fibula from Lapithos (32-27-802, Fig. 28) and one from Kourion (49-12-919) are two-bead variants of the asymmetrical, D-shaped fibulae, but they belong to a specific subtype that are characterized by very long, thin bows. The one from Lapithos is decorated with two bands on either side of the beads, which is fairly characteristic of some other Lapithos examples. The Kourion example, on the other hand, features line decoration on the bead, which resembles 49-12-6.
Only one fibula from the Cypriot examples included in this study is not an asymmetrical, D-shaped fibula (49-12-721, Fig. 29). Instead it displays a plain, round bow with no visible decoration.

The fibulae from Lapithos come from four tombs dating from the CG II to the CA I period. 32-27-793 and 32-27-802 are both from Tomb 73, which dates to the CG II-III period. This is interesting because 32-27-802 is of a fairly different subtype than the rest, but it was found together with a more typical example. 32-27-1047 is from a different tomb of the same period, Tomb 80. 32-27-1201 is the earliest, from Tomb 88 CG II. And 32-27-823 is the latest from Tomb 79, CG III-CA I. It is of a late sub-type of the D-shaped fibula.

The fibulae from Kourion are from fewer tombs that are farther apart in time. The earliest fibulae are 49-12-721, 49-12-722, 49-12-726, which are all from Tomb 25 (CG IA). There are different types mixed together in this group. Not much can be said about the details of the decoration, however, since they are all very corroded. 49-12-988 is from Tomb 36 (CG IB). The latest fibulae include 49-12-912, 49-12-919, 49-12-922, 49-12-969, 49-12-985, which are all from Tomb 33 (CG II). These all display decorative lines on the beads, but this could be a result of the fact that they have all been chemically cleaned in conservation, so the decoration is more visible.

In contrast to the Cypriot examples, the fibulae from Vrokastro are very diverse and distinct. The majority of the fibulae from Vrokastro are unique within the sample. MS4756 (Fig. 30) is a symmetrical bow fibula with bead and reel decoration on either side of the bow. MS4757 (Fig. 31) has a large biconical bead at the center surrounded by elaborate bead and reel decoration on either side. MS4760 (Fig. 32) is only partially
preserved so it is difficult to identify its original shape. MS4622 (Fig. 33) has four large round beads on the bow. The elaborate nature of the decoration on these fibulae suggests that they were all probably made predominantly by casting with only minimal finishing work done to the bows. The clasps, springs, and pins would still have needed to be hammered, and MS4756 provides a good example of an extensively hammered lower foot and upper clasp.

Two of the fibulae (MS4758 and MS4618, Figs. 34-35) have twisted wire bows. These two fibulae were likely made by casting a square wire and then twisting it in several rotations and bending it into a semi-circular shape. The process of twisting the wire marks these two out from the other fibulae that have already been discussed. Interestingly, while MS4618 appears to be very evenly twisted, just above the clasp of MS4758 there is an area with many twists that are not evenly distributed. This might suggest some differences in smithing skill.

X-Radiography

On the whole, the x-radiography supports the conclusion that the majority of fibulae were cast and that their feet, clasps, springs and pins were subsequently hammered into shape. The bows tend to be fairly consistent in density and contain some small porosities, which are typical of cast metal. The feet and clasps often have a more mottled appearance that is produced by hammer marks (see in particular 32-27-1201, 49-12-490, 49-12-722, 49-12-988, and especially MS4756). Unfortunately, the small surface area of feet makes it difficult to discern clear patterns resulting from the direction of working.
The fibulae appear to be fairly evenly cast, without any major flaws, large porosities, or dramatic differences in density throughout the objects. Where there are areas of low density, they tend to concentrate near the edges of the beads (as in the case of MS4757). This would be a difficult area of the mold for the molten metal to fill. There are several small porosities, which form when gas bubbles in the molten metal are trapped as the metal cools. On the whole these porosities are very small, however, which reflects a careful casting process.

One fibula (32-27-793) displays a potential casting flaw that has been mended. The surface of the bow has a crack where the molten metal seems not to have filled in the full mold. In addition, a tube is visible inside the bow of the fibula. It seems likely that it was part of the pin, which was added separately, instead of being cast together with the body of the fibula.

Microscopy (Figs. 36-65)

Samples from nine fibulae were analyzed as part of this study. Six of the samples were MASCA samples taken from fibulae from Vrokastro (MS4622, MS4756, MS4757, MS4758, MS4759, and MS4760, Figs. 36-55), two were taken from Kourion fibulae (49-12-721 and 49-12-988, Figs. 56-62), and one was taken from a Lapithos fibula (32-27-1201, Figs. 63-65). The samples were taken from different areas of the fibulae (the bow, the spring, the pin, etc.) and the microstructures reflect that variation.

Three of the samples from Vrokastro were taken from decorated bows (MS4622, MS4757, MS4760). Each of the bows is unique in its shape and decoration, but the microstructures display some similarities. Namely, they all contain annealing twins but very few slip lines, indicating that they were all annealed during their production but not
extensively worked. The most likely explanation for this is that the entire fibula was heated in order to anneal the spring, pin, and clasp of the fibula, which required extensive cold working. Although the decorated bow did not need to be shaped by hammering, it was nonetheless heated along with the rest of the fibula. In fact, MS4760, was only partially annealed. The core of the sample retains its as-cast, dendritic structure, suggesting that the interior of the bow never got hot enough to alter the structure. From Kourion, 49-12-721 was taken from a plain bow, which has been worked. There are heavy slip lines visible, especially around the edge of the sample, but the last step appears to have been annealing.

The remaining samples come from the pins and springs of the fibulae and most display evidence of cycles of working and annealing the metal into its final shape. MS4756 was taken from the spring of the fibula and its microstructure reflects very heavy working to form the circle. The grains are very small, and the inclusions are elongated in the direction of working. 49-12-988 comes from the area directly above the spring of the fibula. Although only ghost structures are visible in the microstructure due to heavy corrosion, the object appears to have been cold-worked and annealed. 32-27-1201, which comes from the pin, also shows signs of hammering and annealing. The structure is quite similar to the needles from Lapithos, which would have been worked in much the same way. MS4759, on the other hand, is from the pin of the fibulae, but does not show evidence of hammering. This suggests that although the spring must have been hammered into shape, the pin itself was in fact not worked.
Although the microstructures of the decorated bows from Vrokastro are all fairly similar, their chemical compositions are not. First, differences in the composition of inclusions suggest that different ores were used. The chemical composition of these sulfides reflects the minerals present in the ore body, and in this case, they are quite varied. MS4622, MS4756, MS4758, and MS4760 contain sulfide inclusions. The inclusions in MS4760 contain only sulfur and copper. The inclusions in MS4756 also contain selenium and the inclusions in MS4622 and MS4758 contain iron in addition to sulfur. MS4757 and MS4759, on the other hand, do not contain any sulfide inclusions.

The Vrokastro fibulae also display differences in the intentional alloys used in their formation. MS4622, MS4756, MS4757, and MS4760 are all classic tin bronzes with close to 10% tin, whereas MS4758 and MS4759 are low-tin bronzes with 3-5% tin. Furthermore, MS4622, MS4758, and MS4759 contain lead inclusions, while the others do not. Lead may have been added intentionally to increase the fluidity of the metal during casting, which would have made it easier for the molten metal to fill all the spaces in a complex mold. It is also possible that the lead originated in the ore and is therefore an unintentional addition.

The Cypriot fibulae are similar in their alloying practices. Both 32-27-1201 and 49-12-721 have close to 10% tin (8.3 +/- 0.2% and 10.2 +/- 0.2% respectively) and neither contains lead inclusions. 49-12-721 from Kourion has iron sulfide inclusions, however, whereas 32-27-1201 from Lapithos appears to have no inclusions at all. The

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58 There was some machine error running sample MS4759, so this number is taken from the LA-ICP-MS results.
lack of sulfide inclusions is very unusual in the sample. In fact, it is the only sample that can be definitively said to have no sulfide inclusions. This could be the result of using an oxide ore, or it could be a result of dead roasting the ore for longer to drive off all of the sulfur. 49-12-988 is a tin bronze, but it is too corroded to present qualitative data.

LA-ICP-MS

The results of the LA-ICP-MS confirm that the fibulae from Vrokastro are quite heterogeneous with respect to their source and technological history. VK4756, in particular, has unusually high iron content (1.91%) as well as high selenium, and tellurium. These elements are all enriched in the sulfide inclusions, and the high levels are likely the result of the frequent elongated inclusions in the sample. The combination of iron, selenium, and tellurium may point to the use of a Cypriot ore. VK4758 is notable for its high antimony to arsenic ratio content, which may indicate that the ore used for this fibula was higher in antimony than the ore used for the other fibulae.

NEEDLES AND PINS

Greek pins have been the subject of numerous dedicated studies and there are several different typologies (Jacobsthal 1956; Desborough 1972; Kilian-Dirlmeier 1984). The typology for Cypriot pins comes from the SCE publications, which classifies the pins into four main groups and subtypes within those groups (Gjerstad 1948). The scholarship has focused chiefly on the stylistic influences of the pins and their function, rather than on how they were produced. Pins could be bronze, iron, or bi-metallic, and often featured ivory or bone attachments. The wide variety of pin types means that there is not a standard means of production.
There have not been extensive studies of needles, likely because there is not much variety in form. The SCE divides needles into three subtypes depending on how the eye of the needle was formed: punched, folded, or unclear/broken. The punched examples were made by casting a rod, hammering one end flat and punching a hole through it. The folded examples, on the other hand, were likely made by hammering the top edge flat and folding it over to form the eyelet.

Visual Analysis (Figs. 74-108)

The sample includes three pins from Kourion and three from Vrokastro. The three pins from Kourion are each of a completely different type. One pin is fairly thick and has an ivory attachment at the head (49-12-724, Fig. 74). One has an ovular bead and decoration at the head (49-12-989, Fig. 75), and the last is an iron pin with a large bronze ball on the head (49-12-948, Fig. 76). The working techniques for each of the pins would have been fairly different. First, 49-12-989 appears to have been cast as one piece, whereas the other two were constructed from multiple materials and would therefore have involved a more complex assembly process. The central area of 49-12-724 is much denser and heavier, and it is more yellow in color. This might be due to differential corrosion processes in the tomb, but it could also be composed of a metal with a different composition.

The three pins from Vrokastro are more similar to each other. MS4619 and MS4621 both appear to be short needles with four small spheres on the head (although MS4621 is only partially preserved) (Figs. 77-78). They are similar enough that it seems possible that they were cast in the same (or very similar) molds. MS4621 is also bent into a semi-circular shape. It is unclear whether this was intentional during the use-period of
the object, or whether it was post-depositional. Finally, MS4620 (Fig. 79) is a shorter pin with a cube at its head. Like the other two pins, there do appear to be some beads beneath the cube, but they are difficult to make out due to corrosion and cleaning.

The needles included in this study come from Cyprus (11 from Lapithos and 5 from Kourion). All the needles are very similar in their overall method of manufacture, although there are some differences in the details. The eyelets all appear to have been made by punching a hole through the rod, rather than by folding over the tip of the needle. The differences come in the length of the needle and exact shape of the hole punch.

The most noticeable difference between the needles is their varying length. Unfortunately, most examples are fragmentary and their exact length cannot be reconstructed. Three complete examples from Lapithos (32-27-652, 32-27-795, and 32-27-1184, Figs. 80-82) vary in length from 5.5cm to 9cm long. Although there are no fully preserved examples from Kourion, there are definitely still differences in length. The one nearly complete needle 49-12-853 (Fig. 83) is only 7cm in length, but 49-12-545 (Fig. 84) is at least 9.2cm.

Unfortunately, because the sides of the eyelet are thin and vulnerable to corrosion and breakage, most examples are broken halfway through the eyelet. In these cases, it is difficult or impossible to say anything about the shape of the eyelet hole or the amount of flattening that occurred. Needles in this category include 49-12-773, 49-12-982, 49-12-986, 32-27-651, 35-27-721, 32-27-734, 32-27-735, 32-27-744, 32-27-780, 32-27-792, 32-27-1195, and 32-27-743 (Figs. 85-96).
Many of the pins and needles in the sample are heavily corroded and only preserved in fragments. As a result, in many cases it is impossible to tell the pins apart from the needles. These examples will not be discussed in detail, since they cannot be ascribed to either group. Objects which could be pins or needles include 49-12-444, 49-12-1058, 32-27-661, 32-27-611, 32-27-635, 32-27-741, 32-27-742, 32-27-745, 32-27-796, 32-27-820, 32-27-1150, and 32-27-1196 (Figs. 97-108). A list of these objects along with their measurements and descriptions can still be found in Table 1.

X-ray Analysis
The majority of the needles and pins were heavily corroded, without much intact metal remaining in the objects, and thus it is difficult to draw any substantive conclusions about working techniques based on the x-rays. The x-rays were useful, however, in identifying which objects would be suitable for destructive testing. Furthermore, in some cases the x-rays allowed for a definite identification of a fragment as a needle, based on the presence of an eyelet, which was hidden by corrosion but visible in x-rays. In some of the larger and better-preserved pins, there are some small porosities in the cast areas (49-12-989 near the bead, and 49-12-724 in the center).

Microscopy (Figs. 109-131)
Samples were taken from 8 needles and pins from Lapithos (5) and Kourion (3). Six of the objects sampled are certainly needles, whereas the remaining two could be from either needles or pins since the heads are not preserved (32-27-745 and 32-27-1196, Figs. 109-114). Unfortunately, several of the samples are corroded. The examples from Kourion in particular are not well preserved, making it difficult to draw definitive conclusions about their manufacturing history. Samples 32-27-792, 49-12-545, 49-12-982, and 49-12-986 (Figs. 115-124) were heavily corroded, so that only a small amount
of intact metal was visible. In order to preserve the remaining metal for chemical analysis, these samples were not etched.

Two of the needles from Tomb 88 at Lapithos display remarkably similar working techniques (32-27-1195 and 32-27-1196, Figs. 125-128). The microstructures of these samples are characterized by a distinctive, swirling corrosion pattern that outlines the lamina created by working the metal into a rounded shape. There are some subtle variations in the corrosion patterns: 32-27-1195 shows more elongated and rounded lamina, whereas the lines on 32-27-1196 are shorter and run more directly in toward the center of the object. This may reflect the direction of working. Both needles appear to have been worked into shape through a cycle of hammering and annealing. Strain lines from the hammering process are apparent, but the annealing twins are straight and cut through the strain lines, suggesting that annealing was the last step in their production. The last anneal may have been short, since the strain lines are still visible. Both needles are also characterized by frequent, large porosities and infrequent inclusions.

Pin 32-27-735 (Figs. 129-131) from Tomb 66 at Lapithos is very similar to the first two. It displays the same characteristic corrosion pattern as well as slip lines covered by annealing twins. The grain size is considerably smaller, however, and the porosities are flatter and aligned in one direction. This may indicate that it was more heavily worked than the other two samples, which seems plausible since it appears flatter and more ovular in section macroscopically.

Pin 32-27-745 from Tomb 67 at Lapithos is quite distinct from the first three. Instead of displaying the swirling corrosion pattern, it is characterized by extensive intergranular corrosion around the edges of the sample. There are still frequent, large
porosities, but they are accompanied by more frequent inclusions. The microstructure displays worked, deformed grains with bent twin lines, indicating that hammering was the last step in the production process. In particular there are localized areas of extreme deformation running through the samples, which is very distinct from the other needles. The last sample from Lapithos, 32-27-792, is heavily corroded so not much can be said about its microstructure.

Samples 49-12-545 and 49-12-982 from Kourion were heavily corroded, so that only a small amount of intact metal was visible. Nevertheless, there are noticeable similarities between them that may set them apart from the Lapithos examples. First, they have considerably fewer and smaller porosities. Second, they have more frequent and larger inclusions. Finally, the grain sizes are considerably smaller than the Lapithos examples, suggesting that they were either more extensively hammered, or not annealed for as long a time. Sample 49-12-986 is entirely corroded, but some ghost structures are visible. The grains are much larger than in the other examples from Kourion, but the elongated inclusions show that it has been heavily worked.

In summary, all the pins and needles were extensively worked through cycles of hammering and annealing. Three samples from Lapithos show marked similarities in the way they were worked (32-27-735, 32-27-1195, and 32-27-1196). They all display lamina which were likely formed by hammering the object while twisting it in a circular direction, and they were all subjected to a final, brief annealing. The samples from Kourion are very corroded, but the small grain size suggests that they were hammered more extensively or that they were not annealed for as long. In either case, there appears to be a difference in the way the Lapithos and Kourion needles were produced.
SEM-EDS (Figs. 132-137)

The needles and pins display marked similarities in their chemical composition. They all contain iron sulfide inclusions, which likely indicates that the copper was smelted from iron-rich ore such as chalcopyrite or bornite. 32-27-735 is distinguished from the others by the small amount of selenium present in the inclusions. Although this sample is one of only two where selenium was detected in the SEM-EDS results, the ICP-MS results did not find particularly high selenium content in this sample, suggesting that the high selenium content was the result of random variation and is attributable to the location choice for SEM-EDS testing. All of the pins and needles from both sites also have lead inclusions (see below).

The major differences in the chemical composition of the needles come from the amount of tin used in the alloy. The three needles from Lapithos that are very similar in their microstructure are also similar in their chemical composition (32-27-735, 32-27-1195, and 32-27-1196). They are all classic tin bronzes of close to 10% tin. The similarities between these three needles, and especially between 32-27-1195 and 32-27-1196, are very striking, especially considering their similar microstructures. Another needle from Lapithos, 32-27-745, has a lower tin content (4.2 +/- 0.1%). The needles from Kourion are more corroded than those from Lapithos. On the whole, however, they appear to have lower tin contents. 49-12-545 and 49-12-982 have 4.2 +/- 0.1% and 6.7 +/- 0.1% respectively. Finally, 32-27-792 and 49-12-986 are tin bronzes, but they are entirely corroded, so an accurate quantitative reading cannot be given.

LA-ICP-MS

The pins and needles from Lapithos form a fairly cohesive group. They all have noticeably high levels of lead in comparison to the other objects (all >1%). This lead
might have been intentionally added as an alloy in order to increase fluidity during casting. Pins and needles are not difficult to cast, however, so the addition of lead would not seem particularly necessary for this object type. Another possibility is that a leaded bronze object was melted down and the metal was recycled to make the needles. If they were recycled, they might also be expected to have low arsenic and antimony levels, since those elements would have been preferentially lost during resmelting. They do in fact have somewhat lower arsenic than the other samples from Lapithos, but the pattern is less evident with the antimony.

Samples 32-27-1195 and 32-27-1196 in particular have nearly identical chemical compositions, confirming the results of the microscopy and SEM-EDS. These two needles can almost certainly be attributed to a single community of practice, if not a single smith. They were probably made at the same time from the same batch of copper-alloy. 32-27-735 is similar in composition, but not identical. It is distinguished primarily its higher lead content (3.24%, the highest in this study) as well as its higher iron (0.279%) and selenium (72.9 ppm). The lead could be the result of intentional alloying, whereas the iron and selenium reflect the more reducing environment of the smelt. 32-27-745 is also similar in most elements, but it is noticeable for its somewhat lower arsenic and especially antimony levels, which might indicate that it was smelted in less reducing conditions or that it was re-melted.

The needles from Kourion (49-12-545 and 49-12-982) have considerably higher iron than the Lapithos samples, indicating that the ore was smelted in a more controlled, reducing atmosphere. The major difference between them is that 49-12-545 has more lead (0.47%) than 49-12-982 (0.17%). 49-12-545 has higher levels of arsenic and
antimony than 49-12-982, but the ratio of the two elements is similar, suggesting that they could come from the same ore source, but have been smelted under different conditions.

RINGS

To my knowledge there has not been a dedicated study on Cypriot rings. A typology is provided in the SCE, but it does not cover the full range of types that have been found to date (Gjerstad 1948).

*Visual Analysis (Figs. 138-154)*

The rings from Kourion and Lapithos form an interesting counterpoint to the other object categories, because there is such a distinct difference between the two sites. Several different types of rings are found at each site, but specific types are largely confined to single sites. In fact, in several cases, all of the examples of a type were found within the same tomb. Overall it is noticeable that the rings from Kourion are primarily cast and not extensively shaped by hammering, whereas the Lapithos rings rely far more heavily on hammering.

There are two ring types that show up fairly frequently at Lapithos. One is a form of spiral ring, made from a wrapped flat metal sheet. The metal is tightly wound, leaving only a small gap between the wrapped edges of the sheet. This type of ring appears to have been made by hammering out a sheet of metal and tapering the edges to rounded points. Then the metal sheet was hammered around a round dowel or rod in a spiral pattern. Most examples make one and a half rotations, but one example makes two full rotations (32-27-1202A, Fig. 138). Examples include 32-27-1197, 32-27-1198, 32-27-
1200, 32-27-1202A, and 32-27-1202B (Figs. 138-141). Notably these were all found in Tomb 88, which dates to the CG II period.

The other type of ring has been catalogued as a “toe ring.” They consist of very thin, wide strips of metal that are loosely curved and are also twisted from side to side. It is not clear exactly what shape these rings would have formed, since none of them has been preserved intact, but they do not appear to form closed circles that could be worn as actual rings. These are much thinner and more irregularly shaped than the first type and were likely shaped by more extensive hammering. These include 32-27-797, 32-27-798, and 32-27-799 (Figs. 142-144). They all come from Tomb 73, which dates to the CG II-III.

In addition, there are two rings from Lapithos that do not fall into either category. 32-27-1048 (Fig. 145) is also made from a flattened metal sheet, but it is only roughly shaped and does not form a complete, closed circle. It was found in Tomb 80, which dates to the CG II-III period. 32-27-733A (Fig. 146) is a simple ring that is thin and round in section. This ring is more likely to have been cast as a ring and perhaps hammered in finishing. It was found in Tomb 64, which dates to the CA IA period.

There are several examples of a discernable “type” of ring found at Kourion. These rings are wide, thick bands with no visible decoration. They are all close to 2.5 centimeters in diameter. They appear to have been cast as circular rings, although they may also have been lightly worked as part of their finishing. Examples of this type include 49-12-719, 49-12-720, and 49-12-723 (Figs. 147-149). They were all found in Tomb 25, which dates to CG IA.
The other rings do not fall neatly into a category, although they do share certain similarities. 49-12-1004 (Fig. 150) is a wide flat strip of metal roughly shaped into an irregular oval. The two edges do not actually touch or join. 49-12-1005 (Fig. 151) on the other hand appears to have been cast as a wide flat band, where the edges of the strip are overlapping. 49-12-1023 (Fig. 152) is round in section and might have been cast as a circular ring. 49-12-1024 (Fig. 153) is harder to understand: it is also round in section, but the width varies throughout the circle so that it resembles a crescent. It might be an earring rather than a ring. These four rings are from Tomb 36 and they date to the CG IB. Finally, 49-12-544 (Fig. 154) is a very corroded circular band. This ring is from Tomb 23, which dates to the CG II.

**X-Radiography**

Many of the rings did not produce useful x-ray data, for several reasons. First, the shape of the rings and their fragile condition necessitated that they must be x-rayed from the side, which is not an optimal angle, particularly for spiral rings. For example, the x-rays of 32-27-1197, 32-27-1198, 32-27-1200, and 32-27-1202 communicate very little valuable information. Second, many of the rings were made of very thin metal and they are now entirely corroded with no intact metal left. This was the case with 32-27-797, 32-27-798, and 32-27-799.

The thicker, cast rings were the only ones that could be productively x-rayed. 32-27-733A appears to be evenly cast with no noticeable areas of low density, porosities, or hammer marks. Similarly, 49-12-719, 49-12-720, and 49-12-723 all appear to be fairly evenly cast and do not display any hammer marks, confirming suspicion that they were just cast. There are some areas of low density, but they seem to be related to corrosion...
rather than uneven casting. 49-12-1005 is less consistent and there are fairly large areas of low density.

*Microscopy (Figs. 155-162)*

Samples were taken from one ring from Lapithos (32-27-733, Figs. 155-156) and two rings from Kourion (49-12-544 and 49-12-1005, Figs. 157-162). Two of the rings are macroscopically similar, with thin, round or ovular bands (32-27-733 and 49-12-544), while the third is much smaller and has a much thicker, rounder band (49-12-1005). This distinction was also clear microscopically, where 32-27-733 and 49-12-544 show signs of hammering and annealing. Unfortunately, the sample from 49-12-1005 is heavily corroded, making interpretation difficult, but some ghost structures remain. This ring appears to have been left in an as-cast state.

The microstructure of ring 32-27-733 from Lapithos has extensive intergranular corrosion, which makes it difficult to identify inclusions, which are normally congregated at grain boundaries. The grains appear to be recrystallized, indicating that annealing was the last step in a cycle of hammering and annealing. This is similar to the pins and needles from Lapithos, which also displayed final annealing. The sample from ring 49-12-544 from Kourion, on the other hand, has more inclusions and more porosities. It appears to also have been worked through a cycle of hammering and annealing, but the grains are lightly deformed. This may indicate either that the ring was not fully annealed after hammering, or that it was lightly worked after annealing. In either case, it appears to have undergone a slightly different formation process than 32-27-733.
The two macroscopically similar rings (32-27-733 and 49-12-544) also have noticeable differences in their chemical composition. Unsurprisingly, they do not appear to be from the same ore, since 32-27-733 contains sulfide inclusions without iron and 49-12-544 contains sulfide inclusions with iron. It is difficult to compare the amounts of tin in each because 32-27-733 from Lapithos and 49-12-1005 from Kourion are both quite corroded. Only 49-12-544 from Kourion, can be used for quantitative results, and it contains a “classic/typical” amount (9.3 +/- 0.1%). They are similar, however, in that neither includes added lead. The last sample, 49-12-1005 from Kourion, is a tin bronze, but it is entirely corroded so an accurate quantitative reading cannot be given.

Two of the rings were very corroded (32-27-733 and 49-12-1005), so reliable quantitative results can only be achieved for Kourion ring 49-12-544. It contains noticeably high levels of silver, bismuth, arsenic, and antimony. This might indicate that a higher percentage of fahlores was used in the smelt (Pernicka, Lutz, and Stöllner 2016).

Cypriot bowls and other vessels have been extensively studied by Matthäus (Matthäus 2005). By far the most common vessel type in EIA Cyprus was the simple hemispheric bowl, or kalottenschale. These hemispheric bowls were likely formed by casting a round disk and then either “sinking” the bowl by hammering the interior down or “raising” the bowl by hammering the exterior of the bowl, potentially around a mold.

All of the bowls included in this study come from Cyprus (8 from Lapithos and 3 from Kourion, along with 1 strainer from Kourion). The majority of the bowls are plain
hemispherical bowls with thick, undecorated rims. These include 32-27-633, 32-27-634, 32-27-648, 32-27-719, 32-27-720, 32-27-1045, 32-27-1046, 49-12-1051, and 49-12-1052 (Figs. 165-180). These form a largely cohesive group and there are no major differences between them. They are all between 13cm and 15cm in diameter and their heights (where complete) are between 5cm and 7 cm tall. The thickness of the rims in comparison with the centers of the bowls suggests that they were made by sinking rather than raising. Lang notes, however, that this is not a sure indicator, since the rims are sometimes knocked down (Lang and Middleton 2006, 58). There are some slight differences in the shapes of these bowls. For example, 32-27-648 is considerably taller than the others, with sides that form more of a V-shape rather than a rounder semi-circle like the others. 32-27-633 and 32-27-634, which were both found in Tomb 80, have rims that are very slightly outturned.

The one outlier from Lapithos is 32-27-789 (Fig. 181), which is a shallow bowl with a rounded body and straight rim and an incised line running around the outside of the bowl. This bowl may have been turned on a lathe in its finishing to make the incised decoration. 49-12-1055 (Figs. 182-184) from Kourion is a much larger bowl that is very fragmentary. 49-12-1029 (Figs. 185-187) is a strainer, of a common type in Early Iron Age Cyprus.

**X-Radiography**

The majority of the bowls did not x-ray particularly well, for two reasons. First, many of the bowls are very heavily corroded, so that no intact metal is preserved and the only thing visible in the x-ray is the corrosion. Furthermore, most of the bowls had to be x-rayed while sitting upside down on their rims. This means that the sides and rims of the
bowls were compressed into a small area of the x-ray. This was the case for all of the hemispheric bowls, since they were intact. Some of the other bowls could be investigated from the side since they were in fragments. The only hammer marks that are discernable are some linear markings on the rim of 49-12-1005. We might expect something similar on the other bowls if they were better preserved. Furthermore, the same bowl (49-12-1005) and the strainer (49-12-1029) use rivets to connect different elements. These rivets can be clearly seen in the x-ray. Finally, the decorative line running around the outside of bowl 32-27-1045 is much more visible in the x-ray.

Microscopy (Figs. 188-193)

Samples were taken from two bowls from Lapithos (32-27-789 and 32-27-1045). The samples are from macroscopically different bowls. 32-27-789 is a shallow, carinated bowl, whereas 32-27-1045 is a simple hemispherical bowl. Both samples were taken from the rims of the bowls, since this is the area that preserved the most intact metal.

The shallow bowl (32-27-789) has been shaped through a process of hammering and annealing. The annealing twins are straight, but the presence of slip lines suggests that either the last anneal was short or that the bowl was lightly hammered after the last anneal. The bowl has been extensively hammered so that the inclusions have been elongated in the direction of working and there are extensive slip lines from hammering. The slip lines are concentrated on the inside of the bowl, whereas the stress cracking is exclusively on the other side. This may indicate that the inside of the bowl was subjected to hammering while the outside bent more significantly and was put under strain. The hemispheric bowl (32-27-1045) has also been shaped through hammering and annealing.
The microstructure reflects a deformed grain structure, which suggests that the final step was hammering.

**SEM-EDS (Figs. 194-195)**

The two bowls from Lapithos (32-27-789 and 32-27-1045) display somewhat different alloying practices. 32-27-789 is a typical bronze (9.8 +/- 0.1% tin), whereas 32-27-1045 is a high-tin bronze (13.6 +/- 0.1% tin). High tin contents have been noted in other hemispheric bowls from Palaepaphos (Charalambous, Kassianidou, and Papasavvas 2014). High tin contents may have been desirable because they changed the color of the bronze from a yellow gold to a more silver color (Mödlinger et al. 2017).

32-27-1045 contains lead inclusions, whereas 32-27-789 does not. The LA-ICP-MS data confirms the presence of lead at similar levels in both samples. The lead in 32-27-789 may be distributed in much smaller particles that cannot be seen by the SEM. The lead levels in both samples is still relatively low and could just be an unintentional trace element coming from the ore.

**LA-ICP-MS**

The Lapithos bowls are similar in their chemical composition, especially their levels of arsenic and antimony, which suggests they were subjected to similar smelting practices. More iron and zinc have been retained in 32-27-789, which may be due to differences in processing the metal after the initial smelting (resmelting, etc.), since iron is more sensitive than arsenic to these sorts of operations.

**NAILS**

To my knowledge, nails from the Aegean have not been the subject of a dedicated study.
**Visual Analysis (Figs. 196-201)**

There are 6 nails from Vrokastro included in this study. Five of them share overall similarities in form (VK4584.1- VK4584.5, Figs. 196-200). They all appear to have been cast as one piece (pin and head). The edges of the heads are knocked down on all of these examples. The edges of the head of VK4584.5 have been extensively hammered down, leaving the head considerably smaller than the others. In contrast, only a small area of the edges on VK4584.2 and VK4584.4 has been knocked down. Many examples also show facets running along the length of the pin where the smith moved the hammer along it. VK4584.6 (Fig. 201) is very unlike the rest of the examples. It is much larger, and it has a faceted pin that is square in section and a pyramidal head. Unlike the others, it does not seem like a functional nail.

**X-Radiography**

The x-ray images seem to confirm that the nails were all cast as single pieces. They are all fairly consistent in density, with no noticeable porosities. Hammer marks are not readily apparent, although they were presumably worked.

**Microscopy (Figs. 202-207)**

Two samples were taken from nails (MS45814.1 and MS45814.4) from Vrokastro. MS45814.1 was taken from the shaft of the nail, whereas MS45814.4 was taken from the head of the nail, so the microstructures display understandable differences. Nevertheless, the overall structure of the two nails shows definite similarities. Both have very frequent small porosities and fairly frequent inclusions. MS45814.1 was worked through cycles of hammering and annealing, but was left in an annealed state, with fairly large grains. There are no visible slip lines, but there are some areas of intense deformation that could be left over because the last anneal was short or could the result of
light hammering after the last anneal. On the other hand, MS45814.4 from the head of the pin appears to have been more heavily worked. The grains are smaller, and the inclusions are strung out in the direction of working. The last step seems still to have been annealing.

SEM-EDS (Figs. 208-209)

The two nails are strikingly similar in the chemical composition. Both are unalloyed copper, and both contain sulfide inclusions. The use of unalloyed copper for utilitarian objects like nails has been noted in other studies (see below).

LA-ICP-MS

The two nails also show strong similarities across the board in their trace elemental analysis. The biggest difference between the two is a higher iron content in MS45814.4 (2,020ppm compared with 178ppm in MS45814.1). The similar arsenic and antinomy levels suggest they could come from the same smelt. Iron is more sensitive to post-smelting work, so the difference in iron could be due to refining.

TRIPODS

Tripods and four-sided stands have been the focus of a large body of scholarship, much of it concerned with the transmission of metalworking technology (Catling 1964; Papasavvas 2004; Matthäus 2005; Papasavvas 2014; Schorsch and Hendrix 2003; Macnamara and Meeks 1987). These stands are found in both Cyprus and Crete and the general argument is that they originated on Cyprus and were later imitated in Cretan workshops. Despite the prevalence of this argument in scholarship, the available evidence underpinning the argument is not conclusive. First, very few stands have secure,
excavated contexts (Papasavvas 2004). As a result, it is difficult to track their spread over time.

Part of the argument is also that the stands are major technical achievements, so that the technology required to make them would have to be learned. Catling argues that the stands are “very remarkable technological achievements, showing their makers as master craftsmen in the skills of bronze-working” (Catling 1964). Catling divides tripods into “rod-tripods,” which he argues were cast as separate pieces and then assembled by hard soldering (or “brazing”), and “cast tripods,” which he argues were cast as one piece (Catling 1964).

Two technological studies of tripods in the Metropolitan Museum and the British Museum have shown that this is not the case (Macnamara and Meeks 1987; Schorsch and Hendrix 2003). Both studies found that rod tripods were in fact cast as one piece. These tripods were constructed entirely by joining pieces of wax and then cast using the lost-wax method. This involves a very complex system of gating and carefully constructed investiture to ensure that the molten metal does not cool before it reaches all parts of the mold. Papasavvas has argued that it is all the more impressive that Cypriot bronze-workers were able to cast these elaborate pieces as a whole (Papasavvas 2014). Schorsch and Hendrix, on the other hand, draw attention to the very porous nature of the cast and the many flaws including casting fins and cold shuts that are visible on the surface. They argue that the quality of the work is poor overall and little attention is paid to surface finishing (Schorsch and Hendrix 2003).
Visual Analysis (Figs. 210-212)

There is one tripod from Kourion held in the collection of the Penn Museum (49-12-1053). Its three legs have spiral terminals at the top and cloven feet at the bottom. A ring with a leaf pattern between two bands sits on top of the spirals. The legs are supported by struts extending to either side. Where the struts from one leg meet the struts from another there are hoops extending down from the ring. The legs are also supported by struts that protrude towards the center and meet around a central hoop. Noticeably, there are unfinished globs of metal connecting the spiral decoration to the legs and connecting the struts to the central hoop, and in one case connection one of the struts to a hanging hoop.

X-Radiography

As with the x-rayed rod tripods mentioned above, the quality of the casting of 49-12-1053 is quite low. There are frequent, large porosities throughout the object. What sets this tripod apart from the ones featured in other studies is that there are some areas which have clearly been joined after the original casting. These are the areas that are joined by glommed-on additions of blob-like metal mentioned above. In the x-ray it is evident that these areas were soldered together after the struts and the decorative spirals were already cast. Unfortunately, it is quite difficult to say definitively whether this was done intentionally in antiquity, or whether it has been part of the object’s conservation when it came to the Museum in the early 20th century.

Knives

Like the bronze stands, iron knives have frequently been discussed in scholarship about the transmission of technological knowledge in the EIA eastern Mediterranean
In particular, bi-metallic knives with iron blades and bronze rivets are used as evidence that Cyprus was the center of iron-working innovation in this period. Although Cyprus was not necessarily experimenting with iron as early as other regions (Anatolia, the Levant), they moved more quickly from an early experimental phase of iron use into more frequent use (Snodgrass 1982). A large part of the iron believed to have been produced on Cyprus is in the form of these bi-metallic knives. There has been some debate over whether these were utilitarian or prestige items (Sherratt 1994; McConchie 2004). Sherratt has argued that the bi-metallic knives are being mass produced and that iron-working technology is traveling more or less along the same lines of communication as the knives themselves.

Visual Analysis (Figs. 213-222)

The iron knife from Lapithos (32-27-791, Fig. 213) along with two of the iron knives from Kourion (49-12-491 and 49-12-1056, Figs. 214-215) are of the very common type with a single edged iron blade attached to a wooden, bone, or ivory handle with bronze rivets. 49-12-491 is somewhat unusual (but not unique) because the bronze rivets are positioned one on top of the other, instead of in a horizontal line. 49-12-493 (Fig. 216) may be of a similar type, but no handle is preserved and there do not appear to have been any rivets. 49-12-1050 (Fig. 217), on the other hand, is very large and seems like it may have originally been a double-sided dagger rather than a knife. It is in such poor condition, however, that it is difficult to say for sure.

There are two knives from Vrokastro. One, MS4764 (Fig. 218) is a small iron knife that has very little in common with the Cypriot examples. The blade appears to curve in the opposite direction. The handle is also made of iron and there is no indication
of a wooden or bone attachment. The other iron knife (MS4766, Fig. 219) is so poorly preserved that very little can be said about its original shape.

In addition to the knives, there is one dagger from Vrokastro (VK4763, Fig. 220), one spearhead from Vrokastro (VK4765, Fig. 221), and another spearhead from Kourion (49-12-1030, Fig. 222), all heavily corroded.

**X-Radiography**

There is so much corrosion in the knives that x-radiography analysis does not yield valuable results.

**DISCUSSION**

This discussion section is divided into four sections: first, a brief overview of some studies that provide comparative data for my research; second, a reconstruction of the chaîne opératoire used to construct the sampled objects based on the results of testing; third, an explanation of how this reconstruction of the chaîne opératoire can be used to identify communities of practice at each of the three sites; and fourth, a discussion of how knowledge was shared between these communities of practice, drawing them together into a constellation of practice.

**COMPARATIVE DATA**

The majority of the chemical testing that has been done on other EIA Cypriot objects has been limited to non-invasive methods such as p-XRF (Charalambous, Kassianidou, and Papasavvas 2014; Charalambous 2016). Results from p-XRF on bronze objects are known to be affected by the corrosion process and are not as accurate as other, more destructive methods (Ferretti 2014). Although these studies were done on cleaned surfaces to lessen the impact of this distortion in the data, they are still not as accurate as
SEM-EDS on cut samples and are therefore not directly comparable to my results. Nevertheless, since p-XRF data is the only available comparative data, it will be used qualitatively to provide some context for this study.

For the Aegean EIA, however, a number of studies have included invasive sampling for chemical testing. Craddock published a series of three articles on a total of 860 copper-alloy objects from the Bronze Age to the Roman period (1976, 1977, 1987). Soon after, two excavation reports included studies of the copper-alloy objects: Nichoria in Messenia (Rapp et al. 1978) and Lefkandi in Euboea (Jones 1980). A follow up study was also conducted on the objects from Lefkandi (Orfanou 2009). It included microscopy, SEM-EDS, and EPMA of 19 objects. An excavation report from Kalapodi in Phocis also included analytical data of 185 copper-based objects using atomic absorption spectroscopy (AAS) (Riederer 2007). Finally, Rolley and colleagues conducted a study of tripods from Delphi and Olympia with AAS (1983).

**CHAÎNE OPÉRATOIRE**

As discussed in Chapter 3, *chaîne opératoire* refers to the series of steps that a craftsman takes in order to make any object. For example, the *chaîne opératoire* for copper objects includes steps such as mining, smelting, refining, alloying, casting, and working. At each of these steps, craftsmen make decisions that reflect their skill, experience, and training. By looking carefully at these decisions, and at similarities and differences in the *chaîne opératoire* between objects from different sites or of different object types, it is possible to identify strands of local practice and training.
In this section I will go through each of the steps of production, from the mining of the ore to the working of the final product, pulling together the data from each of the scientific tests in order to uncover patterns that are indicative of local styles. The analyses which shed light on the chemical composition of the samples (SEM-EDS and LA-ICP-MS) provide information about the early stages of production, including mining, smelting, refining, and alloying. The microscopy and the X-radiography, on the other hand, provide information about the later stages, including casting, and working. My goal in this section is to identify similarities and differences in practice that can be used to investigate metal working communities in operation at Lapithos, Kourion, and Vrokastro.

**Mining**

The chemical composition of the samples reflects, to some extent, the composition of the ore from which it was smelted. Therefore, by investigating the chemical composition of the metal object, it is possible to infer some aspects of the composition of the ore. Many ores contain sulfur, for example, retained as sulfide inclusions in the metal object, which can be seen in the results of the SEM-EDS. Elements such as arsenic, cobalt, nickel, iron, and others are present in specific concentrations in ore bodies. When raw metal is extracted from ore through smelting, some amount of these elements will remain in the metal as trace elements, seen in the results of the LA-ICP-MS.

The correlation between trace elements in the metal object and ore source in not straightforward, however. Some early, large scale studies such as the Studien zu den Anfangen der Metallurgie (SAM) project attempted to match objects to their sources using trace element analysis (Friedman et al. 1966; Junghans 1960; 1968; 1974). These
studies were criticized for failing to account for the numerous processes between ore and object that have an impact on the concentrations of various elements (Waterbolk and Butler 1965). It is now generally agreed that the composition of an object reflects the technological history of an object at least as much as it does the provenance of the object (Pernicka 1999). Operations such as smelting and refining, as well as mixing, recycling, and alloying metals, all have an impact on the trace elements present in the metal. Furthermore, ore bodies are not homogenous, which complicates the association of ore with object (Pernicka 1999).

Further testing, including Lead Isotope Analysis (LIA), would be essential to assigning the objects in this study to specific ore bodies. LIA was not performed, however, since the focus of this study is not the specific geological provenance of the metal, but the technological sequence used to produce the metals. Nevertheless, this section will make some suggestions about possible ore sources, based on the results of the SEM-EDS and the LA-ICP-MS.

**Sulfide Inclusions**

For the Cypriot objects, it is logical to start by investigating the possibility that the objects come from Cypriot ores. There are two reasons to believe that this is in fact the case. First, the majority of objects have iron sulfide inclusions, seen in the SEM-EDS (Fig. 11). This is consistent with an attribution to Cypriot ores, which are primarily chalcopyrite ores (CuFeS$_2$) with high iron content (Constantinou 1982). The only two Cypriot samples which did not display iron sulfide inclusions are 32-27-733, which has extensive intergranular corrosion that may have obscured the inclusions, and 32-27-1201, which had no detectable inclusions, perhaps because the metal was extensively refined.
before casting. In both cases, it is still possible that the metal came from an ore with high iron content, such as a chalcopyrite. Second, the relatively high levels of selenium and tellurium seen in the results of the LA-ICP-MS point toward a Cypriot source, since selenium and tellurium are heavily enriched in Cypriot ores (Martin et al. 2018). These elements are enriched in sulfide inclusions so the samples with more frequent and larger inclusions have the highest levels (especially 49-12-721, 49-12-544, and 32-27-733).

Whereas nearly all of the Cypriot objects have iron sulfide inclusions, the Cretan objects mostly contain inclusions without any iron (Fig. 11). Exceptions to this are fibulae VK4622 and VK4756, which have iron sulfide inclusions. VK4756 in particular, has very high iron as well as selenium and tellurium, which could indicate a Cypriot ore source. The remaining Cretan fibulae (VK4757, VK4758, VK4759, and VK4760) all have very low iron, selenium, and tellurium. These objects are therefore unlikely to have originated from Cypriot ore. This is consistent with the greater diversity of ore source in use at Vrokastro (discussed below). The variety of ore sources is unsurprising, since there are no copper sources on Crete and all raw metal would have to have been imported.

*Ratio of Arsenic to Antimony*

Arsenic and antimony are commonly found in metal ores and can serve as indications of ore source. As volatile elements, both are preferentially lost during smelting and remelting in oxidizing conditions. Their similar properties mean that they

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59 Trace levels of arsenic can enter the metal with the ore (Giumlia-Mair 1992) or with the flux (Tylecote 1982). Arsenic was detected in the p-XRF study of other Cypriot EIA objects. Charalambous and his colleagues argue that the only Cypriot ore sources containing arsenic are at *Laxia tou Mavrou* and *Pevkos* in the southwest of the Troodos formation. Alternatively, they suggest that the arsenic could come from resmelting arsenical copper objects from the Early or Middle Cypriot period (Balthazar 1990). The modest levels of arsenic in the samples may not be high enough to necessitate detailed explanation, however, since arsenic is present in small but detectable amounts in Cypriot ores (Antivachis 2017).
are lost in proportional amounts, so the ratio of arsenic to antimony remains constant during the smelt, even if the absolute amount is diminished. The ratio of arsenic to antimony should therefore remain fairly constant for metal originating from the same ore body (Figs. 223-224).

Two different groups can be distinguished within the Lapithos samples, one with a comparatively higher antimony to arsenic ratio (Lapithos “A”) than the other (Lapithos “B”), suggesting that the objects originated from two different ore bodies. The samples from Kourion, on the other hand, all have similar antimony to arsenic ratios and could be attributed to a single source. The samples from Vrokastro have a wider spread. Although the majority of the objects cluster together, VK4760 and VK4758 have higher antimony to arsenic ratios, indicating they likely came from different ore sources. Furthermore, although VK4622 and VK4756 have similar arsenic to antimony ratios to the other samples, they have iron sulfide inclusions, and therefore likely come from a different source (or different sources) as well.

Smelting and Refining

Elements that are present in the ore remain in the raw metal, but they are retained in different amounts as a result of smelting and remelting. A more oxidizing smelting atmosphere will result in lower levels of volatile trace elements seen in the results of the LA-ICP-MS, whereas a more reducing atmosphere will result in higher levels. A similar process takes place during remelting, which takes place primarily in open crucibles, in oxidizing environments. Therefore, more refining, or longer refining, also leads to lower levels of volatile trace elements. It is important to note that determining whether these elements were lost during smelting or during refining is difficult.
**Arsenic**

Arsenic has a high affinity for oxygen, and so it is lost through evaporation during metallurgical steps that take place under oxidizing conditions, including dead roasting, smelting, and remelting (Pernicka 1999). Smelting in a more reducing environment will lower the amount of arsenic that is lost during the process. Furthermore, arsenic loss is time and heat dependent (Tylecote, Ghaznavi, and Boydell 1977, 314; Tylecote 1992, 20, 25; Bray and Pollard 2012).

In Figure 224, objects that fall on the upper right side of their fit line were smelted under more reducing conditions, whereas the objects that fall toward the lower left were smelted under more oxidizing conditions. For example, 32-27-745 and VK4622 have noticeably low arsenic and antimony and were likely smelted in an oxidizing atmosphere, whereas on the other end of the spectrum, 49-12-545 and 49-12-544 have very high arsenic and antimony contents, likely because they were smelted in very reducing conditions. Several pairs of objects are very close together on this graph, suggesting they came from the same smelt. This includes the nails from Vrokastro (VK4584−1 and VK4584−4), two needles from Lapithos (32−27−1195 and 32−27−1196), and ring and a pin from Kourion (49−12−544 and 49−12−545).

Overall it is striking that the objects from Vrokastro contain far less arsenic than those from the Cypriot sites (Fig. 225). The arsenic levels at Vrokastro are also lower than those of Lefkandi and Nichoria (Fig. 226).

**Iron**

Iron is one of the most common trace elements in ancient copper and some iron is usually present in finished objects, although the iron content is lowered through
processing and refining. Like arsenic, more iron is retained in more reducing smelting environments. Diachronic studies of objects from Faynan show an increase in retained iron, along with zinc and nickel over time, due to more reducing smelting atmospheres (Hauptmann et al. 1992).

The level of iron in the samples in this study is typically between 0.1 and 0.5\% (Fig. 227). The average amount of iron at Kourion is 0.319\% and at Lapithos is 0.208\%. Charalambous’ p-XRF study of Cypriot bronzes from the Early Iron Age found very similar levels of iron. They interpret the low concentration of iron as a result of careful refining (Charalambous, Kassianidou, and Papasavvas 2014, 213). While it is certainly possible that careful refining was taking place, the iron levels are not unusually low in comparison to other EIA objects.

The average level of iron in the samples from Vrokastro is 0.229\%. This seems comparable to other studies from the Aegean but may in fact be somewhat misleading (Fig. 227), since Vrokastro has a large range of iron values. One outlier VK4756, has significantly higher iron content than any other object in the study (19,140 ppm / 19.2\%). VK4622 and VK4584.4 have iron levels comparable to the Cypriot samples, but the remaining samples (VK4757, VK4758, VK4759, VK4760, and VK4584.1) have less than 400 ppm iron, which is lower than any of the Cypriot examples. It is also much lower than the other studies of Aegean bronzes have found. It is difficult to say whether this

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60 Their study was concerned with objects smelted from the oxide ore found at Faynan, however, and did not directly address the iron levels typical in sulfide ores, which tend to be considerably lower (Pernicka 1999).
discrepancy should be attributed to the ore, the use of a very oxidizing smelting environment, or thorough refining practices.

Whereas arsenic and antimony levels are largely determined by the atmosphere of the smelt, iron levels are more sensitive to post-smelting refining. Iron is much easier to remove from copper by reheating in a crucible and stirring the copper with a stick of green wood. In some of the object pairs that appear to have been smelted under very similar conditions, differences can still be seen in the amount of iron. For example, 49-12-544 and 49-12-545 appear to be cast the same smelt, but 49-12-544 has much lower iron levels, perhaps due to further refining.

Overall, the samples from Kourion have higher levels of arsenic and iron on average than the objects from Lapithos. This is also reflected in the more frequent level of inclusions in the Kourion samples, on average. This suggests that smiths at Kourion were either not dead roasting as long, or they were smelting in more reducing furnaces, or they were not refining as carefully. The majority of the samples from Vrokastro, on the other hand, have remarkably low levels of arsenic and iron, suggesting the ore was smelted in an oxidizing environment or that it was subjected to extensive refining.

Differences in individual smelts are to be expected, since metallurgists in the ancient world did not have tight control over the smelt. Even within communities of practice, therefore, it is common to have some variation in the elemental composition. When taken as a whole, however, trends towards more and less reducing atmospheres in the smelt can be seen.
In several instances, objects found in the same tomb appear to come from the same batch of metal, based on similarities in the levels of trace elements seen in the LA-ICP-MS. This is true of both objects of the same object types (two needles 32-27-1195 and 32-27-1196) and of different object types (needle 49-12-544 and ring 49-12-545). It is seen at both Lapithos and Kourion. Unlike pins or fibulae, which could be assumed to have been purchased and subsequently worn in pairs to secure clothing, there is no practical reason these needles and rings would have been purchased in pairs. Nevertheless, it seems that objects in the same tomb are more likely to have been made from a single bath of metal, perhaps indicating that they were purchased together.

**Alloying**

Alloying is the process of mixing a base metal with other elements or metals to form a new alloy. It can increase the hardness or ductility, change the color of the metal, or produce other desired effects. Copper can be alloyed with a number of elements, including arsenic and tin. In this study, the two main elements that were added to copper were tin and lead. The amount of tin can be seen in both the SEM-EDS and the LA-ICP-MS results, but the latter is used for this discussion, since it provides more accurate results. The amount of lead is also taken from the LA-ICP-MS results.

**Tin**

The majority of the samples included in this study can be classified as classic tin-bronzes containing between 5% and 12% tin (Fig. 228). Classic tin bronzes were the most common type in the EIA Mediterranean. They are suitable for both casting and working (Ottaway and Wang 2004). The optimal amount of tin for making an object with a hard edge is around 10% (Tylecote 1982).
The average amount of tin in the samples from Lapithos is 10.67%. Most of the samples cluster around 8-9%, but the high-tin bowl (discussed below) raises the average. This pattern is similar to other Cypriot EIA bronzes. Charalambous found that objects from Palaepaphos-Skales had 8.1 ± 2.2% tin on average, and objects from Salamis had 6.6 ± 4.5% on average, although this was in large part due to a group of 100 objects from Salamis that contained no tin at all (Charalambous 2016). The average amount of tin in samples from Kourion is slightly lower at 6.79%. The samples are split between the ring and fibulae which have around 8% tin, and the pins which are low-tin bronzes, with only around 5% tin.

Many chemical analyses of bronze objects in the Aegean have been focused on the “bronze shortage theory” proposed by Snodgrass (2017, 237–39). The theory suggests that shortages of copper and especially of tin in the Aegean resulted from the isolation of the region following the LBA collapse. In a study that combines the results of chemical analyses on bronzes from the Aegean covering sites spanning the LH III to the Geometric, Kayafa argued that the data does not support this theory (2006). She notes that there is in fact significant continuity between the LHIII and EIA metalworking traditions, and that differences are more noticeable beginning in the Geometric period. The Geometric bronzes that have been analyzed, however, are mostly statuettes and tripods from sanctuary contexts and the difference in object type and function might account for the lower tin content (Craddock 1976; Philippakis, Rolley, and Magou 1986; Orfanou 2015). In short, the theory of a tin shortage is not supported by the data from EIA studies.
The results from Vrokastro seems to corroborate the picture presented in these studies. The samples from Vrokastro have an average of 5.46% tin, but that average is pulled down by two nails of pure copper (discussed below). If the two nails are excluded, the average is 7.19%. Studies of bronzes from the Aegean EIA had similar averages. Sampled objects from Nichoria had 8.60% tin on average, and from Lefkandi had 13.40% on average. The average amount of tin is lower at sanctuary sites such as Olympia, Delphi, Kalapodi, and Phere (Fig. 226). Again, this is likely attributable to the difference in object types that were common sanctuary dedications, such as tripods. Furthermore, like the sample objects from Nichoria and Lefkandi, the Vrokastro objects seem to fall into one low-tin group with around 5-6% tin, and one high-tin group with around 10-11% tin.

In this study, the one object which can definitively be said to be a high tin bronze is hemispheric bowl 32-27-1045 from Lapithos (15.7% tin). Charalambous identified one group of 28 high tin objects (18.6 ± 2.8% on average) from Palaepaphos-Skales, including mostly bowls but also several rings and a fibula (Charalambous 2016). Higher levels of tin make the alloy brittle and difficult to work, so it is surprising that it would be used for a bowl, which requires extensive working to either raise the sides or sink the center to form a bowl shape. High tin concentrations also change the color of the metal, however, first to red, then to gold, and ultimately to silver at 18-33% tin (Hosler 1994; Fang and McDonnell 2011). In this case, smiths may have used a very high tin bronze to make an object appear more like a gold or silver bowl.
There are several low-tin bronzes in my samples including Kourion needle 49-12-545, Lapithos needle 32-27-745, and Vrokastro fibulae VK4758 and VK4759. Besides having low tin, however, they do not share many other commonalities.

The only two objects in this study without added tin are the two nails from Vrokastro VK4584.1 and VK4584.4. The phenomenon of unalloyed nails has been observed in other studies (Charalambous 2014, Giumlia-Mair 1992). Both authors note the expense of tin and point out that there was no reason to use expensive materials on utilitarian objects like nails. Giumlia-Mair also adds that copper is more corrosion resistant and easier to work, making it suitable for utilitarian objects.

*Lead*

Lead can be intentionally alloyed with copper and tin to lower the melting point and improve fluidity and castability (Klein and Hauptmann 1999). It is also present as a trace element in many copper ores. Differentiating between intentional alloys and unintentional ore components can be difficult and depends on a number of factors. Different studies have used very different minimum percentages for defining intentional lead alloys, ranging from 1.0-1.5% (Gale and Stos-Gale 1982) to 4% or more Pb (Pernicka et al. 1990; Pernicka 1999). Experimental castings have shown that between 2 and 3% is enough to increase fluidity and lower the melting point (Philip 1991). When more than a few percent are used, however, it can reduce the alloys hardness (Giumlia-Mair 1992).

The majority of the objects in this study contain < 0.5% lead (Fig. 229). In other studies of Cypriot metals, however, even < 1% lead was considered an intentional alloy,
since lead is not present in Cypriot copper ores (Charalambous and Webb 2020, 10). At levels this low, however, intentionality is difficult to prove.

The only objects included in this study with lead contents > 1% are the needles from Lapithos (32-27-1195, 32-27-1196, 32-27-735, and 32-27-745). One explanation for their high lead content is that they used recycled metal from leaded bronze objects. The fact that they belong to a single object class may argue for a more intentional alloying process, but it is not clear why lead would be desirable for casting such a simple shape.

Casting and Shaping

All of the objects included in this study were likely cast before they were worked. The casts could have been made from sand, clay, or stone. Both open and closed molds were used. The fibulae with decorated bows were very likely cast in closed, 2-part molds. The needles and pins, on the other hand, are less intricate and could have been cast in open molds. Bowls were likely cast as flat discs and then raised or sunk by hammering. Only a few objects (Vrokastro fibula VK4760 and Kourion ring 49-12-1005) retain their as-cast microstructure, however, since most objects were worked by a cycle of hammering and annealing after their initial casting.

The samples from Lapithos often have frequent, large porosities, which are indicative of poor casting, whereas the samples from Kourion have fewer and smaller porosities on the whole. Porosities are formed by gasses in the molten metal that are trapped as the metal cools. If the metal is too porous it can become brittle and difficult to work. In this case, the porosities are likely not large enough to make a noticeable difference when working the metal.
The samples from Vrokastro have frequent porosities, but they do not resemble the porosities seen in the samples from Lapithos. The nails display small, frequent porosities. Some of the samples from the bows of fibulae display larger porosities, cracks, or other flaws in the center of the object.

After the objects were cast, most were further hammered, or otherwise shaped, and almost all were subjected to further heating treatment. After prolonged hammering, the metal would become brittle and the objects would have to be reheated, or “annealed” to restore its ductility. Most of the objects were likely shaped through a series of hammering and annealing processes. The microstructure of the objects, seen in the microscopy, reflects the final stage of an object’s formation.

The Cypriot objects all show signs of having been worked through a cycle of hammering and annealing. On the whole, the objects from Lapithos also show a greater tendency to have been subjected to a final anneal than those from Kourion. Performing a final anneal can prevent the metal from becoming brittle, whereas leaving the metal in a hammered state improves its hardness. This pattern is observable across several object types including needles, as well as a bowl and a fibula, which suggests that there is no reason tied to the function of the object that smiths would have chosen to anneal as a final step. Instead it seems likely that the difference in practice can be attributed to the preference of different workshops.

Some of the samples from Vrokastro (especially the nails) show a similar pattern of hammering and annealing, but others (especially the fibulae) have been annealed, but not hammered. For the samples that come from intricately cast bows, this is unsurprising, since the smiths would have wanted to retain the shape of the mold. The springs of these
fibulae would have been shaped by hammering, however, and they would have required annealing. While annealing the springs, the smiths would necessarily have annealed the bows, since the fibulae are small. VK4758 has a twisted bow that was also annealed but not hammered. In this case the anneal was likely performed to increase the ductility of the metal so that it could be twisted. One sample from the pin of a fibulae (VK4759) is also unworked. This is unlike the Cypriot sample 32-27-1201, which shows signs of hammering on the pin.

One exception to these trends is the hemispheric bowl 32-27-1045 from Lapithos. It displays large inclusions, small porosities, and a deformed microstructure which indicates that hammering was the last step in its production. It is also the same bowl that has a high tin content, much like the high-tin bowls from Palaepaphos-Skales (see above).

LOCATION OF METALLURGICAL ACTIVITIES

Mining and smelting were likely carried out in a physically distant location from refining, alloying, casting, and working. Mining necessarily must take place at naturally occurring ore sources, and initial smelting is usually carried out close to mining sites. Before smelting, the ore would have contained more unwanted minerals (gangue) than metal. Consequently, it would have been heavy and expensive to transport. Smelting the ore at the mining site would therefore allow for the transport of the more valuable raw metal. The rest of the stages of production would likely have taken place in workshops at the sites. As a result, the metallurgical specialists making decisions about the early stages of production would not necessarily be the same people as those who made the decisions about the final stages.
In Cyprus, mining and smelting likely took place in the mountainous interior of the island, whereas the later stages of production were done in workshops in coastal centers such as Kourion and Lapithos. Differences in the ore and the smelting conditions between the Kourion, Lapithos A, and Lapithos B groups suggest that each group was importing smelted ore from different centers. The differences in the ore bodies exploited are fairly clear from the stratification in the ratios of arsenic to antimony. Furthermore, the objects that come from a single ore source have more in common at the subsequent stages of production, suggesting that each community of practice had a unique relationship with a mining community in the interior of the island.

In Crete, due to the lack of naturally occurring copper sources, all of the raw metal would have been imported. This reliance on imported metal is likely reflected in the wider range of ores and smelting practices seen in the Cretan samples.

COMMUNITIES OF PRACTICE

Decisions made at each step in the châine opératoire reflect ingrained ways of making that are unlikely to change once they have been learned. In particular, gestural knowledge relies on motor skills and muscle memory (Gosselain 1992). Since these ways of making are learned through common training within a community of practice, there are similarities in the way community members make copper-based objects. Consequently, a châine opératoire approach can be used to attribute the samples to individual communities of practice. In the following section, I demonstrate how my conclusions from the previous section on châine opératoire can be used to identify communities of practice active at Kourion, Lapithos, and Vrokastro.
Lapithos

The sampled objects from Lapithos can be divided into two groups: Lapithos A and Lapithos B. Lapithos A contains three needles (32-27-735, 32-27-1195, 32-27-1196), and one fibula (32-27-1201). Lapithos B contains two bowls (32-27-789, 32-27-1045), a pin (32-27-745), and a ring (32-27-733). There are a number of differences in the chaîne opératoire that were used to divide these groups, beginning with mining and smelting, and including alloying, casting, and working. I will analyze each of these steps, beginning with mining, and point out the distinctions between Lapithos A and B samples. Although there is some variation within individual analyses, the sum total of the results overwhelmingly suggests a division between the Lapithos A and B samples.

First, although all the Lapithos objects appear to have been formed from Cypriot copper, Lapithos A objects likely originated from a different ore body than Lapithos B objects. This is reflected in the different antimony to arsenic ratios, as explained above (Figs. 223-224). Lapithos A samples have higher antimony to arsenic ratios than Lapithos B samples. Lead Isotope Analysis (LIA) would be needed to pinpoint the exact ores source.

Next, there are differences in smelting and refining stages between the two groups. Lapithos A samples were either smelted in a more oxidizing atmosphere or they were more thoroughly refined post-smelting than Lapithos B samples. This is evidenced by lower levels of trace elements such as arsenic, antimony, and iron, as well as in fewer inclusions seen in microscopy and SEM-EDS. It is difficult to say with certainty whether these differences should be attributed to smelting or refining. There are also some exceptions to this rule. For example, needle 32-27-735 from Lapithos A has higher iron...
and more inclusions than the other Lapithos A samples, and needle 32-27-745 from Lapithos B has lower iron and fewer inclusions than the other Lapithos B samples. One alternate theory is that pins and needles at Lapithos were subjected to more thorough refining than the bowls and rings. The bowls in particular (32-27-789, 32-27-1045) have more frequent and larger inclusions that might indicate they were less carefully refined.

The alloying practices of the two communities of practice are similar and display some overlap, but Lapithos B samples also display similarities to alloying practices at Kourion and Palaepaphos. The Lapithos A samples are all “classic” bronzes, containing 8-10% copper, whereas the Lapithos B group is more diverse. One of the bowls is a high tin bronze (32-27-1045) and can potentially be linked to a tradition of high tin bronze bowls also seen at Palaepaphos (see above). The needle is a low tin bronze (32-27-745), which is not typical of the other needles from Lapithos, but is seen in needles from Kourion (49-12-545 and 49-12-982). All of the needles from Lapithos, regardless of group, are distinctive for their high lead content (>1%), which appears to have been an intentional alloying decision.

Finally, small differences in the techniques used to cast and shape the objects are noticeable between Lapithos A and Lapithos B. Lapithos A objects, especially the needles, but also the fibula, are characterized by frequent, large porosities in their microstructure. Although these porosities were probably not large enough to impact the workability of the metal, they do indicate a less careful casting process. Objects from Lapithos B, on the other hand, display a less porous microstructure. In addition, all of the objects from Lapithos A appear to have been subjected to a brief final round of annealing. Lapithos B presents a less clear picture. Needle 32-27-745 and bowl 32-27-1045 were left
in a hammered state, bowl 32-27-789 was annealed, and 32-27-733 has too much intergranular corrosion to draw any definite conclusions.

I interpret these two groups as objects produced by two different communities of practice. Each group is characterized by different choices made at each step in the châine opératoire, from mining to working. These choices reflect the training of smiths within one community of practice. An alternate interpretation could attribute these choices to differences in object type, but since each group contains objects from several types, this is less likely. Lapithos A does contain more needles, however, perhaps suggesting that each community could have specialized in particular object types.

Lapithos A is a fairly consistent group, with many internal similarities. The samples in this group show dissimilarities to the Kourion samples, including alloying, casting, and working practices. The Lapithos A community of practice might therefore practice a more local north coast technological style. The Lapithos B samples, on the other hand, are less internally consistent and have more in common with Kourion samples, and with the studied material from Palaepaphos, especially in alloying and working practices. The Lapithos B samples could therefore include both imported objects and objects made with greater influence from the southwest region.

Kourion
The Kourion samples can plausibly be attributed to a single community of practice. Of the seven samples that were taken from Kourion objects, only four preserved enough metal for chemical testing and only one was etched during microscopy. With a sample size this small, idiosyncrasies in individual objects can make it difficult to reliably identify larger patterns. Nevertheless, there are characteristics that unite the Kourion
samples and distinguish them from the Lapithos samples, particularly those from Lapithos A.

The samples can plausibly be attributed to the same Cypriot ore source, since they have similar ratios of antimony to arsenic (as explained above). This could indicate that the smiths at Kourion had a relationship with a specific mining site.

The samples from Kourion were either smelted in more reducing environments or not refined as thoroughly as the Lapithos samples, or both. There is some variation in the smelting practices among the samples, however. Two samples, 49-12-544 and 49-12-545, were likely formed from the same batch of metal, particularly since they come from the same tomb. They were smelted in a more reducing atmosphere than the other two samples (49–12–721 and 49–12–982), which are not as similar and probably come from different smelts.

Overall the Kourion objects appear to have more inclusions than those from Lapithos, suggesting that they were not subjected to as careful refining and accounting for their higher iron, selenium, and tellurium on average. In particular, the two needles (49-12-545 and 49-12-982) both have higher iron contents than the other objects.

The alloying practices in use at Kourion are fairly different from those at Lapithos. This is seen particularly in the needles (49-12-545 and 49-12-982), which are both low tin bronzes. The lead levels in both needles are quite low, suggesting that it was not used as an intentional alloy. This is quite unlike the pattern of intentional lead alloying for needles at Lapithos.
The microstructures of samples from Kourion reflect a different tradition of casting than those from Lapithos. The pins from Kourion have infrequent, small porosities and the ring (49-12-544) and fibulae (49-12-721) have more frequent, but still small, porosities. On the whole this reflects a more careful casting process than the objects from Lapithos, especially those in Lapithos A.

Although the pins did not preserve enough metal to etch the samples, there are some signs that they were more heavily worked or not subjected to as much annealing as those from Lapithos. For example, in samples 49-12-545 and 49-12-982 intergranular corrosion outlines some of the grain boundaries, which indicates that the grain size is quite small. In sample 49-12-986, which only preserved ghost structures, the grain sizes are larger, but the inclusions are elongated and flattened from working. Elongated inclusions are not seen on the needles from Lapithos. Ring 49-12-544 has deformed grains, which show that the last step in the production process was hammering. Fibula 49-12-721, on the other hand, has larger grains and appears to have been annealed as its last step, more like the examples from Lapithos.

There are some minor differences between the Kourion samples, but not with enough consistency to posit more than one community of practice. It should be kept in mind, however, that fewer samples were available for Kourion. If more samples were investigated, differences in practice may have emerged.

**Vrokastro**

The sourcing of the Vrokastro samples is less straightforward. Since there are no copper sources on Crete, raw metal would have had to have been imported. Smiths at Vrokastro appear to have been obtaining copper from a diverse range of sources. Two of
the samples (VK4622 and VK4756) could potentially be attributed to Cypriot ores, since they contain iron sulfide inclusions typical of Cypriot ores. The majority of the samples, however, were not made from Cypriot ore and they contain sulfide inclusions without iron.

Furthermore, there is a great deal of variation in the ratio of arsenic to antimony, suggesting the use of many different ore bodies. This is likely the result of importing copper from a number of different sources, although it could also be caused by smiths remelting and recycling objects or mixing scrap together, which further complicates any potential source attributions.

Despite differences in the source of the metal, smelting practices seem to be fairly standard. Lower arsenic levels point towards smelting in a less reducing atmosphere than the majority of the Cypriot samples. This smelting environment also likely accounts for the low iron content, especially in VK4757, VK4758, VK4759, VK4760, and VK4584.1.

The samples from Vrokastro demonstrate more varied alloying practices than those from Cypriot sites. This is due in part, however, to the object types included in the sample. The use of unalloyed copper for nails was, in fact, common throughout the EIA Mediterranean (see above). Low tin bronze fibulae include VK4758 and VK4759. The remaining fibula all fall within the category of classic tin bronze, but VK4622 is at the lower end with 6.36% tin whereas VK4756, VK4757, and VK4760 are all the higher end with 9-10% tin. This differs from the Cypriot samples, which cluster in the middle around 8% tin. Lead does not appear to have been used as an intentional alloy at Vrokastro. They only contain 0.22% lead on average, which is considerably lower, not only than the Cypriot sites, but also than other Aegean sites such as Lefkandi (0.4% on average),
Nichoria (0.8% on average), and sanctuary sites, which contain much higher levels (1.5-4.0% on average).

It is difficult to compare working practices based on the microstructures because the Vrokastro samples were taken from different areas of the fibulae. Nevertheless, some variation can be seen. Many of the fibulae have elaborately decorated bows that were annealed, but not hammered. Probably they were annealed in order to allow for further hammering of the springs, which are not preserved. There are also fibulae, however, that were formed by twisting and annealing the plain bow.

Unfortunately, without scientific testing of other bronze objects from Early Iron Age Crete, it is difficult to draw conclusions about how the Vrokastro samples fit into a regional Bay of Mirabello or larger Cretan technological style. Future study would profit from sampling more objects from Crete, especially from nearby sites such as Kavousi, in order to understand local patterns of interaction, as well as from Knossos, which would provide an interesting comparison.

**Constellations of Practice**

Whereas communities of practice are understood as locally grounded, constellations of practice are more diffuse configurations, which can connect physically distant communities. Communities can be linked together through brokers or boundary objects, which exhibit attributes or forming practices of multiple communities.

*Within Cyprus*

My research provides evidence for knowledge-sharing between communities of practice on Cyprus. This is indicated, first, by similarities in practice between Lapithos and Kourion, that are not seen at Vrokastro. One reason for these similarities is that there
was more overlap in the types of objects tested from the Cypriot sites (needles, rings, bowls, and fibulae) than there were with the Vrokastro (fibulae, and nails). This too reflects more similarities in the assemblages seen at Cypriot sites than between Cypriot and Cretan sites.

The scientific analyses presented above show a number of similarities between samples from Cypriot objects. The ore was all mined in Cyprus and it was likely smelted in a more reducing atmosphere than the Cretan samples. This might suggest some overall similarities in the styles of furnaces that were used for the initial smelt. There are also similarities in how the raw metal was handled once it arrived in workshops on the coast. It was typically alloyed with tin at levels of around 8-10% tin, with a few exceptions like the high-tin bowl and low-tin needles.

In addition to the fact that on the whole the Cypriot samples are more similar, there are also some examples of boundary objects which “constellate” practice by bringing together formation practices typical of different sites. In particular, the Lapithos B samples, make use of formation techniques typical of both Lapithos A and Kourion. For example, I interpret Lapithos B needle 32-27-745 as a boundary object, since it incorporates elements of both Lapithos A and Kourion objects, without fitting in neatly with either group. As stated above, it was carefully refined, like the Lapithos A samples. It is a low tin bronze, like the Kourion needles, yet it contains lead in a level more comparable to the Lapithos A needles.

The Lapithos B bowls (32-27-789 and 32-27-1045) can also be understood as boundary objects. The bowls are similar in their chemical composition, suggesting that they could have come from the same ore source and that they were smelted in a similar
environment. Bowl 32-27-1045 contains more frequent and larger inclusions than the other Lapithos objects and it was not subjected to a final anneal as Lapithos A objects were, making it more similar to the sampled Kourion objects. It is also a high-tin bronze (15.7% tin), comparable to a group of high-tin hemispheric bowls from Palaepaphos (discussed above). Overall it has much in common with objects from the southwest and could plausibly be considered an import, except for the fact that it is similar to the other bowl in chemical composition. Bowl 32-27-789, on the other hand, displays a more thorough refining process and a brief final anneal, which is seen in Lapithos A objects. More so than 32-27-1045, then, it seems to conform to a Lapithos technological style.

These boundary objects which merge elements of local Lapithos and Kourion technological styles provide the best evidence for metallurgical specialists moving between the two sites. The employment of multiple local techniques in the formation of a single object suggests that an individual smith might be familiar the typical forming practices of two communities, having come into contact with both of them.

Some aspects of the chaine opératoire were more likely to be shared than others. For example, similarities in annealing time and hammering direction are typically confined within a single community of practice. This can be seen, for example, in the circular hammering pattern seen only on the needles that belong to the Lapithos A community of practice. On the other hand, stages of production that are less reliant on gestural knowledge and are easier to alter such as alloying, are more often shared between sites at a regional level. For example, Lapithos B needle 32-27-745 displays a tin level that is more in line with Kourion needles, and a lead level that is more in line with Lapithos A needles.
**Between Cyprus and Crete**

Constellations of practice is a framework that could also be used to address connections between Cypriot and Cretan communities of practice. However, my research has demonstrated that it is much more difficult to find a clear connection between the Cypriot and Cretan samples. The samples show significant differences in many steps in the production sequence.

Only a couple of the Vrokastro samples were made from Cypriot ore. As was discussed in Chapter 2, there is increasing doubt that Cyprus provided the majority of the copper used by Aegean smiths, particularly during the 10th and 9th centuries. My conclusions seem to corroborate the possibility that Aegean smiths were importing ore from a wider range of sources.

Cypriot smiths likely had a different relationship with the mining and smelting region than those at Vrokastro. The Cypriot samples from the same ore body had similarities in later stages of production, leading me to conclude that communities of practice at the coastal sites may have had close relationships with specific mining and smelting sites. The Vrokastro samples, on the other hand, come from a wider variety of ore bodies and for the most part there do not seem to be other similarities between samples from similar ore bodies. One exception is the two nails which appear to have originated as a single batch of metal and were treated similarly at every step of production.

Since the majority of the Vrokastro samples did not use metal that was mined or smelted on Cyprus, there is no reason to assume there would be any similarity in smelting practices to the Cypriot samples. Indeed, the samples from Vrokastro showed lower
levels of arsenic, iron, and other trace elements, indicating that they were either smelted in a less reducing atmosphere or that they were more thoroughly refined than the Cypriot samples.

The Vrokastro objects also display some variety in alloying practices. Unlike the Cypriot objects, which mostly cluster around 8-9% tin, the Vrokastro fibulae seem to form low tin group at around 3-6% tin and a high tin group with 9-10% tin. The sample size is quite small, and the pattern should not be over interpreted, but it does seem to accord with larger patterns seen in objects from other Aegean sites like Lefkandi and Nichoria.

**CONCLUSION**

Using a series of scientific tests including X-radiography, microscopy, SEM-EDS, and LA-ICP-MS, I have reconstructed the *châine opératoire* used to create bronze objects from Kourion, Lapithos, and Vrokastro. Since technological choices are culturally determined and established within learning communities, highlighting divergences in the operational sequences allowed me to identify communities of practice at work at each of the sites. I argue that the samples from Kourion can be attributed to a single community of practice, whereas the samples from Lapithos can be separated into two communities, which I label Lapithos A and Lapithos B. The Vrokastro samples are more difficult to assign, but they appear to have been by a variety of communities of practice both at Vrokastro and elsewhere.

The *châine opératoire* approach can also be used to identify signs of knowledge sharing between communities of practice. For example, communities of practice at Kourion and Lapithos use relatively similar copper smithing practices that indicate
knowledge sharing between them, and likely between many Cypriot sites, was common. Also, certain “boundary objects,” especially those from the Lapithos B group, demonstrate elements of technological style from the Lapithos community and others from the Kourion community. These objects present the best evidence for smiths moving from one site to another. At Vrokastro, on the other hand, there are not many similarities with the practices used on Cyprus. Overall, this leads me to conclude that ways of making were locally specific and that the knowledge sharing that did take place, was predominantly on a local or regional level.
CHAPTER 5: NETWORKS OF BRONZE AND IRON OBJECTS IN EARLY IRON AGE CYPRUS AND CRETE

The following two chapters of this dissertation build out from the previous in-depth, technological case study, expanding the perspective to encompass the broader social context of the spread of knowledge and innovation in the Early Iron Age eastern Mediterranean. In this study, I aim to (1) construct a network which represents social interaction between metal working communities of practice and (2) investigate the ways in which the structure of that network allowed for and shaped the flow of information and knowledge in the Early Iron Age eastern Mediterranean.

This chapter (Chapter 5) presents a blueprint for this study, including the data, which forms the foundation of the analysis, the methodologies applied to it, and the larger theoretical scaffolding. The following chapter (Chapter 6) presents the results of this analysis and discusses the implications for our broader understanding of the flows of knowledge in the Early Iron Age eastern Mediterranean.

This chapter begins with an explanation of my theoretical position. I ground my analysis in network theory, which allows me to highlight the interpersonal relationships that underpinned the communication of new ideas and the transfer of technical knowledge. I combine this approach with perspectives on the diffusion of innovation drawn from sociology. Finally, I incorporate an understanding of situated learning and the transmission of knowledge that is drawn from anthropological models of communities of practice.
In the second section of this chapter, I present the data that underlies this study. I highlight common difficulties when dealing with archaeological material and point to best practices for handling these notoriously complex datasets. I also outline the procedure I used to collect data for this study.

In the final section of this chapter, I present the specific methodologies employed in my analysis of knowledge networks. I draw heavily on quantitative methods of network analysis to generate similarity networks that represent social interactions between communities of practice. I calculate several metrics which describe the structure of the network and the diffusion processes which characterize the social system.

**DIFFUSION OF INNOVATION THEORY**

My approach to the transmission of technical knowledge and skill is shaped by several theoretical outlooks drawn from social network theory, sociological perspectives on diffusion of innovation, and communities of practice. This section outlines the ways that I draw on each of these theoretical strands and how they can be put in conversation with one another in order to elucidate the spread of information in the EIA Eastern Mediterranean.

Network analysis forms the basis of my approach. Network analysis is well suited to the study of diffusion of innovation, because it is primarily concerned with human relationships, which are the essential steppingstones for the spread of information. Networks can provide unique insights into the social structures that shape the paths along which information travels. In this study, networks are used to represent the relationships
between communities of metal workers in operation throughout the EIA eastern Mediterranean.

Network analysis and sociological models of diffusion of innovation have been considered a beneficial pairing in sociological research for some time but have only recently been used together in the archaeological literature. I use network analysis in combination with sociological models of diffusion of innovation, in order to situate the adoption of technologies in specific times and places. Whereas network analysis is particularly useful for plotting potential routes of diffusion through space, sociological models are more concerned with the temporal dimension of diffusion. The two can be used in tandem to present a holistic view of the transmission of knowledge.

I also draw on Wenger’s concept of “constellations of practice,” which provides a useful framework for understanding the ways in which communities of practice interface with one another and become entwined. Constellations of practice can be combined with network analysis to mutual advantage. Both perspectives are concerned with the socially embedded nature of learning and the transmission of knowledge. Furthermore, specific network metrics can be used to understand the structure of constellations of practice by drawing out specific clusters and points of connection between them.

**DIFFUSION AND MIGRATION IN ARCHAEOLOGICAL THEORY**

The concept of diffusion has a very fraught history in archaeological theory. In the late 19th and early 20th century diffusion, migration, and invasion were often considered the primary forces of change in prehistory. Culture-historians leaned heavily...

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61 The history of archaeological scholarship on diffusion has followed a very similar trajectory to that of migration scholarship. Anthony suggests that in avoiding the study of migration due to its problematic use
on these phenomena, often without sufficient evidence of cross-cultural contact and without considering alternative explanations for cultural change. Some culture-historians took these explanations to an extreme, attributing all cultural innovation to diffusion from a common ancestor, and even suggesting that one culture was the mother of all civilization. These arguments, which Storey and Jones refer to as “hyperdiffusionist,” left little room for investigating independent innovation or for understanding local populations as intelligent or creative (2011). The resulting scholarship varied in how far they took these assumptions, but much of it was openly racist and ethnocentric.

In the 1970s processual archaeologists rejected diffusion and migration as explanations of cultural change. They denounced diffusion as unscientific, unquantifiable, and a distraction from the development of archaeological theory. Diffusionism was replaced by explanations of cultural change that focused on the local or regional level and relied more heavily on demographic pressure and climate variation (S. R. Binford and Binford 1968; Renfrew 1972). With the advent of post-processualism in the 1990s, there was a desire to consider a wider range of factors impacting past human behavior.

Recently there has been a dramatic increase in archaeological interest in both migration and diffusion as forces of cultural change. Renewed interest in migration has been spurred on by advancements first in isotope analysis and more recently in DNA analysis that allows archaeologists to view the movement of people in the ancient world by early culture-historians, scholars have discarded “the useful migrationist baby [along with] the properly discarded bathwater” (Anthony 1990, 896).
in an altogether new way (Bentley 2006; Matisoo-Smith 2012). Scientists can now use DNA sequencing and population genetics, for example, to more precisely identify individual migratory events which occurred in the same general regions over thousands of years (Reich 2018). While these techniques may be useful in examining some (especially large scale) population movements, they are not sufficiently precise to be useful in the study of mobile craftsmen so they will not be featured in this study.

The study of diffusion, although not as directly impacted by these scientific advancements, has also been the subject of increased scholarly attention within a number of disciplinary and theoretical perspectives. Much of this research draws on network theory (Mills 2018; Peeples 2018). Increasing interest in the topic can also be seen in neo-Darwinist approaches (O’Brien 2011; Kuhn 2004; Eerkens and Lipo 2007) and in situated learning and communities of practice research (Wendrich 2013; Roux 2013; Gosselain 2008). These approaches are not incompatible, and they can be combined to produce more holistic frameworks for studying the diffusion of innovation.

Many scholars today agree that migration and diffusion have always been driving factors in cross-cultural contact. Studies of diffusion must, however, take precautions to avoid inadvertently repeating the problematic assumptions of the past. The challenge of this work is to formulate new methodologies and theoretical frameworks to bring to bear on these old questions. New approaches should encourage more nuanced understandings of the many and varied ways in which cultural contact takes place and innovations are

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62 For example strontium isotope analysis on residents of Teotihuacan (Price, Manzanilla, and Middleton 2000; Price et al. 2008; Manzanilla 2017) as well as various isotope analyses of Alpine populations (Walsh and Mocci 2011; Müller et al. 2018).
encountered, evaluated, tested, and ultimately adopted, adapted, or rejected. The goal is to acknowledge that past people were “sophisticated, innovative, intelligent, and also interactive” (Storey and Jones 2011, 7).

Despite its problematic past, I use the term “diffusion” in this study for several reasons. First, replacing the term “diffusion” with another, such as “cultural transmission,” does not avoid any of the deeper problems associated with its use. Second, its appearance serves as a reminder of its potential pitfalls and offers an opportunity to examine them openly. Finally, “diffusion of innovation” research is prevalent in other fields such as sociology and network studies, which do not have a history of misuse of the term. Since this study draws on theoretical and methodological frameworks that have their origin in these disciplines, the term “diffusion of innovation” is used in order to engage in cross-disciplinary discussion.

NETWORK APPROACHES

Networks Approaches in Archaeology

Network studies include a diverse array of approaches, which draw on a wide range of disciplinary backgrounds and theoretical perspectives to answer a variety of research questions. The field is united, however, in its focus on the relationships between entities (sites, people, objects), rather than on the entities themselves. Network approaches are concerned with the structure that is formed by the relationships between entities, and in the often-unintended ways in which that organically formed structure allows for but also constrains human activity.

The concept of networks is not new to archaeology and the term “network” has often been applied metaphorically and in a descriptive sense (Knappett 2013, 3). Over the
past few decades, however, there has been a surge of scholarly activity dedicated to the application of a formal, theoretical lens to archaeological studies of networks, which allows scholars to harness some of the explanatory power of networks (Malkin 2011). The application of a formal lens involves conceptualizing an archaeological phenomenon in such a way that network concepts and network data can be brought to bear on it (Collar et al. 2015, 4). In other words, data must be abstracted as individual “nodes” and the “edges” that connect them.

Social Network Analysis (SNA) is the type of network analysis most commonly used by archaeologists to model or uncover social systems of the past. Social Network Analysis has its roots in sociometry, which was developed in the 1930s, as well as in graph theory, statistical and probability theory, and algebraic models that were incorporated in the 1940s and 1950s. Wasserman and Faust define SNA according to its four central tenants: (1) that actors and their actions are interdependent, (2) that ties between actors are channels for the transfer of resources, (3) that the structural environment of the network provides opportunities for, or constraints on, individual action, and (4) that network models conceptualize structure (social, economic, political, and so forth) as lasting patterns of relations among actors (Wasserman and Faust 1994).

Archaeologists can apply SNA to their datasets, for example, to determine the most central nodes in a network, which could be interpreted as sites that act as leaders or bridges in a trade network. Archaeologists have also used SNA in order to hypothesize what kind of network a system of interactions formed. A particular distribution of nodes and edges could indicate, for example, a small world network, which is characterized by a small average shortest path length and large clustering coefficients (Watts and Strogatz...
Small world networks have variously been understood by archaeologists either as networks that are initially quite disparate but are drawn together by the addition of a few key connections (Malkin 2011) or as more locally grounded networks, in close contact with their neighbors and only occasional contact with far-off sites (Broodbank 2000; Tartaron 2013).

**Network Approaches to Diffusion of Innovation**

Social network analysis is particularly well suited to studying the diffusion of innovation. Rogers’ classic definition of diffusion as “the process by which an innovation is communicated through certain channels over time among the members of a social system,” can easily be understood within the terminology of social network analysis (Rogers 1983, 5). The “members of a social system” can be represented as the nodes of a network and the “channels” through which innovation is communicated can be represented as the edges. The basic tenet of diffusion of innovation research, that diffusion travels through social relationships and that these relationships are key to understanding the diffusion process, accords extremely well with social network perspectives, which hold that relationships between entities facilitates the flow of resources, both material and non-material. Brughmans notes that “according to the social networks perspective, social relations are channels of social contagion and persuasion, and as such instrumental to the diffusion process” (Brughmans 2013, 635).

The structure of a network provides the basic topography through which information diffuses and it therefore fundamentally shapes paths along which innovation can travel. Three valuable metrics that can shed light on the structure of a network are density, centrality, and clustering. These metrics are quantifiable reflections of a
network’s structure, and they allow us to come to some preliminary conclusions about the timeline and paths of diffusion. For example, density refers to the ratio of the actual number of ties to the number of all possible ties. Information spreads more rapidly and more completely in a densely connected network. Similar conclusions can be drawn from the clustering coefficient, which measures the tendency of nodes in a network to cluster together. A third metric, centrality, refers to the ranked position of a particular node in relation to other nodes in the network. For example, if an individual node is more central or in a neighborhood with high clustering it is more likely to be an early adopter. Also, if an innovation is introduced at a central node or a node with high density, it is likely to spread throughout the network more quickly than if it had been introduced at a marginal node.

Taken collectively, these metrics can help identify the overall structure of the network. For example, metrics in certain ranges can signal the network as a small-world network versus a random network. Their utility comes with especially large or complex networks. Central nodes and nodes with high density are easy to identify when working with a small or simple network, and metrics can be redundant in these cases. When dealing with networks of ever-increasing size, however, a quantifiable indication of importance and centrality can greatly simplify analysis and even reveal unexpected conclusions.

**Sociological Approaches to Diffusion of Innovation**

The study of diffusion of innovation has a long history of research in sociology. Ryan and Gross’s seminal article on the spread of hybrid corn seed use among Iowa farmers kicked off this important field of study, when they discovered that it was
interpersonal relations, rather than mass marketing, that compelled farmers to adopt a new seed type (1943). Rogers’ foundational textbook, *Diffusion of Innovations*, first printed in 1962 and now in its fifth edition, reviews many of the studies on this topic. As mentioned above, diffusion is defined by Rogers as “the process by which an innovation is communicated through certain channels over time among the members of a social system” (Rogers 1983, 10). These innovations can vary from social movements, to fashionable trends, to technological innovation.

The “rate of adoption,” and the related cumulative percentage of new adopters at any particular moment usually follows a similar pattern over time. An innovation is usually adopted first by a small number of people (known as early adopters), followed by a rapid increase in the number of adopters (majority adopters), and then as larger numbers of people adopt, the rate of adoption slows until only a few people are adopting (late adopters) and the diffusion process tapers off. When this pattern is visualized as a line graph with time from the invention of the innovation on the x-axis and cumulative percentage of adopters on the y-axis, a “diffusion curve” forms a logistic S-shape, which is characteristic of a chain reaction. Anything that diffuses through a social network should share this basic diffusion curve, but there are many variable elements of the structure of networks that can impact the exact manner in which an innovation is likely to traverse the social landscape.

Rogers argues that the diffusion of innovation is impacted by a wide range of factors including the nature of the innovation, the personal characteristics of the adopters, and social environment in which it is being transmitted (1983). Further details about how
these elements impact the way innovations are diffused and how they can be understood in a network framework follow.

**Sociological Models of Diffusion of Innovation and Networks**

Network analysis is often used as a spatial organizational technique, whereas sociological diffusion studies are more concerned with temporal tracking, investigating how easily, how far, or how completely something can spread. Combining the two techniques entails creating a network schema and then tracing the adoption of a trend through the system in order to reveal details of its transmission such as: which nodes adopted the trend relatively quickly after being exposed to it, and which ones lagged far longer than expected in adoption? Were there sites that played special roles facilitating or blocking the trend from spreading to their neighbors? What was the critical point after which the vast majority of sites decided to adopt a relatively new trend?

The most simplistic models assume that one-time contact with one “infected” individual is enough to spark “contagion” in any individual. Sociological research has proven, however, that there is considerable variation in individuals’ likelihood to adopt various innovations based on a number of factors. These factors include individual thresholds for adoption, innovativeness of individual nodes, and the speed of transfer along edges. More complex models have therefore attempted to account for some of the complexity of the lived experience of innovation diffusion.

First, the perceived attributes of an innovation influence the way it spreads. The most important factor is the perceived costs or risks associated with adopting the innovation. An innovation that presents a larger risk such as migration to an unknown location or adoption of unproven technologies will often have a higher threshold for
adoption and will thus diffuse more slowly. Costs include both direct costs (new seeds, for example) and indirect costs (specialized fertilizer for the new seeds). Indirect costs can also be non-monetary; often the associated costs are social rather than economic.

Rogers sets out five additional attributes of innovations that impact their diffusion: (1) “relative advantage,” or the degree to which the innovation is perceived as better than the innovation it supplants, (2) “compatibility” with the values, beliefs, and past experiences of individuals in the social system, (3) “complexity,” or the degree to which the innovation is perceived as difficult to learn or understand, (4) “trialability,” or the degree to which the innovation may be experimented with on a trial basis, and (5) “observability,” or the degree to which the results of the innovation are visible to others (Rogers 1983, 14–16). Importantly, these attributes have more to do with the perceived values and risks of the innovations than the actual values and risks. For archaeologists, it is very difficult to know what beliefs might have been held about innovations.

Second, differences in adoption patterns also emerge based on the personal characteristics of the social actors. Rogers defines a number of “adoption categories,” which classify people according to their adoption time relative to all other adopters. These categories include: (1) innovators, (2) early adopters, (3) early majority, (4) late majority, and (5) laggards (Rogers 1983, 22). The “innovation-decision process” takes time and it involves a sequence of events, which Rogers defines as (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation (Rogers 1983, 20–22). Different individuals will go through this process at different time scales.

Another way to investigate the innovativeness of different actors is to look at “threshold categories,” which consider the actor’s willingness to adopt innovations in
relation to their personal network. In network models, it is assumed that actors expose all of their contacts to innovations that they have already adopted. It is logical to assume that an actor is more likely to adopt when they have been exposed to an innovation from multiple other adopters. The “exposure” of a node at a particular moment is the proportion of those nodes to which the node is connected who have adopted before that time. Different actors usually require different levels of exposure before they choose to adopt. In other words, some actors are more easily persuaded than others. The “threshold” of an actor can be understood as their exposure at the time of adoption.

In conclusion, network analysis and diffusion studies, when analyzed together, imbue a system with a dimensionality unachieved by either technique alone. The network structure acts as a substrate, like a base map, shaping and delimiting the way innovation flows. The social factors related to the diffusion process, such as thresholds, add an additional dimension, giving the base map topography with peaks and valleys. The ways in which the innovation or trend forms, spreads, and dissipates are ultimately influenced by both the network structure and the social factors.

CONSTELLATIONS OF PRACTICE

The related frameworks of situated learning and communities of practice have entered archaeology as a productive way to investigate social relationships and the transmission of embodied knowledge and skill. Since these two perspectives are addressed in Chapter 3, they will not be detailed here. Instead I focus on the related concept of “constellations of practice.”
Scholars working with the communities of practice framework have recognized the need to address the scalar aspects of learning and the transmission of knowledge (Roddick and Stahl 2016, 4). Communities of practice are traditionally understood to rely on frequent face-to-face interactions between participants and therefore to be hyper-localized entities. It is clear, however, that many crafting practices and techniques spread outside these confines, moving from one community of practice to another. How were these techniques encountered, reproduced, and transformed as they moved through larger expanses of space and time? Questions like this led Wenger to coin the term “constellations of practice,” referring to configurations “too far removed from the scope of engagement of participants, too broad, too diverse, or too diffuse to be usefully treated as single communities of practice” (Wenger 1998, 126–27).

Constellations of practice allow for the theorization of learning that takes place among more dispersed groups of practitioners, across different communities of practice. Wenger provides a number of reasons that one might group communities of practice together into a constellation including (1) shared historical roots, (2) having related enterprises, (3) serving a cause or belonging to an institution, (4) facing similar conditions, (5) having members in common, (6) sharing artifacts, (7) having geographical relations of proximity or interaction, (8) having overlapping styles or discourses, and (9) competing for the same resources (Wenger 1998, 127). A constellation can be variously defined according to the viewpoint of a member of the group or an outside observer. Consequently, a constellation may or may not be recognized by its participants (Wenger 1998, 127).
The concept of constellations of practice has recently been taken up by some anthropologists and archaeologists working on material culture and especially craft production (Mills 2016; Roddick and Stahl 2016). Archaeologists often work at broad temporal and geographic scales, which are well suited to a constellations of practice framework.

**Boundary Objects and Brokerage**

Communities of practice may be linked by common objects, practices, or discourses, known as “boundary objects.” This term can be applied to both objects and practices that either travel between communities or occupy the boundaries between communities, as well as elements of style that spread as people copy, borrow, imitate, import, adapt, and reinterpret ways of behaving (Wenger 1998, 129). The presence of objects or practices that travel between communities of practice provide a way for archaeologists to investigate these connections between communities. For example, Mills has used the concept of boundary objects in her study of potting communities of practice in the American Southwest and on “how marriage networks created opportunities for innovation through the production, distribution, and consumption of boundary objects” (Mills 2018, 1051).

**Constellating Practice and Network Analysis**

Both networks and communities of practice offer important insights into the ways that knowledge is transmitted, and they offer similar and compatible views on that process. Both approaches see learning as a social process, emphasizing the importance of interpersonal relationships in the adoption of innovative technologies. Both are also concerned with investigating the structure of social relations in order to identify specific
sources and channels for resources and information. Finally, both can be easily deployed in the study of multi-scalar phenomena.

Wenger does not himself incorporate a network approach. He advocates a “focus on the practice that is created in the process rather than on the network of relations and the flow of information” (Wenger 1998, 287). Mills, however, points out that there is nothing inherent to network approaches that excludes an investigation of process or practice, topics which many network scholars are interested in exploring (Mills 2016, 251). Mills and other scholars have successfully combined communities of practice theory and network approaches (Knappett 2013; Mills 2016; Blair 2016; Peeples 2018).

Beyond their general similarities in outlook, there are some specific ways that constellations of practice approaches can be used in tandem with social network analysis to provide further insight into the diffusion of innovation. Several facets of network structure, such as clustering and centrality can be viewed through the lens of communities of practice. A few examples are given below:

1. Identifying communities of practice in networks

Clusters within a network can be seen as proxies for communities of practice. Clusters represent groupings of nodes that are pulled together by their proximity and by overlapping edges that entangle the group. Likewise, communities of practice are linked by common practices and by their participation in group dynamics. Blair uses different clustering metrics to investigate communities of practice at both the production and consumption level (Blair 2016).
Another way to conceptualize communities of practice within a network is to investigate the strength of the ties that draw the community together. Communities of practice research posits that learning takes place in close-knit communities and involves hands-on participation. Similar ideas regarding the necessary strength of interpersonal relations for the adoption of new technologies are also emerging in network studies.

Whereas Granovetter’s influential study, “The Strength of Weak Ties,” suggested that “weak ties” connecting distant acquaintances are instrumental to the flow of information, since they provided short-cuts between otherwise distant nodes (Granovetter 1973), Centola and Macy have argued that complex contagions, defined as “behaviors [that] are costly, risky, or controversial,” require social affirmation and reinforcement before they are adopted (Centola and Macy 2007). Whereas weak ties provide unique information from distant sources, strong ties between friends tend to be redundant and reinforce the same information from multiple friends, which provides the validation from multiple sources that is necessary for the adoption of complex contagions (Centola and Macy 2007). This reinforces the basic conceit of communities of practice research, that complex technologies are more likely to be learned within the confines of a community of practice.

2. Identifying brokers, boundary objects, and other roles within the network

As mentioned above, “brokers” and “boundary objects” are people, objects, or practices which connect multiple communities of practice into larger constellations. The concept of brokerage is also a popular one in network analysis, where a broker is a node which connects previously unconnected actors (Peeples and Haas 2013). These network brokers can be identified using network analysis, opening up possibilities for identifying
boundary objects and brokers which pull communities together. Blair uses another method to identify boundary objects. He identifies nodes that move from cluster to cluster depending on the method of cluster analysis used. Since his clusters represent different communities of practice, nodes that can be variously associated with multiple clusters are argued to have links to multiple communities of practice (Blair 2016).

Blair suggests that some common network metrics such as centrality might also be used to identify important roles within communities of practice. For example, he suggests that more central nodes might be considered old-timers in the community of practice, since they are very well-connected (Blair 2016, 114).

COLLECTING DATA FOR NETWORKS OF KNOWLEDGE

In this section, I present the data used as the foundation for building the networks described in this chapter. I begin with an overview of some problems commonly encountered when working with archaeological data, which is by its nature incomplete. Network analysis was not designed with archaeological datasets in mind and it is important to acknowledge the limitations that are inherent in working with archaeological data. In the section, I argue that quantitative data produced with network analysis should be treated with caution and that the network analysis presented in my dissertation should be seen as a data visualization exercise, intended to shed light on new ways of thinking about old questions, rather than providing definite answers or predictive models.

I also define the scope of the data used in this study, which is drawn from metal objects from Early Iron Age contexts in Cyprus and Crete taken from published excavation reports. In particular cases, I also draw on unpublished field reports and
Each metal object is recorded with information about its context, date, material, dimensions, and “technological style,” which is broken down into a number of visible attributes described below. This data is used to form a general-similarity network in which the similarity of objects is employed as the defining edge characteristic.

DEALING WITH ARCHAEOLOGICAL DATA

Network analysis has provided scholars in many disciplines with a powerful tool for the visualization and analysis of large volumes of data. As a result, new data sets can be envisaged and interrogated in ways that provoke new ways of looking at old questions. Network analysis presents some clear advantages over other multivariate analytical techniques, such as cluster or principal components analysis, since it is multi-scalar and places an emphasis on interactions and connectivity. While network analysis has a lot to offer archaeologists, it was originally designed to handle very different data sets than the ones currently available to most archaeologists. Most network methods presuppose robust data that does not suffer from the uncertainty and incomplete nature of the archaeological record. Network analysis is still a powerful and helpful tool, but it should be used with a certain amount of caution.

Incomplete Datasets

Archaeological data sets present unique challenges because they inevitably represent incomplete records of past social systems. The physical remains left behind as a result of social relationships are limited in their ability to reveal the social relationships

63 This is true for the sites of Kourion, Lapithos, and Vrokastro, which form the case study in the previous section of my dissertation.
themselves. In other words, archaeologists must use material remains as a proxy for social relationships which cannot be directly investigated. Furthermore, archaeologists must confront problems relating to survival, sampling, and comparability (Sindbæk 2007, 74). The differential survival of certain materials over others in the archaeological record leads to an imperfect and biased record of past social relationships. Of the materials that survive, sampling bias will inevitably affect which are excavated and published.

These issues of survival and sampling indicate that there is undoubtedly information missing from the archaeological record, but it is difficult to know the scale of that missing information. It is therefore necessary to consider potential gaps in the data and how they might impact the results of network analysis. For example, the picture of Northern Cyprus presented in this study would undoubtedly look different if excavations had continued until the present day. On the whole, the incomplete nature of the data means that archaeologically-based networks, though useful, cannot be taken as accurate predictions of ancient behavior. Instead, they should be seen as useful tools for synthesizing and visualizing data and revealing patterns that would not be discernable otherwise.

Black Boxes

For most of their use-life, objects’ paths through time and space remain obscured to archaeologists. Often the only locational information available about an object is its final destination. In some cases, source determination can provide further information about where the material originated. Nevertheless, the path along which an object traveled and the hands it passed through to get to its final destination are almost always unknown. Archaeologists generally lack the transactional data needed to distinguish an
object which arrived in a final location through down-the-line trade from one that arrived as a result of the movement of populations, for example. Renfrew notes the multiplicity of pathways and modes of exchange that objects can travel along (Renfrew 1975). The issue of opacity of transmission is especially true of metal objects, which can be melted down and re-formed to live another life as entirely new objects. Sindbæk refers to this informational difficulty as a “black box” problem, since in dealing with ancient networks some of the inputs and outputs are known, but the interior process is concealed from view (Sindbæk 2007, 71). Despite their murkiness, the internal workings of the “black box” are the primary interest of many archaeologists.

Many archaeological networks are based on the similarity of assemblages between sites. These similarities can reflect a number of social processes including “exchange, emulation, population movement, and especially, shared contexts of production or learning” (Peeples et al. 2016, 61). Often, they reflect a number of these factors combined. Therefore, while comparing assemblages can give a general indication of the closeness between sites that may result from these processes, it cannot disentangle the various threads that came together to create the connection or determine which of those processes is most responsible for the similarity of the assemblage.

Data for Networks of Knowledge and Diffusion of Innovations

As with any other type of analysis, it is important to keep in mind what a data set can and cannot speak to regarding social relationships. Various types of data are better suited to different research questions. For example, source determination data can be used to form networks of production (Mills, Clark, et al. 2013), whereas data related to object frequencies within assemblages is better suited to networks of consumption (Mills 2016).
For the time in between production and deposition, however, there is no convenient statistic that directly addresses exchange, emulation, migration, or shared production contexts (Peeples et al. 2016, 61). Investigating shared communities of practice and knowledge networks requires the application of different data than would be used in investigating exchange networks. Scholars who have applied a network perspective to the study of communities of practice have typically based their analyses around the similarity of objects across sites. They have, however, approached data collection in unique ways, and the object attributes they have chosen to highlight are different. Östborn and Gerding (2015) investigate the diffusion of fired bricks in the Hellenistic world, using brick dimensions and architectural contexts as the basis of similarities. Peeples looks at technological style in pottery from the Greater Cibola Region. His attributes for comparison have to do with forming practices such as coil width, smudging, indentation alignment, and surface treatment (Peeples 2018). Blair investigates bead-making and bead-consuming communities of practice at 17th century Mission Santa Catalina de Guale. He uses glass-making and bead-finishing processes as his similarity criteria (Blair 2016). I draw heavily on these three studies in the formation of my own criteria for data collection.

My study is, however, constrained by certain challenges associated with the investigation of metal objects. First, metalworking techniques, unlike forming techniques of ceramic vessels, are very difficult to investigate macroscopically. Many important steps in the formation of metals can only be understood through microscopic and chemical testing, which require destructive sampling. Limiting the data to sampled metals would make the data for the network too sparse to be statistically significant. In order to
account for this trade-off, my networks consist of a large number of unsampled objects. Second, unlike pottery or bricks, for which a convincing argument can potentially be made that much of it was produced and consumed locally, small metal objects like the ones included in this study are highly mobile objects. Due to both their higher value and their small size, these objects were likely to travel long distances and pass through many hands before arriving at their final destination.

DATA SELECTION AND COLLECTION

The fundamental starting point for any network is how nodes and edges are defined. For this study, I built an “object-based” network, which used objects as the nodes. This network is a similarity network, which use relative similarities in attributes to connect nodes. The data used in these networks was collected from published data and in some cases from personal observations and scientific analysis. It was aggregated and compiled in an excel spreadsheet. The geographical location, site type, site size, and date were recorded for 3 sites in Crete and 4 sites in Cyprus. The full assemblage of bronze and iron objects, including object attributes such as object type, dimensions, date, and decorative features were also recorded.

Site Selection, Definition, and Attributes

In deciding which sites to include in the database, I looked for sites that would provide similar granularity of data in order to support meaningful comparisons. I limited the pool of available sites to those that have been systematically excavated and published, reaching a minimum standard for data quality. In order to ensure that my findings will be as accurate as possible, I only targeted studies in which the publication of metal objects
contained at least a basic description and dimensions of each object. As a result, many sites that have only been preliminarily or partially published were excluded.

Object Selection and Attributes
I only include bronze and iron objects in this study. The bronze objects include items of ornament (fibulae, pins, and rings), vessels (bowls), and weapons (knives, daggers, spearheads). The iron objects are restricted to weapons (knives, daggers, spearheads). These object types were chosen because they were found to be the most common in the archaeological reports. Since they are commonly found at most sites, they can be compared across sites, whereas miscellany cannot. Miscellaneous objects were not included in the object-based networks. The recorded object attributes differed for various object types, and information on attributes, objects types, and sites can be found in Figures 233-236.

Dating Archaeological Materials
Drawing connections between objects at different sites based on their similarities is a useful exercise, but connections formed in this way are only meaningful if the assemblages are of the same period. Thus, connections should only be formed if it can be established that the sites are contemporaneous, adding credence to the argument that the similarity could be the result of social interaction and not happenstance. This makes a “date” attribute distinct from, and more crucial than, other attributes, since overlapping dates are a necessary precondition for any further assessment of similarity.

The difficulty of dating metal objects is of particular relevance here. Metal objects cannot be dated very precisely, since metallurgical styles do not change as quickly as styles in other media, such as ceramics. The objects in this study are therefore typically
dated based on pottery associated with the burial or tomb in which they were found. While some metal objects can be more precisely dated based on their association with a particular burial, many can only be associated with the tomb as a whole, due to post-depositional processes both environmental and human.\textsuperscript{64} Thus the tomb date is often the limiting factor on the precision of the dating, and many of the tombs under study were occupied for centuries, spanning multiple periods.

In order to assess whether the date of various contexts overlap, it is necessary to quantify the date in some way. Most archaeologists using network analysis approach this by dividing their time period of interest into equal time slices. These can vary from 1,000-year intervals in the Neolithic Near East (Coward 2013) to 50-year intervals in the Late Prehispanic US Southwest (Mills, Roberts, et al. 2013). Creating these time slices involves the transformation of relative chronologies into discreet date ranges. The cross-regional nature of my study adds an additional level of complexity. The dates given in publications use the unique relative chronologies of each of the regions under study. It is therefore necessary to correlate the relative dating of each region. For this I have relied on generally accepted equivalences between chronologies based on the work of many scholars before me (see Fig. 2). I elected to split the chronological data by period, rather than by a set interval of years. This accounts for the fact that some of the periods are considerably longer than others (CG III for example lasts approximately 150 years, where CG II lasts only 50).

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\textsuperscript{64} At Lapithos in particular, flooding has affected most of the tombs.
METHODS AND ANALYSIS

In this study I employ a combination of quantitative and qualitative methods in order to evaluate the networks of knowledge that were at play in the Early Iron Age Eastern Mediterranean. By placing my data within the schema of a network, I am able to arrange it using various similarity criteria, which reveal new points of connection and identify paths of transmission. This allows me to track streams of diffusion as they move through the network.

First, I assemble object data and rely on the objects and their attributes to construct several general-similarity networks, where connections are made between objects based on the similarity of predetermined attributes for each object type. These attributes could include, for example, the material (bronze or iron) and number (1-6) of rivets used to secure hilt plates to an iron knife. The resulting networks display groupings of objects based on the similarity of their working techniques and technological style, which shed light on the interactions of metalworking communities over time. Once these networks have been constructed, I analyze the different similarity-networks by object type, which can be broadly classified as either site-specific graphs or time-specific graphs. I use a set of quantitative metrics to investigate the structure of these networks and identify local and global trends in the data. For example, some nodes are central in their immediate communities, while others occupy a central position in the entire network system. I use these metrics in combination with a more qualitative understanding of network dynamics that draws on communities of practice frameworks. Finally, I track the temporal trends in object styles and locations, and I apply a number of statistical tests to the network data to give credence to the observed trends (discussed below).
The overarching framework of network approaches includes a diverse array of methods, making it a very flexible perspective. Archaeologists working with networks have applied both highly quantitative approaches, which rely heavily on mathematical models borrowed from other disciplines, and more qualitative models, which make use of networks as analogies without quantifying their results (Brughmans 2013; Knappett 2013; Mills 2017; Collar et al. 2015; Malkin c2011; Tartaron 2013). There are of course benefits and limitations to both of these methods. Quantitative and qualitative models are not mutually exclusive, and this study draws on elements of each to investigate knowledge networks and the diffusion of innovation in the EIA eastern Mediterranean.

Although quantitative methods can sometimes elucidate possibilities that would not have been uncovered with qualitative methods, they have the potential to be over-interpreted (Östborn and Gerding 2014, 79). Mathematical models can lend an aura of scientific authenticity to the results that appears to certify them, but this is often misleading (Malkin c2011; Tartaron 2018). All models should be approached with caution, since the quality of the results is highly dependent on the data available and any associated uncertainties. The incomplete nature of archaeological data itself means that it is impossible to say that the current material record is a representative sample of the past, ruling out any claim to statistical exactness. Also, all models are subjective and are influenced and distorted by all of the choices made by the researcher. The researchers choose the criteria on which connections are based, as well as individual ranges of values within the criteria. The researcher also chooses what types of tests to perform and which features to more thoroughly investigate, undoubtedly omitting many relevant aspects of
the network (Östborn and Gerding 2014, 83–84). For this reason, it is of paramount importance that the various decisions that went into the analysis are made clear and that any alternate possibilities are investigated and presented.

In this study I employ quantitative methods as a starting point, but I do not aim to achieve predictive quantitative results. Instead, I follow Östborn and Gerding in suggesting that general similarity networks should be seen as a qualitative method with quantitative outputs (Östborn and Gerding 2014, 83). The networks created in this study are intended to reflect current understanding of knowledge networks in the EIA and to present them in a way that provokes further discussion and suggests directions for future investigation.

BUILDING THE NETWORK

General Similarity Networks

In archaeological studies, the edges that connect nodes can be roughly divided into three different types of evidence, although researchers are not limited to any one of these methods, and often they combine multiple lines of evidence. First, the edges may be based on the geographical distance between sites. This is the case, for example, in nearest neighbor or proximal point analysis (PPA), which is particularly popular in island archaeology and can be seen in the work of Knappett and colleagues (Broodbank 2000; Knappett, Evans, and Rivers 2008). Second, written sources can be used to form historical networks, which include both route networks, such as Graham’s study of the stops along the Antonine Itinerary (Graham 2006), and networks based on epigraphic evidence (Collar 2013). Finally, the edges can be based on site similarity, usually
measures based on the co-presence of similar objects types in the site assemblages (Sindbæk 2007; Blake 2014; Mills, Roberts, et al. 2013).

In this study, I employed the third method, which relies on “general similarity networks” (Östborn and Gerding 2014). Similarity-based networks are based on the assumption that more similar assemblages are indicative of increased social interaction. They have been used to address a range of research topics including social networks, trade networks, and the formation of ethnic identity. For example, Sindbæk studied Viking Age trade routes in Scandinavia in a system where edges were formed by the co-presence of any artifact type between pairs of sites, with the additional restriction that edges were formed along shortest paths (Sindbæk 2007). Coward also used pairwise co-presence of objects and found that there were statistically significant trends in social network formation over time in the early Neolithic Near East (Coward 2010). Gjesfjeld and Phillips used similarity analysis with edges based on co-presence of clay sources to construct social networks and shared production contexts in the Kuril Islands (Gjesfjeld and Phillips 2013). Blake used co-presence of artifacts in pre-Roman Italy, with the stipulation that edges could be no longer than 50 km, to investigate the emergence of ethnic identities (Blake 2013).

Similarity networks are also a common method of investigating communities of practice and the diffusion of innovation, which are of particular importance to this project (Peeples 2018; Östborn and Gerding 2015; Blair 2016). Similarity networks are well suited to the identification of similar technological styles, which can be used to identify

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65 Although it cannot be proven that assemblage similarity reflects interaction, it has been used as a reasonable proxy by many archaeologists. See (Östborn and Gerding 2014) for a list.
communities of practice. It is then possible to track the diffusion of techniques through time. Östborn and Gerding, Peeples, and Blair all use similarity networks based on co-presence of objects between pairs of sites to form the edges in their networks. Their projects differ in many other ways, however, including in the significance threshold for an edge and in the specific calculation of the similarity (discussed below).

In this study, I employed similarity networks, but rather than using the similarity between assemblages to construct ties between sites, I use the similarity between objects to connect the objects themselves. The networks included in this study use objects as nodes and similarities between object attributes as the basis for edges. For example, there is a network of fibulae in which the connections between fibulae were based on the relative similarity of the attributes of each pair of fibulae. I refer to these networks as “object-based” similarity networks. Each object-based network includes only one object type (e.g. fibulae, pins, rings, etc.). This restriction is necessary in order to compare object attributes across all objects in the category, since it would be meaningless to compare the attributes of a fibula to the attributes of a bowl, for example. Object-based networks allow for the investigation of the relative spread and distribution of certain technological and stylistic attributes, which can be used to investigate communities of practice. In my formulation, edges between objects are based on similarities in a number of attributes and are intended to represent a certain level of technological similarity between the objects. These networks rely only on the similarities between objects and are independent of their sites of origin.
**Similarity Matrices**

The first step in calculating similarity scores for the object-networks was to produce a database for each object type (fibula, bowl, etc.) with each of the objects as the rows and each of the object attributes as the columns. The similarity of the object attributes was used to assign edges between the nodes. Mathematically, the initial matrix has dimensions \( n \times p \), with \( n \) being the number of objects and \( p \) being the number of attributes. The database was then used to construct “similarity matrices,” in Microsoft Excel, which contains the objects as both rows and columns. The entries in this matrix are based on the number of common attributes between pairs of objects. If, for example, object A and object B both share a certain object attribute which is not present in object C, there would be a similarity score (e.g. “1”) between A and B but a score of “0” between A and C and between B and C. This process is then repeated for all attributes and for all pairs of objects until the final matrix is established. The end result is an \( n \times n \) matrix, with the entries of the matrix calculated from \( p \) attributes (Habiba et al. 2018, 63).

It is from these matrices that the object-networks were constructed.

Attributes in the object-networks can be broadly classified into two groupings: (1) continuous or discrete numbers, and (2) categories. Each type of data must be quantified in some way to produce a similarity score, although the methods of quantification vary between data types. Dealing with discrete or continuous data sometimes needs to be manipulated in order to calculate relative similarity. Discrete attributes, such as the number of spring rotations in a fibula, are the easiest to handle. For example, if two fibulae each have one spring rotation, there is a point of similarity, but if one has two spring rotations and another has one spring rotation, there is no similarity for this
attribute. In some cases where a few objects have uncommon discrete values, such as the number of rivets for a knife, bucketing was used to keep the number of possible values small. The number of rivets has categories of “0”, “1”, “2”, and “3+” and objects in the same category have similarity for that attribute. Continuous attributes, such as the bowl diameter, can have a similarity condition based on overlapping intervals. If two objects have values within a certain interval of each other (e.g. two centimeters for bowl diameter), a point of similarity is recorded.

Most of the attributes in the object-networks contain data that are sorted into several possible categories which are qualitative in nature. In some cases, such as the knife edge shape, there are only three choices of category which do not overlap (concave, convex, and straight). For data with more gradual differences, entries for each attribute are placed on a relative scale in order to extract quantifiable metrics. For example, the “1st bead size” attribute for fibula consists of the following possible values: very small, small, small/medium, medium, medium/large, large, very large. Then, interval matching is employed in one step each direction. This means that a small/medium object will have a point of similarity with a small object or a medium object, but not a medium/large object. This inclusivity is employed so that a potential arbitrary ruling on size does not needlessly sever a connection. The majority of the attributes in the object-networks employ some sort of gradual scale.

Once these levels of similarity have been measured for each individual attribute in an object-network, they can be combined into a single similarity score for each pair of objects. A total similarity score between two contexts is calculating by the summing up all of the similarity points for shared attributes. Simple addition across all attributes is
known as the Euclidean distance method. Overall similarity scores will be higher for pairs of objects which have more attributes in common and will thus properly reflect the strength of a connection. The above procedure is a specific instance of a general technique referred to as the m-slice method.

The final consideration for inclusion in a network is the dating. If the date range for two objects do not overlap at any point, the pair is given an overall similarity score of 0 and the connection is not included in the network. If the date ranges overlap at any point, the objects are included in the network. This final dating criterion reflects the fact that only contexts that were active during the same time period can be considered possible candidates for a social relationship and for the transmission of information.

The m-slice method is one way to produce similarity scores for a dataset and to visualize the result. Another approach applicable for datasets with many attributes is multidimensional scaling, also known as principal coordinates analysis. In his study of technological style in pottery from the Greater Cibola Region, Peeples used principal coordinates analysis to plot data points according to similarity, and then used cluster analysis to identify groups of similarity on the basis of their scores (Peeples 2018). Principal coordinates analysis allows for the integration of more complex data, but in the process the data loses much of its granularity and specificity (Östborn and Gerding 2014).

In this study, I choose to rely on the m-slice method to form edge connections in order to retain more information in the connections in the network. One advantage of the m-slice method is all of the original attributes remain accessible at every stage in the analysis. This can be contrasted with principal coordinates analysis, which converts all the data into a convenient but inherently meaningless system of coordinates. The m-slice
method is especially useful in cases of technological diffusion because certain attributes may flow differently through the network, and m-slice allows these attributes to be individually investigated.

**Thresholds for Adding Edges**

One further step is required in order to decide which nodes should receive a connection for each particular network. Not every similarity score can be converted to an edge in a network, since doing so would lead to a messy diagram and deprive the network of its usefulness. There must be a “threshold” or cut-off for how high a similarity score between two nodes must be in order to warrant the addition of an edge between them. There are different techniques for how to choose which connections are most appropriate. Peeples advocates running Monte Carlo simulations to determine what score a random connection would produce and then assigning the threshold to be one standard deviation higher than the average random score, ultimately arriving at a similarity score of .66 and above making the cut (Peeples 2018). Östborn and Gerding ran multiple trials with cutoff scores ranging from 8 or more similarities (X=8) for a connection to 13 or more similarities (X=13) for a connection. They ultimately decided to use the “critical value” of X=9, the point above which the network thinned out and split into two separate networks (Östborn and Gerding 2014). For this project I chose to follow Östborn and Gerding. Separate thresholds were chosen for each graph, selected to be the similarity score above which the network began to break apart. One added benefit of this approach is the ability to create different versions of a network based on more and more stringent connection requirements to view the evolution of the network and to see how the model behaves in different situations.
Networks are sometimes depicted with weighted edges, where stronger connections are seen as more important. In this study, weighted edges are used in the construction of the network, but the impact of the edge weighting is diminished due to the use of thresholds. Connections are included on a graph if and only if the total similarity score is greater than or equal to the chosen threshold. In addition, weighted edges are used in this study to yield information in the analysis of the network metrics. For example, weighted edges are used in the calculation of eigenvector centrality (explained below), one of several measures of importance in a network.

The edges of the network can be directed or undirected. Undirected edges indicate no directional relationship between two connected nodes, while directed edges indicate that the direction of the interaction is important. When studying the diffusion of information, it is useful to include directed edges in order to look at the direction of the flow of information. One simple way to determine the direction of the nodes is to look at which context has an earlier date (Östborn and Gerding 2014). Analyzing a network using directed edges can shed light on the spatial flow of information, either directional or from larger cities down to smaller towns.

**METHODS OF ANALYSIS**

The network described above was constructed using “igraph” package in R. I then employed several metrics in order to categorize the network structure and look at diffusion trends. These metrics can be calculated at both the local level (individual nodes) and global level (the entire network) in order to characterize different elements of graph structure (Peeples et al. 2016).
**Clustering**

Clustering is the quality most fundamentally linked to the structure of a network. Clustering of nodes in a network can provide strong evidence that a structure is not random (Östborn and Gerding 2015). I use clustering in two related ways. First, I employ cluster analysis to supplement visual grouping of nodes in order to discern the network structure. In doing so, I rely chiefly on k-means cluster analysis, which aims to simultaneously minimize the least-squares Euclidean distance between nodes within clusters and maximize the least-squares Euclidean distance between clusters. I relied on the optimal, fast greedy, and spinglass algorithm functions inherent in the igraph package of R for clustering detection. Second, I calculate the clustering coefficients of all of the nodes in order to analyze clustering at a local level. The clustering coefficient for a node is calculated by taking all of the nodes connected to it (“neighboring nodes”), considering all potential pairs of neighboring nodes, and calculating the ratio of those pairs that are actually connected. Looking at clustering coefficients on a local level can reveal important or central nodes that might not be apparent based on purely visual analysis. In diffusive systems, higher clustering generally indicates the potential for quicker spread of technology.

**Centrality**

Centrality refers to measures that summarize the ranked position of a particular node in relation to other nodes in the network. There are several methods for assessing centrality, including (1) degree centrality, (2) closeness centrality, (3) betweenness centrality, and (4) eigenvector centrality. Degree centrality is a localized measure and is the simplest of the four measures listed above, representing purely the number of neighboring nodes connected to a selected node. Degree signifies importance to the
extent that importance is correlated with direct connections. In a diffusion context, a higher degree measure for a node indicates more opportunities for something to spread to that node. Closeness centrality is a global measure, taking into account the overall network structure. It considers the shortest-path distances from one node to all other nodes. Nodes with high closeness centrality are important in diffusion since they decrease the time it takes for information to spread between peripheral nodes. Betweenness centrality is also a global measure and considers how nodes bridge the paths between all of the nodes in the system. Nodes with high betweenness centrality serve as important links between otherwise unconnected areas of a network. In a diffusive system, nodes with high betweenness centrality act as gatekeepers, having the ability to introduce, mediate, or even cut off the spread of information to certain parts of the network. Finally, eigenvector centrality is a metric that places importance on nodes that are connected to other “important” nodes. Connections are not valued equally, and a node will have a higher score based on a connection to an “important” node versus the same connection to a less important node. Google’s page rank algorithm, for example, is based on eigenvector centrality (de Nooy et al. 2005).

I calculated and compared all of these centrality measures. When considered as a whole, they shed important light on how the network is structured, how information can flow, and which individual nodes serve the most important roles in the system. While all methods of centrality added something to the overall understanding of the network structure, the betweenness centrality score is the most significant to my project. Nodes with high betweenness centrality can be cultural mediators and are located in positions that bridge between different cultural areas. In cases of technological diffusion and the
spread of innovation, bridge nodes are extremely important for seeing whether a technological innovation will continue to disperse or will die out.

*Shortest Paths and Edge Lengths*

Analyzing the paths in a network can also elucidate network characteristics and structure. A shortest path for any two nodes consists of the links traversed in order to travel from one node to the other in as few connections as possible. When the lengths of the shortest paths for all pairs of nodes in a network are averaged together, the result is a metric called the average shortest path. The average shortest path can contribute to the determination of a network’s structure. For example, small-world networks and random networks are characterized by a low average shortest path length, whereas a lattice-like network typically has a longer average shortest path length (Östborn and Gerding 2015, 311). Furthermore, in a time dependent network, mapping the shortest path between the earliest node and latest node indicates a simplified trajectory of diffusion in one helpful visual.

The distribution of edge lengths can also reveal and quantify the structure of a network. For example, small-world networks will have a substantial number of large edge lengths, whereas lattice-like networks will have mostly short edge lengths and random networks will have uniformly distributed edge lengths. In my site-specific graphs, I defined the length of an edge as the number of years between the dates of the two nodes that edge connects.

**Statistical Testing**

Once a network is constructed and all of the network metrics have been calculated, it is crucial to affirm that the patterns of connections in the network are not a
result of random chance. This is especially important to consider when dealing with a diffusion network. Diffusion processes are both spatially and temporally dependent, and it is necessary to test whether the diffusion across time and space is statistically significant. I performed significance testing for temporal diffusion in my site-specific networks.

Like Östborn and Gerding, I defined diffusion as “if and only if causal links between contexts are such that it is by cause and effect (and not random)” (Östborn and Gerding 2015). In order to determine whether or not the diffusion was random, I employed random permutation tests to look at the median edge lengths of the network. For diffusive networks, one would expect to see a correlation between similarity and dating (temporal diffusion). Temporal random permutation testing involves keeping all of the attributes of a node the same except the date - the date is then randomly assigned as the location of an existing node, and this process is repeated for every node. This randomization, and the subsequently-explained comparisons that accompany the randomization, was simulated 10,000 times to ensure consistency and accuracy.

A network was then created for the newly randomized nodes and compared with the original network. The networks were then compared based on median edge length. If the original network has a lower median edge length than, for example, a temporally randomized network, this means that connections are formed between nodes with closer temporal proximity more often than would be expected for random connections. This provides statistical rigor to the assertion that diffusion is taking place. Finally, median edge length is not the only point of comparison. All of the metrics listed before, such as clustering coefficients and path length, can be compared between the original networks.
and randomized networks to see whether the network shape is statistically significant and not random (Östborn and Gerding 2015).

**CONCLUSION**

The goal of this chapter has been to present the theory, data, and methods which form the basis of my study of the networks of knowledge in the EIA eastern Mediterranean. I employ data about metal objects excavated from EIA sites in the eastern Mediterranean drawn primarily from published reports and supplemented with my own observations in particular cases. This data is used as the basis for the formation of several related general-similarity networks. Various aspects of the networks’ structure are investigated in order to learn how the structure of the network impacts the way knowledge diffuses through the system. I supplement my interpretation of these quantitative network measures with an understanding of the transmission of knowledge, which is grounded in the sociology of knowledge and communities of practice-based research.

In this study I ultimately seek to understand how technological knowledge and innovations in metalworking practices were diffused on a local and regional scale. I investigate questions such as: (1) which sites played key roles in shaping paths of diffusion, either as gatekeepers, hubs, or bridges and why do certain sites hold these positions, (2) which sites were early or late adopters of new technologies and was the adoption time influenced by their position in the overall network structure or by non-structural cultural factors, (3) are pathways of transmission significantly different on local, versus regional, scales, and (4) how did the structure of the network shift over time and how did that impact the changing pathways of diffusion throughout the EIA?
Chapter 6, I apply the methodological and theoretical frameworks presented here to the data set of metal objects drawn from published excavations in order to address these questions.
CHAPTER 6: RESULTS AND DISCUSSION OF NETWORKS OF BRONZE AND IRON OBJECTS IN EARLY IRON AGE CYPRUS AND CRETE

This chapter details the results of the network analysis of published bronze and iron objects from EIA sites in Cyprus (Palaepaphos, Kourion, Amathous, and Lapithos) and Crete (Knossos, Vrokastro, and Kavousi) and discusses its implications. I begin with a brief overview of the published data included in the analysis. The second section of the chapter presents the network analysis of the bronze and iron objects from Cypriot sites. This is organized by object type and broken down by site and time period. The third section presents a similar overview of objects from Crete. This section relies more heavily on qualitative analysis of the data, since there is a less robust data set for objects from Crete.

SITES INCLUDED IN STUDY

All of the bronze and iron objects used in the network analysis came from tombs in an effort to make all the contexts as directly comparable as possible.\(^{66}\) Furthermore, only sites that contained over ten tombs were included in this study.\(^{67}\) Sites with fewer than ten tombs rarely produced enough metal objects to be able to draw significant conclusions. An exception was made, however, for smaller cemeteries associated with

\(^{66}\) For the Cypriot material, the major impact of this decision was excluding the settlement material from Enkomi and Idalion.

\(^{67}\) For the Cypriot material, this excluded some important material from sites such as Kition.
larger sites, where data from multiple cemeteries could be aggregated to produce a workable amount of data. Finally, only cemeteries that have been extensively published were included.\textsuperscript{68} Publications that only indicated presence/absence data without images were not included. Objects excluded for any of the above reasons will still be used anecdotally in the discussion section where relevant.

The following sections present an overview of the sites included in the study, including their periods of use and history of excavations. The goal of this section is to clarify which publications provided the data used in this study and which were excluded. It should also be noted that the use of material across a number of publications adds a certain amount of inherent bias. An imbalance in the level of detail provided between publications can preclude valid comparisons. Where major differences in the publication style seemed to have an effect on the network structure, a note is made in the text.

\textbf{Cyprus}

I include tombs from cemeteries around Palaepaphos, Kourion, Amathous, and Lapithos (Fig. 237). Palaepaphos and Amathous are some of the best published cemeteries of the Cypriot EIA and they have produced the largest number of bronze and iron objects. They can be used to create a detailed picture of the southwestern region which can provide context for the finds at Kourion. Taken together, the material from Palaepaphos and Amathous cover the whole of the EIA, since the material from Palaepaphos covers the early part of the EIA and the material from Amathous covers the

\textsuperscript{68} For the Cypriot material, this excluded, notably, the early excavations of the British Museum and of Ohnefalsh-Richter and di Cesnola, which often did not include exact information about the location of the objects or did not include images.
later part. Unfortunately, there is no equivalent data that might help put Lapithos in its regional context, since no legal excavation has taken place in Northern Cyprus since 1974.

*Amathous*

Amathous is located on the south coast of Cyprus, approximately 10km east of modern Limassol. Unlike the other Cypriot sites included in this study, there was not a major Bronze Age city at the site. The CG IA tomb at Diplostrati (T109) provides the earliest evidence for the occupation of the site. Three major EIA necropoleis surround the city: Anemos to the west, Ayia Varvara to the east, and Kambos to the north. Additionally, there are small groups of tombs excavated on the acropolis and at Kafkalla and Diplostrati on the road leading west out of the city.\(^{69}\)

In the late 19\(^{th}\) century, di Cesnola, Ohnefalsch-Richter, and Walters uncovered hundreds of tombs in the vicinity of Amathous.\(^{70}\) Although these tombs produced a wealth of material, they were not included in this study because the publications do not contain date and location information in sufficient detail for the analysis. In 1930, the Swedish Cyprus Expedition excavated 26 tombs (T.1-26) in Anemos and Ayia Varvara (Gjerstad et al. 1934). Since the 1950s there have been extensive rescue excavations carried out by the Department of Antiquities. Their excavation of Tombs 113-385 between 1950 and 1983 has been published and is included in this study (Tytgat 1989; Chavane 1990; Macdonald 1992). Since the 1980s, building activity in the area has

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\(^{69}\) See (Janes 2008) for a full discussion of the funerary landscape.

\(^{70}\) First, di Cesnola reported excavating hundreds of tombs to the north of Amathous in 1874-1875, although these were not sufficiently published to be included in this study (Cesnola 1878). Next, Ohnefalsch-Richter explored the area in 1885 (Ohnefalsch-Richter 1893). Finally, the Turner Bequest excavations on behalf of the British Museum excavated 312 tombs in 1893-1894 (Myres 1899).
rapidly increased, to the extent that it has not been possible to keep pace in publication.

Many tombs have been very cursorily recorded in the BCH and several tombs have received more in-depth treatment in RDAC (Aupert and Tytgat 1984; Hermary and Iacovou 1999; Karageorghis and Iacovou 1990; Nicolaou 1985; Tytgat 1995; Coldstream 1995; Flourentzos 2004; Christou 1978). Although there is no final publication of these items, the information that could be gleaned from the initial reports was included in this study.

**Kourion**

Kourion is located in southwestern Cyprus, on the western end of the Akrotiri peninsula (see Chapter 3 for a more extensive discussion). The Late Bronze Age city was located at Episkopi-*Bamboula*, where there were also LBA burials and a few EIA burials. For the most part, however, the EIA burials were located at Episkopi-*Kaloriziki*.

The earliest excavations were carried out by di Cesnola in 1875. Soon after, in 1885, Walters excavated 118 tombs in five cemeteries labeled A-E on behalf of the British Museum as part of the Turner Bequest excavations (Myres 1899; Kiely 2009). Although these excavations were published, there was not enough detailed information about the finds to make the data useable.\(^7\) In 1933 Dikaios excavated tombs at the site of Episkopi-*Kaloriziki* on behalf of the Cyprus Department of Antiquity, which to my knowledge remain unpublished. From 1934-1954 a team from the Penn Museum excavated at a number of sites throughout Kourion, including tombs at Episkopi-

\(^7\) Recently there was an article published with information from the field journals, which helps, but it is still presence/absence data (Kiely 2009).
Bamboula and Episkopi-Kaloriziki (Benson et al. 1972; Benson 1973). The objects from the Penn Museum excavations are the only ones included in this study.

Lapithos

Lapithos is located on the northern slopes of the Pentadaktylos mountains on the coast of Northern Cyprus (see Chapter 3 for a more extensive discussion). EIA cemeteries have been excavated at Kastros, Plakes, and the Upper Geometric Cemetery, which are all located up in the hills as well as at the Lower Geometric Cemetery located closer to the coast.  

In 1914, 1915, and 1917, Markides excavated three tombs at Ayia Anastasia (T.501-3). From 1927-1928 the SCE excavated 28 tombs (T.401-429) at Kastros and 3 tombs (T.601-603) at Plakes (also called Alonia ton Plakon) (Gjerstad et al. 1934, 1:172–264). Soon afterwards, between 1931 and 1934, Bert Hodge Hill directed the excavations of 20 tombs (T.451-470) at the Lower Geometric cemetery and sixteen tombs (T.471-486) at the Upper Geometric / Kato Kastros cemetery on behalf of the University Museum. Between 1934 and 1974, the Department of Antiquities also undertook various rescue excavations. In 1940, during the construction of the Karavas-Lapithos road, the Department of Antiquities excavated four EIA tombs (T.1-3) and a fourth was found by a local in 1953 (T.4) (Pieridou 1964). Seven other CG tombs were excavated in 1973 but were not fully published and therefore are not included in this study.

Palaepaphos

72 For a more complete discussion of the funerary landscape see (Diakou 2013)
74 With the exception of tomb T.474, which was published by Pieridou in RDAC (Pieridou 1965), these tombs remained unpublished until they were the subject of two doctoral dissertations at Penn (Donohoe 1992; Diakou 2013).
Palaepaphos is located on the southwestern coast of Cyprus, around the modern village of Kouklia. The LBA burial areas that have been identified around Kouklia are located around the eastern edge of the city, and they appear to be intramural. In the Cypro-Geometric period, however, the burial areas moved outside the settlement walls to Skales, Plakes, Lakkos tou Skarnou, and Xerolimni. In the Cypro-Archaic period, tombs were built in the existing LBA and CG cemeteries, as well as in new areas, such as Kato Alonia.

The earliest excavations in the area of Palaepaphos were carried out by the Cyprus Exploration Fund in 1888 (Myres 1899). Excavations were next undertaken in 1950-1955 by T.B. Mitford and J.H. Iliffe on behalf of the University of St. Andrews and the Liverpool Museums. They excavated tombs at Asproyi, Evreti, Kaminia and Skales, but they were only preliminarily published with the exception of Tomb VIII at Evreti (Catling 1968). The Swiss-German mission, which has been ongoing since 1966, has not focused on excavations of tombs.

Most of the excavations of cemeteries, however, has been carried out by the Department of Antiquities in response to development in the area. In 1979 and 1980, rescue excavations were carried out at the large cemetery of Palaepaphos-Skales (T.44-93) (Karageorghis 1983). The Department of Antiquities excavated 22 tombs at Kouklia-Eliomylia, although only four have been fully published (T.7 CA, T.8 CA, T.119 LBA, T.125 CA) (Karageorghis 1990). The Department of Antiquities excavated 2 tombs at Kouklia-Teratsoudhia (T104 and T105) (Karageorghis 1990). In 1993, the Department of Antiquities excavated a single tomb (T.186) at Kouklia-Xylinos (Karageorghis and
Raptou 2014). In 1999, roadwork at Kouklia-Plakes uncovered seven tombs (T.142-148) that were excavated under the direction of Raptou (Karageorghis and Raptou 2014).

**CRETE**

I include EIA tombs from the area around the Bay of Mirabello, including Vrokastro and Kavousi (Fig. 238). Although there has been extensive excavation in this region, there were difficulties accumulating a large data set. Many of the tombs in this region have been thoroughly looted and contain very few metal objects. Furthermore, the publication of some important sites is still forthcoming. A large assemblage of bronze and iron objects is available, however, from Knossos and the surrounding area. The Knossos material was therefore used as a point of comparison for the Bay of Mirabello data. This allows for some comparison of different regions in Crete.

**Vrokastro**

Vrokastro overlooks the Bay of Mirabello in East Crete. A number of tombs were excavated by Hall in various locations around Vrokastro in 1912-1913 (Dohan 1914). She excavated one tholos (Tomb IV, SM-PG) and one pithos burial of an inhumed adult at Amigdali, one tholos (Tomb I, SM-PG) and five bone enclosures (BE I-V) at Karakovilia, three tholoi (Tombs V-VIII, appear to be LM IIIC-PG) and six bone enclosures (BE VII-XII) at Kopranes, and two tholoi (Tombs II SM and LG-EO and III PG-EG) and one burial enclosure (BE VI) at Mazichortia. More recently there has been a survey of the region, but no excavations were carried out, so the survey is not included in this study (Hayden 2003; 2004a; 2005).

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75 I also looked at Dreros but there were so few metal objects published that they had essentially no impact on the networks.
Kavousi

Kavousi is located on the eastern side of the Bay of Mirabello, not far from Vrokastro. Harriet Boyd and other members of her team excavated a number of tombs in the vicinity of Kavousi between 1900 and 1904. Boyd excavated one large plundered LG-EO tholos tomb at Skouriasmenos (Boyd 1901). She also excavated eight tombs near Vronda (Tombs I-VIII also called A-D and 1-4), four of which (A-D) were empty and three of which (1, 2, and 4) had been looted (Boyd 1901). The three main periods of use for the tombs, based on the pottery, were SM-EPG, PGB, and EG-MG. Boyd’s assistant Blanche Wheeler excavated four tholos tombs at Skala Aloni in 1904 (Hawes 1904, 15–17). Very few finds from these tombs were published and the date of the burial is in question. Other tombs have been found in the area including a tholos tomb at Azoria and shaft graves at Chondrovolakes, but these are not included in the data, because of the dearth of metal finds and/or lack of publication.

Knossos

Knossos has a long and complicated history of excavation and the naming conventions for the cemeteries has been inconsistent historically. For the sake of clarity, the site number (KS#) from the survey of the area by Hood and Smyth is provided in the discussion below along with the site name. The North Cemetery refers to a very large group of tombs from a number of sites including Teke (Ambelokipi), the Knossos Medical Faculty (University Site), Venizelio Hospital (Sanitorium), and Fortetsa (North).

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76 Two more tombs were excavated more recently. One was excavated by a local landowner in 1951 (Tomb IX) and the other was excavated by the Kavousi Project in 1981 (Tomb X) (Gesell 1985). It seems that no metal objects were recovered from either of these tombs.
77 Only a small number of finds have been published, and they date from LM IIIC/SM-LG. The directors of the Kavousi Project suggested that the tombs were in use in SM-EPG, PGB, and EG-LG.
The majority of the Knossos tombs included in this study come from the Medical Facility. In 1978, 86 tombs (T.1-310, not continuous) were excavated at the Medical Facility site at KS #62 (Coldstream and Catling 1996).

A group of tombs labeled “Fortetsa” are located about 100m to the south of the Medical Facility at KS #52. Payne and Blakeway excavated three tombs (L, TFT, and Pi) dating to the SM-EO in 1933 (Brock 1957). About 50m west, immediately opposite the Sanatorium, three chamber tombs were excavated by Hood at KS #56 (Hood and Boardman 1961). Finally, Coldstream and Huxley excavated ten additional nearby tombs in 1967 at KS #55 (Tombs F67/1-15?) (Coldstream and Catling 1996).

The site of Teke (Ambelokipi) is likely a northern extension of the north cemetery and it contains several different groups of tombs (Eaby 2007, 159). In 1939-40, Hutchison excavated a tholos tomb known as “Khaniale Tekke” at KS #46 (Hutchinson and Boardman 1954). In 1959, Coldstream excavated an EPG chamber tomb (labeled Teke) at site KS #50 (Coldstream 1963). Then in 1975-1976 13 or more tombs (PG-O) were excavated by Popham, Sackett, Howell, and Smyth at site KS #47 (Coldstream and Catling 1996).78

Another cemetery confusingly also called “Fortetsa,” but not a part of the North Cemetery, is located at KS #151. This cemetery on the lower slopes of the western face of the acropolis slope (KS #151) contains 17 or 18 tombs that were excavated between 1933 and 1935. Tombs I-VII, LST, and BLT were excavated by Payne and Blakeway in 1933, Tombs F, Theta, and Phi were excavated by Blakeway in 1935, and Tombs VIII-XI

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78 In 1975, Popham and Sackett excavated Ts. A, B, D, E and F. The following year Howell and Smyth, excavated Ts. G, H, J, K, L, M, N and O. T.Q was excavated by Howell in 1976.
and OD were excavated by Brock in 1935.\textsuperscript{79} They were in use from EPG-LO. All of these were published by Brock (Brock 1957).

**BRONZE AND IRON WORKING COMMUNITIES IN EIA CYPRUS**

In the following section, I address some of the most common types of bronze and iron objects in the EIA Cyprus individually. I present a brief overview on the scholarship that has been done on each object type, including the existing typologies. For object types with enough data to create useful networks, I present the results of my network analysis, by site and by time period. Each subsection is devoted to a specific series of graphs in the figures, which is referenced in the heading. For object types without enough data to create useful networks, I only present a qualitative discussion of my findings.

**FIBULAE**

Many typologies of Cypriot fibulae have been created over the years. A full review of these typologies is outside the scope of this dissertation, but a brief overview is presented here.\textsuperscript{80} Early attempts to form a typology of Cypriot fibulae were made by both Myres and Cesnola (Cesnola 1878; Myres and Ohnefalsch-Richter 1899). Blinkenberg’s fundamental work on fibulae in the eastern Mediterranean in 1926 was influential and continues to be used as a central reference (Blinkenberg 1926). In the same year, Gjerstad published his dissertation, which presented a typology incorporating the material from the Swedish Cyprus Expedition. This typology was also reproduced in the SCE volume when it was published (Gjerstad 1948). In 1959 Stronach published an article primarily dealing with Near Eastern examples, but including some Cypriot examples as well (Stronach

\textsuperscript{79} These appear in Payne (1935, 166) as Tombs A-F.

\textsuperscript{80} For a more thorough discussion see Giesen (2000, 12–21).
Cypriot examples got a more full treatment in Birmingham’s 1963 article (Birmingham 1963). A year later, Catling published his own fibulae typology in his work, “Cypriot Bronzework in the Mycenaean World” (Catling 1964). Giesen’s dissertation presents the most thorough discussion of Cypriot fibulae to date (Giesen 2000).

The fibulae found on Cyprus in the EIA encompass a wide range of types, only some of which will be considered in depth in this study. I will focus on asymmetrical and symmetrical fibulae with 2 to 4 beaded attachments. These fibulae far outnumber other types and they are the only types that provide a large enough sample size to provide statistically significant results. Other types of fibulae are found in such small numbers that they do not have comparative value in the network.

Asymmetrical fibulae with 2 beads are characterized by plain arms, and beads on either side of a swollen bow (equivalent to SCE 2b, Birmingham I.A(iv), Giesen VII) (e.g. Figs. 19-20). Examples date from LC III B2 to the end of the CG period, with a highpoint in CG IA (Giesen 2000, 109). The earliest examples are entirely hammered. Instead of the plastic beads, which become popular later, they only have incisions marking off the beaded area. During the highpoint of this type’s use, the beads are typically round or squat with decorative bands or incisions on either side. Blinkenberg and Catling argued that this form derived from Greek examples seen at the Kerameikos and other cemeteries. Birmingham and Giesen take the opposite stance, arguing for a Cypriot origin based on the dating of the Cypriot examples, which is as early as the Greek ones.

Asymmetrical fibulae with 3 beads are characterized by a bead on the arm, 2 beads flanking a swollen bow, and usually a simple needle loop (equivalent to SCE 2a,
Birmingham I.A(v), Giesen VIII) (e.g. Figs. 16-18). Gjerstad and Catling again argue that this form has a Greek origin, but Birmingham and Giesen contend that it is a local Cypriot type and that the Greek examples are exports from Cyprus. They maintain that the prevalence of this form (it is the most commonly found type on Cyprus) and its long duration (they are in use from the 11th-6th centuries) confirms its local Cypriot nature (Birmingham 1963, 90–91; Giesen 2000, 143). Birmingham divides these 3-beaded fibulae into sub-groups based on their dating. She notes that the thinner asymmetrical variety, which bears a closer resemblance to the earlier asymmetrical 2-beaded fibulae, can be dated to around 1075-900 BCE (Birmingham 1963, 92). The more symmetrical and thicker version of the 3 bead fibulae (SCE 2c; Birmingham II.A(i)), on the other hand, gained popularity around 925-800 BCE (Birmingham 1963, 96). These distinctions and their associated dates are clearly corroborated in my network figures (discussed below).

Finally, the 4-beaded fibula are characterized by one large bead above the needle holder, a square bow followed by three more beads, and often an inserted needle (equivalent to SCE 2d, Birmingham II.A(ii), Giesen IX). Giesen argues that they are derived from the thicker, symmetrical 3-beaded fibulae, with which they overlap in date (Giesen 2000, 177). My network analysis draws clear connections between these two forms, which lends further support to her assertion. The 4-beaded fibulae are found almost exclusively at Amathous, with only a few examples from Tarsus (Giesen 2000). Unlike the other fibula types, the 4-bead type can therefore be seen as a local Amathousian form.
Overview (Figs. 239-242, Fibulae, All Dates, All Sites, T=7):

In order to narrow down the number of attributes to be considered in the network, it was necessary to resolve which attributes had the greatest impact on the shape of the network, and which attributes were only minimally influential. This was determined for each attribute by calculating the probability that any two nodes sharing the attribute would also share a connection in a large sample network built from all possible attributes. The attributes that related to the overall shape and type of the fibula (such as number of beads, symmetrical/asymmetrical, overall shape) had the greatest impact. I decided to use these categories as the basis for the network connections. Although they were recorded, categories with low impact (such as needle holder shape and size) were not used in the creation of the network. It is expected, then, that the large-scale network structure reflects the typology discussed above since both rely primarily on attributes related to the overall shape of the fibulae (Fig. 242). In particular, the two later forms, the symmetrical 3-beaded fibulae and the 4-beaded fibulae, form very distinct clusters. The two-beaded asymmetrical fibulae and the three-beaded asymmetrical fibulae, on the other hand, show significant overlap. Besides the addition of a bead on the arm of the fibula, there are not many differences between these two types.

These influential attributes, which relate to the overall shape of the fibulae, are heavily impacted by the shape of the mold, rather than by the decisions made by the smith in the finishing stages of production. In contrast, attributes that can be directly related to the finishing (the needle holder shape and size, spring shape and size, incised decoration on or around the beads, and in some cases the angle of extension of the arm) appear to have very little impact on the shape of the network (Fig. 242) and at first glance
do not always form clear patterns in the data. For example, an asymmetrical 2-beaded fibula is no more likely to have a tall triangular needle holder than a symmetrical 3-beaded fibula. This may suggest that molds were used by multiple smiths or communities of practice. Alternatively, it may suggest that finishing techniques were not very standardized, even within a community of practice.

There are, however, some exceptions to this rule, in which the attributes determined by the shape of the mold show stronger correlations to finishing techniques. For example, symmetrical 3-beaded fibulae and 4-beaded fibulae are more likely to have short, wide, round catch plates, they are more likely to have double incisions flanking their beads, and they are more likely to have springs that form two rotations and that are made separately before being attached to the body of the fibulae. All of these choices are decisions made by the smith after the fibula has come out of the mold and they should be independent of the mold shape. The correlations therefore suggest that smiths using those molds may also have similar training that indicates membership in a shared community of practice.

_Palaepaphos (Figs. 243-244, Fibulae, Palaepaphos, All Dates, T=7):_ The graph from Palaepaphos is quite dispersed and does not cluster clearly into separate groups. Nearly every edge length is between 0 and 50 years, with some exceptions for edges connecting to nodes from long-lived tombs. The network has a lower clustering coefficient compared with the clustering coefficient in the Amathous-only network and has a lattice-like structure. The number of short edge-lengths is statistically significant at p=0.05, demonstrating that there is non-random temporal diffusion in the network.
One group of CG IA fibulae (yellow nodes) form an arc around the bottom center of the graph. They are asymmetrical 2 beaded fibulae with flat arms (P68.5, P85.78, P85.93A, P85.94, and P89.88). Another CG IA group is located in center of the graph, consisting of asymmetrical fibulae with beads that are surrounded by raised bands on either side (Fig. 243, P84.13, P89.99, and P91.65). Above them is a group of CG IB-CG II (green nodes) of the same type (P49.14 and P67.111). Some of the later CG III-CA I fibulae (blue nodes) are branching off in the lower right. In contrast the CG III-CA I fibulae (blue nodes) from Tomb 54 are closer to the center of the graph, and more similar to earlier forms. The outer area of the graph is primarily made up of asymmetrical fibulae with corroded beads. Since there is less information about corroded fibulae, they have fewer opportunities to form connections with each other and so float at the edges of the graph. Looking at the graph that is colored by time period, the progression in time from the upper right corner toward the lower left is somewhat evident.

One group of CG IA 2-beaded fibulae from Palaepaphos is characterized by flat arms. The turn into the arm in the upper left corner of the fibulae is typically sharp, and the arm itself is flattened so that it has a rectangular section. The arms typically do not expand at the needle holder, and the needle holder itself is often tall and pointed. The beads of these fibulae are often very corroded, so it is difficult to draw definite conclusions, but no raised bands or incised decoration is visible. These include P68.5, P85.78, P85.93A, P85.94, and P89.88, which form an arc on the lower center of the

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81 Note that the term “clusters” is used to refer to groups recognized by clustering algorithms provided by the network software, whereas the term “groupings” is used to discuss groups recognized by personal observation. Note that the software-generated clusters are not inherently more valid than groupings noticed by visual analysis. Most programs cluster the nodes into 3-4 subgroups, and there can be several meaningful, smaller groupings not distinguished by the clustering program.
graph, as well as P54.3 and P61.29 nearby. Also P44.139, P48.29, P48.30, and P144.174 do not appear on the graph, but should certainly be included in this group. These fibulae are primarily found in Palaepaphos and it seems likely that they were a product of Palaepaphos workshops, although scientific testing would be needed to confirm this hypothesis.

Another distinctive type from Palaepaphos is fibulae with beads that are surrounded on either side by raised bands. The examples from the CG IA period are characterized by 2 squat beads with thick bands on either side (P84.13, P85.98, and P89.99). Similar fibulae from the CG IB-CG II also feature beads with raised bands on either side, but many have 3 beads instead of 2, have rounder beads, and feature distinctive splaying needle holders (P49.13, P49.14, P50.3, and P67.111). P91.67 may represent a transitional form, since it dates to the CG IA, but it displays the 3 round beads and a splaying needle holder that are characteristic of the later examples.  

Like the 2-beaded type discussed above, these fibulae are primarily found in Palaepaphos and we might hypothesize that they were a product of Palaepaphos workshops.

Asymmetrical three-beaded fibulae are less common at Palaepaphos, but there are several small groups of them clustered in the upper part of the graph. First, there are a number of fibulae with three round beads (P76.18, P92.1, and P50.4). These do not seem to have any decoration on their beads, although 76.18 in particular is very corroded, so it is difficult to say. There are also 3 fibulae with 3 undecorated biconical beads from Tomb 82 (P82.96, P82.97, P82.11).

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82 There are also some more unusual examples. P76.21 (CG IA-IB) has long, thin vertical lines on the beads and also a hexagonal bow. P43.84 (CG IA) has double raised bands on either side of its 3 beads.
Finally, Palaepaphos has a set of symmetrical 3-beaded fibulae that more closely resemble later types that are popular at Amathous (P62.55, P64.1, and P86.4). Symmetrical 3-beaded fibulae are not common at Palaepaphos and it is possible that these should all be considered imports to the site. On the other hand, some examples seem to display typical Palaepaphos characteristics. For example, P62.55 has a very pointed needle holder, which is more common in fibulae from Palaepaphos than from other sites. Furthermore, they all have biconical beads, which have some precedent at Palaepaphos. This might indicate that some production of these forms was taking place at Palaepaphos, although maybe on a small scale.

Amathous (Figs. 245-246, Fibulae, Amathous, All Dates, T=7):
The fibulae from Amathous are clearly divided into three large clusters. The clustering is much stronger than at Palaepaphos. The edge length distribution follows a Poisson distribution, and the frequency of longer edge lengths decreases slowly. The degree distribution is fairly uniform except for a spike in nodes with degree between 15 and 20. Given the high clustering coefficient and the low average path length, the Amathous network resembles a small-world network.

The cluster on the lower right (Spinglass red, Fig. 246) contains the asymmetrical fibulae, the one in the center (Spinglass green, Fig. 246) contains asymmetrical 3-bead fibulae, and the one on the upper left (Spinglass blue) contains 4-beaded fibulae. Looking at the graph that is colored by time period, the progression in time from the lower right corner toward the upper left is immediately evident. This temporal trend is confirmed by statistical calculations, which indicate that the temporal diffusion in the network is statistically significant at p = 0.05.
Some of the earliest fibulae are clustered in the bottom right corner. Of these, A331.37 and A23.63 both feature round beads with raised bands on either side and vertical line decoration. The far more common type going forward, however, either has incised rings on either side of the squat beads (A7.19, A308.37 and A380.26) or has no decoration at all (A11.91, A378.29, A380.23). About half of the examples with incised rings also have vertical lines incised on the bead itself (A308.37, A378.29, and A7.19). There does not appear to be any pattern governing which ones have vertical line decoration.

The symmetrical 3-beaded fibulae are grouped together in the central cluster, but they separate clearly into two groups. A group with squat beads is located in the bottom right corner of the cluster and is closely connected to the asymmetrical fibulae with squat beads (A222.71, A369.23, A232.138, A165.22, A314.2, A5.29, A7.79, A7.165, A7.192, A237.81, A378.21). Like the asymmetrical fibulae mentioned above, they sometimes have incisions around the beads, and sometimes vertical lines on the beads. They only characteristics separating them from the asymmetrical version are a more symmetrical shape and thicker arm. Fibulae with undecorated biconical beads, on the other hand, are grouped on the upper left side of the cluster (A11.96, A114.11, A114.14, A12.7, A232.52, and A232.132). For the most part these either have no decoration or they have two incised lines on the outside of the beads.

Symmetrical fibulae of the 3-beaded varieties are much more common at Amathous than at any of the other sites investigated. This can be attributed to their late date and the fact that Amathous was active in a later period than the other sites, but it seems likely that they were being produced at Amathous.
The 4-beaded fibulae form a compact cluster at the upper left of the graph. These fibulae demonstrate consistency across many different attributes, and do not easily reveal subgroups. In many instances, the fibulae do not have applicable or observable attributions, which makes it difficult to analyze this subgroup with any granularity. As mentioned above, however, they are found nearly exclusively at Amathous. Their similarity in form may be attributable to their exclusively local production.

*CG I (Figs. 247-248, Fibulae, All Sites, CG I, T=6)*:

The vast majority of fibulae in this graph are from Palaepaphos and are asymmetrical. There are a few examples from Amathous that are symmetrical, but these are likely from later periods of long-lived tombs. Unlike graphs from later periods, it is difficult to distinguish clusters, since many attributes are shared in common and there is less variation among different groupings.

In the upper right section is the group of 2-beaded fibulae from Palaepaphos with no decoration on the beads. This confirms my observation in the Palaepaphos section that there are no fibulae from other sites in this group. In the upper left section of this graph, there is a grouping of the Palaepaphos type with 2 or 3 beads and raised band decoration. The 2-bead and 3-bead varieties are overlap very closely, indicating the close similarities between them. One fibula from Kourion is located near this group (K 21.c) (perhaps because it has a squat bead), even though it has incised ring decoration, which differentiates it from all the examples from Palaepaphos. There is an interesting group of 3 fibulae with 3 undecorated biconical beads in the bottom center of the graph (K21.f, P82.96, P82.109).
*CG II (Figs. 249-250, Fibulae, All Sites, CG II, T=6):*

The bottom center grouping represents the 2- and 3-beaded asymmetrical fibulae.

On the upper right side of this group there is a group of fibulae with round or squat beads with raised bands on either side and (sometimes) vertical line decoration (P49.19, P67.111, A23.63, A331.37). The Palaepaphos examples included in this group (P49.19 and P67.111) are both late 3-beaded versions of the Palaepaphos type that is characterized by raised bands on either side of the beads. The Amathous examples (A23.63 and A331.37) are the earliest example of this type found at Amathous. The connection between these four nodes points to these fibulae as potential boundary objects between the two communities of practice. Interestingly, these examples are somewhat unusual for both sites. The vertical line decoration on the beads is quite unusual for fibulae from Palaepaphos, and the raised bands around the beads are unusual for Amathous. In a way, they could be seen as a meeting place between the two traditions.

In the upper area of this grouping, there is a grouping of fibulae with squat beads flanked by incised rings and sometimes featuring vertical line decoration on the beads themselves (K21.c, K34.3, A7.19, and A308.37). The group is closely connected to the symmetrical fibulae that also have squat beads and incised grooves (the middle cluster in this graph). It is notably lacking in examples from Palaepaphos, suggesting that this transition between asymmetrical and symmetrical fibulae did not occur at Palaepaphos.

On the bottom left side of this grouping are the fibulae with biconical beads (K21.f, K35.8, K35.9, P82.96, A381.11). The prevalence of examples of this biconical type at Kourion is striking, and perhaps suggests that Kourion was a center of production. These
asymmetrical fibulae with biconical beads also have a connection to the symmetrical fibulae with biconical beads in the central cluster.

The nodes in this cluster with the highest centrality are K21.f, and to a lesser extent A7.19, P49.14. It is interesting to note that each of these nodes belongs to a different subcategory discussed above. They are all 3 bead fibulae that have strong connections to the symmetrical 3 beaded cluster. This gives them a high centrality in the network since they act as gateways through which the other asymmetrical fibulae are connected to the rest of the network. K21.f may be more central because the squat bead type becomes more popular as a symmetrical type. These nodes could be interpreted as important brokers between the asymmetrical and symmetrical beads.

The upper left grouping contains symmetrical fibulae with squat beads (A7.79, A7.192, A165.22, A315.16, A7.165, and A7.191). The CG II is the early period of development for symmetrical fibulae and there is still significant experimentation in form. There are several fibulae with biconical and disk beads that do not appear on the network. The high centrality nodes in the second cluster are A7.165, and A7.192, which both have squat undecorated beads, and A7.192 has incised grooves, while A7.165 is completely plain.

**CG III (Figs. 251-252, Fibulae, All Sites, CG III, T=6):**
The bottom right cluster (green nodes) represents the asymmetrical fibulae. In this period, they are almost exclusively 3-beaded fibulae, although a few 2-beaded ones from Palaepaphos can be seen at the very bottom right of the graph. For the most part, the

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83 The asymmetrical fibulae from Palaepaphos are all from Tomb 54, and they cluster together at the bottom of the graph. This tomb contains two pairs of fibulae, one pair with 2 beads and the other with 3 beads. As mentioned above, they are very similar to the earlier fibulae at Palaepaphos and may in fact be
asymmetrical fibulae are fairly standardized by this period. The most common forms are those with squat beads, incised lines and vertical line decoration (A308.37, A7.19, and A380.26), and those with squat beads and no decoration (A378.29, A117.27, A380.23). In earlier periods there was no correlation between flanking incised lines and vertical line decoration on the bead. By the CG III they have separated into two more distinct types.

The central cluster (blue nodes) contains symmetrical 3-beaded fibulae. The ones with biconical beads are more distinctly separated out from the ones with squat beads than in the CG II, perhaps because the types are becoming more distinct and standardized over time. Two of the examples from Palaepaphos (P62.55 and P86.4) have undecorated biconical beads. This is unsurprising because Palaepaphos seems to have a tradition of asymmetrical biconical fibulae that might have evolved into a symmetrical version, but they do not seem to have any tradition of fibulae with incised decoration. P62.55 in particular, is interesting because it looks like the Amathous examples, but it also has a triangular needle holder, which is fairly characteristic of Palaepaphos bronzeworking.

CA I (Figs. 253-254, Fibulae, All Sites, CA I, T=6):

The cluster on the lower right (green nodes) contains asymmetrical fibulae, but there are very few left in this period and they very well could be old fibulae that are still in circulation, rather than fibulae that have been recently produced. The bulk of fibulae production seems to have shifted to focus on symmetrical fibulae in both 3 and 4 beaded varieties. Based on our current evidence, this also suggests that the majority of

heirlooms that had a long use before being deposited in this tomb. A23.63 is a strange outlier, because it has round beads with raised bands and vertical line decoration, as well as a hexagonal bow, which is more common in the CG II. The majority have squat beads with single incisions, with or without vertical lines.
production has shifted to Amathous, although additional excavation could alter this picture.

The middle cluster (blue nodes) contains the symmetrical 3-beaded fibulae. In this graph, the fibulae with biconical beads are grouped towards the top of the cluster and the ones with squat beads are grouped towards the bottom. The top left cluster (red nodes) contains the 4-beaded fibulae of the Amathous type. Among both of these groups there is an increase in springs that make two rotations instead of one. There is also an increase in pins that are made separately and then attached to the third bead.

Conclusions
In the CG IA, fibulae are primarily of the asymmetrical 2-bead type, but there is considerable variety within this form. The majority of fibulae that can be securely dated to the CG IA are from Palaepaphos. Some have undecorated beads (85.93, 94; 88.83, 114), while others feature vertical or diagonal incised lines on the beads (44.139, 85.102; 91.65), and others feature raised bands on either side of the beads (84.4, 13; 89.99). For the most part, the type with raised bands does not overlap with the type with vertical lines on the beads. Some of the fibulae with raised bands or incised lines also have square or diagonal arms or hexagonal bows (89.99, 88.1, 84.4, 76.21, 132.114). Asymmetrical fibulae with 2-beads are also the most common type found in secure CG IA contexts at the other sites (Kourion, Amathous, and Lapithos). Some have undecorated beads. The type that is seen at Palaepaphos, however, with raised bands on either side of the beads, is almost never seen at other sites. One exception is a fibula from LC IIIB Kourion (K40.24), which is quite similar to the Palaepaphos examples. Instead, the other sites have more examples with incised lines on either side of the beads (K1035 and A15.62).
At Lapithos in particular many of the fibulae have lines incised around the outside of the beads as well as vertical or diagonal lines incised on the beads (L406.15a, 406.7, 406.102).

In the CG IB, the most common form, which is seen at each site, is the asymmetrical 3-beaded fibula. Those with incisions on either side of the beads are particularly common and are found at Palaepaphos (50.4; 82.96, 90.5), Kourion (35.8, 21c), and Lapithos (416.2, 474.4). Most of these have plain beads, but some are decorated with vertical lines, especially at Lapithos. There are also examples with no incisions, although in some cases this may be due to the state of preservation. At Palaepaphos some fibulae with 2 undecorated beads remained in circulation. Furthermore, fibulae with raised bands on either side of the beads, which had been common in 2-bead varieties in the CG IA, were produced in both 2-bead (49.13, 48A.11; 48.29; 67.111) 3-bead (49.14, 50.3) varieties in the CG IB. Several similar fibulae were also produced at Amathous in the CG II (A331.37 and A23.63).

In the CG II, the most common form at every site continues to be the asymmetrical 3-beaded fibulae, although 2 beaded varieties continue as well, especially at Palaepaphos. There are also several of a somewhat unusual type (L422.3, 4, and K34.M40), which have small beads decorated with vertical incisions and very long, thin bows.

In the CG III, there is a more significant shift, and a greater variety in types, which have grown more distinct from each other indicated by strong clustering on the graphs. Most examples come from Amathous. Asymmetrical three-beaded fibulae are still in circulation at Amathous (7.190, 314.20, 380.26), but the majority of the fibulae are
symmetrical with thick bows. Mostly these have squat beads with single or double incisions on either side of the beads, although some have raised bands. Roughly half also have vertical lines incised on the beads. There are also fibulae with biconical beads. One subtype of these has totally undecorated biconical beads (P86.4, P62.55, A9.71 and 72, A11.96, A12.7, A232.52, and 132), whereas the other features biconical bows decorated with incised lines (A11.18, A114.11, A142.93, A538.113). These fibulae are more likely to have springs that make 2 rotations. In this period, 4-beaded fibulae from Amathous also became more common. These fibulae are not found at any other sites, so they appear to be a local type. They have certain commonalities with the symmetrical 3-beaded types, including the use of springs with two rotations.

Many of the attributes of fibulae can be attributed to the change in styles over time rather than site-specific differences. Examples of changes over time include the progression from 2-beaded to 3-beaded fibulae and the progression from asymmetrical to symmetrical, which are seen at every site. Since some sites have produced far more fibulae in certain periods than others (e.g. the majority of CG IA fibulae come from Palaepaphos and the majority of CG III come from Amathous), it can be difficult to compare local styles within a single period.

Nevertheless, there are some traits that appear to be locally specific. Some are related to the shape of the mold. Most notably of these, the use of bands around the outsides of the beads as well as the occasional use of hexagonal or diamond-shaped bows and feet is found at Palaepaphos specifically. Other distinctive features are linked instead to post-casting forming practices, especially incising. For example, fibulae from Lapithos make more use of incised decoration, both around the beads and as decoration on the
beads. The presence of unique local types, such as the 4-beaded “Amathous type” fibulae, is also an indication of local technological styles.

**Bowls**

Hemispheric bowls ("kalottenschalen") were common grave goods in Cyprus, particularly in the LC III period, but continuing on into the CG and to a lesser extent the CA periods (Matthäus 2005, 99). Matthäus notes that the form is simple and common, so it is difficult to track its movement through the eastern Mediterranean. Nevertheless he suggests that the form may have come to Cyprus from the Near East or the Levant, where it was common in the LBA (Matthäus 2005, 100).

The form of the hemispheric bowl is fairly standard and Matthäus does not attempt to define a typology, but he does give the typical lip profiles (A-K), which I draw on in my analysis. He also notes that bowls of the EIA tend have smaller diameters than those of the LBA, but other than that there are not large distinctions. This is confirmed by my data as well.

*Overview (Figs. 255-257, Bowls, All Sites, All Dates, T=3):*

The network analysis of bowls faced more structural challenges than the analysis of the fibulae. The primary difficulty is that there are far fewer attributes that can be compared across artifacts. The characteristic that has the most impact on the network is the shape of the bowl, especially the depth and the shape of the walls. This might be a reflection of correlations between categories such as the angle of the walls, depth of the bowl, and shape of the base. Correlations between attributes are not inherently bad, and in fact reflect real world production practices, but they can effectively further reduce the number of distinct categories which can be compared. Nevertheless, we can investigate
the relationship between the shape and other characteristics such as diameter and rim shape. The diameter of the bowls does correlate with the shape of the bowls in some cases (for example, the shallow bowls are more likely to have larger diameters), but the correlation is not straightforward, since diameter also changes over time. Bowls from the CG I period are more likely to have large diameters, while in the CG II more bowls have a more standard 10-14cm diameter. Larger diameters become common again into the CG III period (Fig. 255). Furthermore, the shape of the rim has no discernible correlation to bowl shape or size. This is surprising, since forming the lip of the bowl seems like something that would be consistent within a community of practice. The lip shape is unknown for roughly half of the entries in the bowl network. This lack of information could be preventing some correlations from appearing.

In the bowl networks it is often the case that the bowls of the most typical shape and size (round bowls with a 10-12cm diameter and shape B lips) gather toward the center of the graph and all other types are pushed to the outskirts. Specifically, the bowls from Palaepaphos are more tightly connected to each other, whereas the Amathous bowls drift out towards the edges of the network. This is perhaps due to actual similarities of the Palaepaphos bowls, but likely also reflects the nature of their publication. Many more of the bowls from Palaepaphos were published with sections, so more could be said about their lip shape, which gave them more points of connections with each other.

The bowls can be roughly divided into three groups, which are reflected in the clustering (Fig. 257). The cluster in the lower right section of the graph (green nodes) are typically shallow, and have round, open, or occasionally bottom-heavy walls. The second cluster is located in the upper left section of the graph (blue nodes). These bowls tend to
be medium or deep, with large diameters (14-18cm), and triangular, pentagonal, or sometimes bottom-heavy walls. Finally, the group in the center left section of the graph (red nodes) is the most consistent group. These bowls tend to have medium depths and round walls. All of the types were found at both Amathous and Palaepaphos in every period between the CG I and CA I, so it is difficult to establish their regional origins.

**Palaepaphos (Figs. 258-259, Bowls, Palaepaphos, All Dates, T=2.5):**

The earliest bowls at Palaepaphos come from Eliomylia Tomb 119. The bowls from this tomb are quite varied and all of the wall shapes are represented. Most have round sides (P119.8, P119.24, P119.25, P119.41, P119.68), but other have pentagonal sides (P119.9, P119.11, P119.12), and one is shallow with open sides (P119.44). The ones with drawn profiles have either shape F or J rims, which seem to be a feature of early bowls.

In the CG I and II (yellow and green nodes) round bowls with small diameters are the most common type. An early example (P186.2) is surrounded by later ones (yellow nodes: P56.4b, P58.89, P58.12) and a later group further dispersed (green node P83.101 and yellow nodes P49.8, P49.3, P49.7, P49.5, P76.37). There are some later examples (blue node P79.1), but it is less popular in later periods. Triangular bowls, on the other hand, become more common in the CG III. An early example is (yellow: P76.108), but most of the other examples are late (green: P55.1 and P55.2, blue: P74.33, P79.18, and P86.73). Pentagonal bowls also appear to be somewhat more common in the CG II (yellow: P49.4, P67.82, P67.14), but bottom-heavy bowls occur in all periods. The shape of the Palaepaphos network seems to be particularly influenced by bottom shape, with
round-bottom bowls congregating toward the top of the graph, flat-bottom bowls toward the bottom, and four round/flat bottoms in between.

The network shape is influenced by time in addition to, or in conjunction with, influential attributes. The overall shape of the Palaepaphos-only and Amathous-only graphs both have a statistically significant proportion of short edge lengths (at p=0.05), which indicates that there is site-specific temporal connection in both networks.

Amathous (Figs. 260-261, Bowls, Amathous, All Dates, T=3):

The earliest bowls at Amathous are from the CG I, and there are bowls in each type already in this early period. Round bowls separate into two distinct areas based on diameter. First, there is a grouping of 9th and 8th century bowls with small diameters around the early bowl A109.7 (A315.3, A7.256, A371.3). This becomes the more popular and standardized bowl form in later periods. Second, there is a less dense grouping of CG III bowls (A315.4, A382.38.1) around the CG I bowl A15.57, which has a larger diameter. These round bowls with larger diameters never became as common as the smaller ones.

Triangular bowls are unexpectedly disparate on this graph. A15.58 and A109.6 are both CG I triangular bowls with very large diameters. They are connected to later triangular bowls with smaller diameters (308.41, 379.1), but are separate from other triangular bowls that have large diameters (5.41, 18.18). As with the Palaepaphos bowls, the bottom shape is determinative of the overall shape of the network. In addition, the height categories are clearly separated in this graph, with medium height bowls clustering together and shallow bowls clustering together. In between these clusters are the
shallow/medium examples, and finally the very shallow examples are closest to the shallow ones and furthest from the medium ones.

**CG I (Figs. 262-263, Bowls, Southwest Region, CG I, T=2.5):**

In the CG I graph, the shallow bowls with open or bottom-heavy walls roughly aligns to the green cluster, the deep bowls with triangular walls to the red cluster, and the medium-depth bowls with round profiles to the blue cluster. Overall, the bowls within each group are quite varied in terms of their diameters and the shapes of their lips and consequently the three clusters are fairly intertwined with each other. Most of the bowls in this period are from Palaepaphos, and the ones from Amathous, Kourion, and Lapithos are interspersed throughout the categories.

The only type that can potentially be associated with a specific site are the round bowls with diameters between 10 and 12cm, and usually a rim in shape B which are more common at Palaepaphos (P49.5, P49.7, P49.8, P76.37, P56.4b, P58.89, , forming a central grouping). The only one of this type found at Amathous in the CG I comes from Diplostrati (A109.7).

There is a grouping of 4 Palaepaphos bowls that are very central to the network (49.4, 58.111, 76.37 and 49.5) in the upper center. These are interesting because they are at the center of the network and have very high centrality but are not all the same shape: two are round, one is pentagonal, and one is bottom heavy. They are held together by certain similarities such as their small diameters, shallow profiles and shape B rims.

**CG II (Figs. 264-265, Bowls, All Sites, CG II, T=2.5):**

In the CG II graph, bowls with pentagonal, bottom-heavy, or open walls roughly align to the lower center grouping, bowls with triangular walls to upper left grouping, and
bowls with round walls to the top right grouping. The clusters align better with the wall shapes in this period, suggesting an evolution into more distinct, standardized types. In addition, the Amathous and Palaepaphos examples begin to separate into more distinct clusters, with Amathous nodes more frequent in roughly the right half of the graph and Palaepaphos nodes more frequent at the upper center.

The triangular bowls in particular form a very coherent group in this period. They show a clear tendency for large diameters (14-18cm). They are evenly represented by examples from Amathous and Palaepaphos, however, so it is difficult to argue for a single point of origin. The round bowls which were a common Palaepaphos type in the CG I become increasingly popular at Amathous in the CG II. The bottom-heavy/pentagonal/open group is much better represented at Amathous in this period.

Central nodes include P83.101, followed by P145.64 and P55.2 in the triangular group, and A7.256 in the pentagonal group. Interestingly, these bowls are all round, with small diameters, shallow profiles, and shape B or D rims. As with the CG I network, they are located in the center of the graph and are more closely related to the most common form. The round cluster does not have any large central nodes because they are all more integrated into the network, whereas the triangular and bottom-heavy nodes all share a connection with a small number of central nodes.

*CG III (Figs. 266-267, Bowls, All Sites, CG III, T=2.5):*

In the CG III graph, bowls with round walls roughly align to the upper left grouping, bowls with triangular walls to the bottom grouping, and bowls with pentagonal, bottom-heavy, or open walls to the upper right grouping. At this point there are more round bowls from Amathous, although the other two categories remain fairly mixed. A
high percentage of the Palaepaphos nodes have triangular nodes in comparison to earlier periods. The central nodes are P79.1 (round), P55.2 (triangular), and A371.3 (bottom-heavy).

**Conclusions**

It is difficult to draw conclusions about local trends in bowl making or about interactions between sites, since the data is quite limited. What can be seen is a shift in the most popular bowl forms at Palaepaphos and Amathous over time. Overall, however there are not major differences between the assemblages at different sites, perhaps suggesting that bowl making practices were not locally restricted. Also, the shape of the bowl, which in most cases is reflective of the process used to raise the bowl from a cast disk, did not correlate to the profile of the lip. This suggests fairly non-standard production, where smiths do not conform to a strict set of techniques.

RINGS

Like bowls, rings offer very few attributes upon which a network analysis could be based. In this case there were not even enough attributes to justify the use of network analysis. Instead the results will be discussed only qualitatively. Another critical issue with the ring data is that objects with many different functions are often classified as “rings,” including earrings, hair rings, toe rings, finger rings, as well as rings from other objects such as bowl handles or bridles. Each of these objects might have different attributes that reflect their functional use, rather than reflecting the training of the smiths who made them.

A qualitative inspection of the rings shows that there are stark regional contrasts in ring production, which suggests that ring production was locally segmented. For
example, there is one ring type that is very typical of Kourion and Palaepaphos. It is a thick, cast finger ring with a lunate profile and a diameter between 2 and 2.5 cm (e.g. Figs. 147-149). There are three of these rings from Episkopi-Kaloriziki Tomb 25 and one from Palaepaphos-Xylinos which date to the LC IIIB. The others from Palaepaphos date primarily to the CG I. No rings of this type have been found at Amathous or Lapithos. This is particularly interesting, since this is the only ring type that doesn’t rely on extensive hammering and shaping after casting, so the process of production would have been quite different from other rings. Other CG I ring forms have also been found at Palaepaphos and Kourion, but they do not form a consistent group.

Lapithos, on the other hand, has a different tradition of ring production, one that relies far more heavily on hammering. The ring types from Lapithos are often consistent within and restricted to a single tomb. This is likely because they belong to sets of jewelry meant to be worn together. For example, Tomb 474 (CG I) contains three rings with a flat profile and overlapping terminals (e.g. Figs. 138-141). Tomb 2 (also CG I), on the other hand, contains two wire rings with slightly overlapping terminals, which are probably earrings. Tomb 488 (CG II) contained 5 spiral rings with flat profiles. Finally, Tomb 473 (CG II-III) contains three rings that are hammered very thin and loosely twisted and wrapped (e.g. Figs. 142-144). These are certainly not finger rings, although their exact function is unclear.

Spiral rings with round sections are found at both Palaepaphos and Amathous in the CG III-CA I. These are often gold-plated, presumably because they imitate a more common spiral ring in gold (P56.4, P71.28, P62.59).
PINS

Like rings, pins are difficult to study using network analysis. There are few visible attributes that can be used to create the network. Instead, I will discuss pins only qualitatively. An additional problem with pins is that they do not preserve well, because they are thin and quickly become entirely corroded. As a result, many potential pins cannot be separated from needles, which are also a very common part of burial assemblages in EIA Cyprus. Many needles have been catalogued as pins or vice versa. I will only discuss examples that are certainly pins, although this greatly reduces the size of the data set.

One common type is a bronze pin with a pomegranate head. These are common at Palaepaphos in the CG I (67.25, 68.7, 82.105, 85.99, 91.72b) and also at Lapithos (Kastros 426.6, Upper 474.271, Vathyrikas 1.27). There is a related form where a gold leaf pomegranate head is attached to an iron pin, which is found only at Palaepaphos (Skales Tomb 85.99, Plakes 146.17, 146.110).

The other distinctive pin type has a conical attachment at the head made of either bone or ivory. The attachment typically has some incised decoration involving circles and lines, although the exact pattern varies. At Palaepaphos (P78.38, P86.6, P91.75) and Amathous (A117.28) the pins are iron, but at Kourion there is an LC III example with a bronze pin (K25.i)
Knives

The importance of iron knives in scholarly models of iron distribution has already been discussed (Chapter 2). There are several existing typologies of Cypriot iron knives, but none that encompass the full range of excavated examples (Gjerstad 1935, II:575–76, pl. 173 and Gjerstad 1948, IV:2:132–35, 213, Fig. 21; Åström 1967, 1; 1972, IV:1D:473, Fig. 60, Catling 1964, 102–4, Macdonald). Most of these typologies only address a limited time period. Furthermore, most are based on only one or a few sites, and none account for the large number of iron knives found at Palaepaphos. For a more thorough discussion and reevaluation of iron knife typologies see (Palermo 2018).

The most common form of Cypriot iron knife has a convex spine and concave edge. Variants of this type have a tip that tapers evenly to a point or a spine that comes down to meet the edge or vice versa. There are other examples with a concave or straight spine. Many of the tangs are either not preserved or not visible, but where they can be examined, they are typically either flat or fishtail. The vast majority of Cypriot iron knives that have preserved handles have wooden handles, although there are a few examples in ivory or bone. Bronze or iron rivets in varying numbers are used to secure the hilt plate to the tang.

Overview (Figs. 268-270, Knives, All Sites, All Dates, T=4):

The attribute that is most influential in creating the shape of the knives network is the shape of the spine (convex, concave, or straight). The major clusters that can be seen in the network graphs reflect this distinction (Fig. 268). The convex-backed knives form

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84 Knives are also the most common iron object in the LC III, CG I and CG II.
the largest group by far, but all three large categories are present at all the investigated
sites across the entire LC III-CA I period.

Another very influential attribute in the network is whether the knives use bronze
or iron rivets to attach the hilt plates to the tang. The networks nodes display a sharp
contrast between bronze and iron rivets. Rivet material, however, was weighted equally
with several other attributes, which indicates that there must be weak correlations
between rivet material and some other attributes, even if they are difficult to identify
precisely. Other categories have surprisingly little influence. In particular, the location
and intensity of the bend in the blade do not appear to have a large impact on the shape of
the network.

There are some trends that can be noticed across all the graphs. First, earlier
knives tend to use many rivets. Their purpose is apparently decorative, since they are
used in excess of what would be necessary to secure the hilt plates. Also, they are
sometimes arranged in decorative patterns, with alternating bronze and iron rivets or
bronze rivets capped in alternating silver and gold. Later knives, especially those from
the CG III – CA I tend to use only one or two rivets. Also, there are some noticeable
regional differences in tang shape. Many of the tangs from Palaepaphos are not
preserved, but the ones that remain are flat or slightly rounded. Amathous has produced
some knives with flat tangs, but the majority of preserved tangs are in a fishtail shape.

_Palaepaphos (Figs. 271-272, Knives, Palaepaphos, All Dates, T=2.5):_ The network graph of Palaepaphos knives consists of a lattice-like core of knives
with convex spines, a dispersed grouping of knives with straight spines, and a central
offshoot of knives with concave spines. The edge lengths are fairly uniform between 0
and 200 years, and the degree distribution is fairly uniform. This particular network is shaped by attributes rather than time: the proportion of edge lengths of this network is not statistically significant, indicating no provable temporal trends in the graph.

Several separate clusters of convex-back knives from the CG I period (yellow nodes) can be distinguished on the graph. They are primarily separated by whether they use bronze or iron rivets. Knives with iron rivets and bends at the top or middle are grouped on the top left side of the graph (P89.111; P49.12; P76.133). To the right is a group with bronze rivets and their bend in the middle of the blade (P142.81 and P48.2) and further right than that a couple knives with bronze rivets and the bend near the top of the blade (P76.72 and P76.134). In between these two groupings there are two knives with gradual bends (P146.96 and P147.19) which hold a central position in the network. Although P146.96 has iron rivets and P147.19 has bronze rivets, they both have gradual bends, which makes them more similar to later knives and supports their high centrality. The concave-backed knives are located in a different cluster in the top of the graph (83.8; 83.72; 84.15; 89.112; 114.64). Almost all of them have iron rivets. Finally, there are two straight-backed knives that connect the concave-backed knives to the rest of the network (76.23 and 76.96).

During the CG I, there was considerable experimentation in form, as can be seen by the dispersed location of these nodes. This variation of style suggests that knife production was not centralized and or uniform. It may hint at a collection of many communities of practice or perhaps at very experimental practices within fewer communities of practice. Even so, there are some characteristics that hold many of these knives together on the right side of the graph: the fact that they mostly have sharp bends.
either in the middle or the top of the blade, as well as the relative prevalence of iron rivets in this period.

There are not many knives from the short CG II period (green nodes). There are a few lingering knives with iron rivets in the CG II (convex-backed P53.7 and concave-backed P64.8), but the majority of the knives have bronze rivets. There is a concentration of CG II knives in the lower right area of the main grouping that have gradual bends and bronze rivets (P145.31, P63.51, P77.27, and P83.76). There is also P83.7 in the center of the convex-backed cluster, which has bronze rivets and a bend at the top of the blade. This knife is very connected to a cluster of CG III knives, suggesting that it might be a link between the earlier bronze rivetted knives with bends and the top and the later bronze rivetted knives with bends in the middle.

In the CG III (blue nodes) there is less experimentation and a single form emerges as the main knife type at Palaepaphos. These are the convex-backed knives with a bend in the middle of the blade and 2 bronze rivets in a central location on the left side of the graph. (P74.3, P148.18, P86.4, P52.1a, and P86.19). The nodes are quite close together suggesting a more centralized production. Knives with iron rivets become far less common in this period and the only one in the graph is P71.36 in the top part of the convex-backed cluster.85 Another CG III node is straight-backed knife P79.95, which represents a new variant with a flat back that drops flat down to the edge was developed in this period and continued on into the CA I (P54.8).

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85 P53.1c is similar to earlier knives with iron rivets from Palaepaphos, but P71.36 is fairly unusual. It is only slightly convex, and it has bronze and iron rivets. It is perhaps more similar to examples from Amathous.
**Amathous (Figs. 273-274, Knives, Amathous, All Dates, T=4):**

Like the graph for the Palaepaphos knives, the network graph of Amathous knives has core of knives with convex spines with an offshoot for other types. The edge-lengths are short, and most of the nodes have low degree. The proportion of short edge-lengths is statistically significant at p=0.05, meaning there is temporal influence on the network shape.

The only CG I-II knives (green nodes) at Amathous are A329.65.3 and A311.15, which are located on the right side of the graph. They are both convex-backed knives with bronze rivets. A311.15 has a bend at the bottom, which is very rare, but not unprecedented at Palaepaphos (for example P64.8) and which does not continue as a form at Amathous. This might suggest that A311.15 is a broker or an import.

In the CG III period (light blue nodes), a cluster of convex knives with bronze rivets emerges around the two earliest nodes (A310.11, A310.19, A373.8, A313.106, A313.101). These mostly have bends in the middle of the blade and many bronze rivets. These knives form a fairly standardized group, especially considering it is the early period of knife production. Perhaps this suggests that unlike Palaepaphos, where there was a long period of experimentation, at Amathous the technology was already somewhat standardized before it was adopted. In the CG III, there is only one knife with iron rivets (A310.1).

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86 P311.15 is not on the graph, but it is similar except that it has a bend at the bottom.
The forms being produced in CG III Amathous become more common in the CA I (dark blue and purple nodes). The CG III cluster knives with bronze rivets (including 310.19, 313.106, and 313.101) is closely connected to a group of similar CA I knives (including 314.27.2, 243.47.3, and 259.29). Similarly, the only CG III knife with iron rivets (A310.1) sits at the center of a group of similar CA I knives (including 321.91, 222.69, 142.94, 346.5.1, and 202.7). Unlike the knives with iron rivets that were popular at Palaepaphos earlier, these knives typically have a slight bend at the top of the blade and only one or two iron rivets.

The straight-backed knives branch off from the convex-backed cluster. They begin in the CG II, but are most common in the CA. Most of the examples that appear on the graph are of the type that has straight backs that slope straight down to the edge (A240.82, A443.66, A450.75, A313.79). This type also appears at Palaepaphos, however those examples tend to have the slope at the middle or top of the blade, whereas the examples from Amathous more often have the slope at the bottom of the blade. There are several other knives that are straight without a sloping back, but they are not well preserved and therefore do not appear on the graph.

There is a cluster of concave-backed knives at the very top of the graph (A302.67, A369.21, A301.8). All of these knives date to the CA I. Most are slightly concave with a gradual curve, but there are no noticeable correlations in rivet material or number. There is nothing to suggest that they are related to the concave-backed knives that were popular in CG I Palaepaphos.
CG I-II (Figs. 275-276, Knives, CG I-II, All Sites, T=3):
The large cluster in the upper right part of the graph represents convex-backed knives. As with the Palaepaphos-only network, the convex-backed knives display a combination of attributes that cannot be easily divided into specific types. The clustering primarily reflects a distinction between bronze and iron rivets, but each cluster contains knives with bends at the top, middle, and bottom of the blade. The only noticeable group is the knives with iron rivets, most of which have strong bends at the top of the blade. It is difficult to say whether this apparent randomness of attribute groups in the convex-backed cluster is the result of early experimentation in form the result of a paucity of data.

The majority of the convex-backed knives in this period are from Palaepaphos, but the three knives from Amathous A329.65.3, A311.15, and A329.65.3 are very central nodes in the graph. They are convex-backed knives with bronze rivets. Their many connections to knives from Palaepaphos suggest that these knives were important brokers in connecting the CG I-II knife making practices of Palaepaphos with the later traditions that would emerge at Amathous.

A group of concave-backed knives with iron rivets, mostly from Palaepaphos, are grouped in the lower right section of the graph (P84.15, P89.112, P83.8, P77.5, P144.64, P83.72). There is a noticeable preference for iron rivets in these knives. The only one that uses bronze rivets is the knife from Kourion. They do not have many other similarities in form. For example, they have bends at the top, middle, bottom and throughout.
CG III (Figs. 277-278, Knives, CG III, All Sites, T=3):
The CG III graph is interesting because there are a fairly equal number of examples from Palaepaphos and Amathous, allowing for a comparison between formation practices at the two sites.

The large cluster in the upper right of the graph consists of convex-backed knives. There is some differentiation between the Amathous nodes (left side) and Palaepaphos nodes (right side). The Palaepaphos knives all have bronze rivets, but the location of the bends is very variable. The Amathous knives, on the other hand, have a mix of bronze and iron rivets. The examples with iron rivets are more likely to have their bends at the top, whereas the bronze examples are more likely to have bends in the middle.

While knives with iron rivets are commonplace in the earlier periods of Palaepaphos, they dramatically drop in the CG III. Amathous has the opposite pattern, with iron rivets picking up in the CG III and predominating in the CA I. One important distinction is that the earlier Palaepaphos knives with iron rivets often have 3 or more iron rivets in the hilt. In other words, they are being used in much the same way as bronze rivets of that period. The later knives, which seem to be an Amathous innovation, use only one (or in a few examples 2) iron rivets. They also have slight bends at the top of the blade, and fishtail tangs and wooden handle plates (A379.5.2, A310.1, A321.91, A142.94).

Connecting the convex-backed knives from Palaepaphos and Amathous are a number of knives with a very high degree centrality including A313.106, A314.27.2, A310.1, A310.19, and A313.101. As Palaepaphos-type knives that were found at Amathous, A310.19 and A313.101 can be considered important brokers in this network.
The projecting group in the left of the graph contains the straight-backed knives. They are a mix of examples from Palaepaphos and Amathous. Most are examples of the type with a straight back than slopes straight down to the edge (P71.29, P54.8, A313.79, P79.95). For the most part they have bronze rivets (with the exception of P54.8), although they all have different numbers of rivets. Despite similarities in form, they may be produced at both sites, since the examples from Amathous have fishtail tangs and the examples from Palaepaphos have flat tangs.

*CA I (Figs. 279-280, Knives, CA I, All Sites, T=3):*

The CA I knives are predominantly from Amathous, with only a few scattered examples from Palaepaphos. Consequently, this graph is very similar to the graph from Amathous and there is very little information to be gained about the interaction between the sites.

The convex-backed knives are in the top right cluster of the graph. They can be divided into three groups, which roughly correspond to the clusters. In the bottom (blue nodes) there are knives with bronze rivets and bends in the middle of the blade. In the upper left area (green nodes) are knives with iron rivets, some of which have their bends at the top, but many of which are very poorly preserved. The iron rivetted knives of this period are much more likely to have only slight bends. Lastly, on the right of the cluster (red nodes) are knives with no rivets preserved, and gradual bends.

The lower left branches of the graph contain the straight-backed knives as well as some poorly preserved knives that cannot be identified as convex, concave, or straight. This sector of the graph is less densely populated. The section branching off to the upper
left of this graph contains the concave-backed knives. These are discussed in the above section on Amathous.

Conclusions

Some observations can be made about different working techniques in use by communities of practice at Palaepaphos and Amathous. Most noticeably, the tang is often fishtail shaped at Amathous, and typically flat at Palaepaphos. There are also differences in the use of bronze or iron rivets at the two sites. Whereas iron rivets are commonly used in early knives at Palaepaphos, they only become popular at Amathous significantly later. The networks for each individual site also display a strong difference between bronze-rivet and iron-rivet knives, suggesting that this difference correlates to other attributes and may be indicative of separate communities of practice.

Iron knives are also a useful category for looking at changes in time. Trends could be seen both at the individual site level, but also at the regional level. For Palaepaphos knife production was not uniform during the CG I period but became more standardized by CG III. At Amathous, on the other hand, knife production was more uniform in the CG II and more variation in types were developed in the CG III and CA I. There are several examples of knives form an earlier that are very central in the network because that form becomes popular later on. For example, the only knife with iron rivets in the CG III (A313.1) shares many connections with a set of CA I knives that also feature iron rivets (including 321.91, 222.69, 142.94, 346.5.1, and 202.7). In this instance, A313.1 can be seen as the progenitor of a new form. Interactions are also seen between the sites. In another instance, knives A329.65.3, A311.15, and A523.99 were identified as brokers between the CG I-II period at Palaepaphos and Amathous.
**SPEARHEADS**

There are not many spearheads in the database (only around 40 useable examples), so the networks are not as robust as the networks for other object classes. The spearheads cannot be subdivided into smaller networks and maintain the desired credibility of results. As a result, the only graph presented here includes all sites and all time periods. Furthermore, the majority of these forms seem to have been produced for very long periods of time and there are not enough examples to securely trace changes within types over time. Nevertheless, some results can be observed from the graph (Figs. 281-283). Objects which are not included on the networks are still described in this section. The network contains a cluster at the bottom-right with short edge lengths, with longer edge lengths branching out from the dense cluster. Both the edge-length and degree follow Poisson distributions. Using the average edge-length, there is temporal diffusion present, statistically significant at p=0.10. The network resembles a small-world network, both in its visual appearance and in its underlying metrics.

It is immediately evident that the Palaepaphos and Amathous spearheads form distinct clusters separate from one another and that the Palaepaphos group contains more bronze spearheads, whereas the Amathous group contains more iron spearheads. This distinction almost certainly reflects a temporal trend in which iron spearheads make up a higher percentage of the total spearheads over time.

The spearheads from Palaepaphos form two fairly cohesive groups in the graph – one group of bronze spearheads and the other of iron. The bronze spearheads can be further divided into two groups. First, there are very tall, square plain spearheads of the SCE type 1a (P49.16, P49.17, P49.18, P67.56, P146.6, P146.7). The majority, however,
fall into the SCE type 2 and these cluster at the lower right side of the graph. Several belong to the long, narrow spearheads classified as 2a, 3 (P144.68, P76.65) or 2a,4 (P49.15, P58.16). The majority, however, belong to the shorter variety with slightly wider wings, 2b, 5 (P119.5, P51.21, P58.36, P86.71, P89.82, P89.108, P104.N64).

The bronze spearhead type 2a,5 in fact seems to have two distinct rib types, one with a low, flat midrib (represented at both Palaepaphos and Amathous and therefore present in the typology), and one with a high, narrow, round midrib (only found at Palaepaphos). There does not appear to be a temporal distinction between the two types, and it is possible that they represent two different communities of practice.

The iron spearheads from Palaepaphos are also very consistent in form, and they are clustered in the upper right side of the graph. They do not clearly belong to a typology for iron spearheads laid out in the SCE, instead they have more in common with the bronze spearheads type 2b,6 (P69.51, P77.24, P77.51, P143.1, P144.69).

The spearheads from Amathous are more heterogeneous and form a wide halo around the outside of the graph. The bronze spearheads include the SCE Type 1a (A49.16, 17, and 18). There are also some of SCE type 2b, 5-8 (A6.13, A21.12, A21.39, A23.61, A42.4). The iron spearheads correspond better to the SCE types, which is unsurprising since the typology was formed in part based on the Amathousian examples. SCE iron spearhead Type 2b forms have more of a diamond shaped blade, with the widest point higher up than the socket. Spearheads of this type further separate into two subgroups: forms that have more rounded wings (varying midribs), and form that have more diamond-shaped wings (tall, narrow, round midribs).
One curious observation from the network is that the majority of iron spearheads from Palaepaphos are in a form that is also produced in bronze (2b, 6). In fact, this is a form that is more popular at Amathous than it is at Palaepaphos. This trend can be observed on the graph, where Amathous nodes (esp. A366.1 and A21.39) are the main link connecting the iron spearheads from Palaepaphos to the rest of the nodes. The iron spearheads from Amathous, on the other hand, are primarily in several related forms that are not made in bronze (2b, 9-11).

BRONZE AND IRON WORKING COMMUNITIES IN EIA CRETE

FIBULAE

The fibulae from Crete are much more heterogeneous than those from Cyprus. Whereas the Cypriot examples belonged overwhelmingly to a small number of types, the Cretan examples come in a wide variety of forms.87 The two major studies that address fibulae typologies in the Aegean islands are (Blinkenberg 1926) and (Sapouna-Sakellaraki 1978). The type numbers used in this discussion come from Sapouna-Sakellaraki. This does not allow for a comparison of workmanship within types, making it impossible to perform the kind of network analysis utilized for the Cypriot examples. Perhaps, more importantly, the low number of fibulae in such a vast array of types suggests that they were not locally made. Catling notes, in fact, that none of the forms found at Knossos is unique to Crete, and many have wide ranging find spots. If these fibulae are imported, they cannot be indicative of local bronzeworking techniques.

87 For example, among the 37 classifiable examples in the Knossos North Cemetery publication, seventeen distinct types are represented (Coldstream and Catling 1996, 551).
After examining the distribution of fibula types that are commonly found at Knossos, Vrokastro, and Kavousi, it is clear that the major networks in which the Cretans are enmeshed are within the Aegean and western Asia Minor. The most common types have distributions around the Aegean islands and mainland, including fibulae with highly decorated beaded bows (SIIIb, SIIIc, and SIIIe) and fibulae with tall catch plates and swollen bows or spherical bosses (SIVd, SVa, and SVIIIa). The Cretan assemblages also contain some mainland types, including Attic-Boeotian types (SIVd) and spectacle fibulae, common in Northern Greece.

There are several fibula types which plausibly could have been locally produced. Among these Cretan types, those found at Knossos and those found in the Bay of Mirabello have some very noticeable differences (Fig. 284). Notably, within the heading of “bow fibulae,” Knossos has many more examples with a rounded bow (SIIa), whereas the Bay of Mirabello sites are far more likely to have square bows (SIIc), flat bows (SIIId), and twisted bows (SIIIf). Of the fibulae with decorative beaded bows and large catch plates, Vrokastro has produced more examples with round (SIIIb) or biconical (SIIIc) beads and Knossos has produced more examples with round and biconical beads together (SIIIe). Fibulae with swollen bows (SIVa-b, but especially SIVb) are vastly more common at Vrokastro than Knossos. Fibulae with swollen bows or spherical bosses and large catch plates (SIVd, SVa, SVIIIa) are found fairly commonly at Knossos and not at all at Vrokastro.

The forms that make up the majority of the Vrokastro assemblage are twisted bow fibulae (SIIf), swollen bow fibulae (IIIf), and beaded fibulae with biconical beads (IVb). The forms that are most common at Knossos are more spread out, but they are dominated
by the types with swollen bows or spherical bosses and large catch plates (SIVd, SVa, and SVIIIa). This suggests that even within primarily Aegean-based networks, Knossos is enmeshed in a slightly different network from the Bay of Mirabello.

The preponderance of non-Cretan fibula types in Cretan tombs makes a network of forming practices and smithing difficult to isolate and construct. The network of forming practices can become indistinguishable from a network of trade relationships. Nevertheless, I created a network of Cretan fibulae using the same method I employed in creating the Cypriot fibulae networks (Figs. 285-286). The Cretan network covers all dates and has a threshold of 6. The shape of the network is overwhelmingly determined by fibula type, discussed above. There are so many different fibula types present that each example only contains a small number of nodes, and larger correlations or interactions cannot be distinguished. There is some separation of Knossos nodes from Vrokastro nodes in the graph, confirming my observation that certain fibula types are more frequent in Knossos than in Vrokastro and vice-versa.

There is very little to suggest any connection to Cypriot fibulae, let alone to support any claim of local Cretan production of Cypriot forms. The only form that may provide some connection is the simple bow fibula. Sapouna-Sakellaraki points out that they were produced in Crete and Cyprus but does not argue for a direct connection. This type is very early (the examples from Crete date primarily to the SM period), so if there was a connection between the two metal working communities it would have to be quite early and did not continue. There are also a few examples of asymmetrical fibulae from Vrokastro that might be argued to resemble Cypriot forms, but they are very rare and probably imported.
**BOWLS**

Hemispheric bowls were not common in the LBA Aegean, although they were common in the Levant and Cyprus (Matthäus 2005, 99). It is likely that the form traveled to the Aegean in the EIA. Unfortunately, however, most of the bowls from contexts on Crete were found in terrible condition and not much can be said about the shape or profile. The poor quality of the evidence makes it impossible to attempt anything more than a qualitative discussion.

The most common vessel is the hemispheric bowl, which provided the basis for the network analysis of Cypriot bowls presented above. Several bowls of this type were excavated at Knossos (100. 35-37; 207.6; 285.59; G.2, 3), but the vast majority were fragmentary. They are quite similar to Cypriot examples in size and shape. They have diameters of between 12 and 20 cm and heights between 4.8 and 6.5 cm. Some have holes, either for hanging or for attaching them as lids on vessels (207.6 and G.3). This is not a common feature of these bowls on Cyprus, but since the holes likely reflect their final use rather than their manufacturing history, this feature cannot be used to comment on crafting practices.

Other more decorative vessels have been used to support the Cypriot connection with Crete, but there are very few of these overall. Several bowls with lotus-bud handles have been found at Knossos (Knossos 219.85, 93, 97). In these examples, the handle escutcheon is in the shape of a figure eight, to which a horizontal loop handle with a lotus bud finial is attached. This handle form has parallels on Cyprus that seem to date to the early CG (two at Amathous, two at Palaepaphos, and 7 without provenance). Similarly,
there are several vessels with bolster hands from Knossos (Knossos 219.118, G.6), which have a rough parallel in a strainer from Kaloriziki (49-12-1029, PGB-EG).

**Knives**

As on Cyprus, iron knives are one of the most frequent iron finds on EIA Crete. Similar to the Cypriot knives, they can be separated by the shape of the spine (convex, concave, or straight). Whereas the most common form on Cyprus has a convex back, the most common form in Crete has a straight back. The majority of the knives included in this network are from Knossos, where straight backed knives make up the vast majority of the assemblage. Vrokastro has only produced a few iron knives, and Kavousi none at all. Although the sample size is very small, the Vrokastro knives appear to be quite distinct from the Knossos examples, since they have convex or concave backs. This suggests that iron knife production may have been confined to local production.

The knives from Crete display some particularities that are not very common on Cyprus. Notably, many have hand-stops where the blade joins the tang. This feature is known on Cypriot examples, but it is not common. Also, examples from Crete usually have between 0 and 2 rivets, unlike Cypriot examples (Coldstream and Catling, 585). Although not many rivets are preserved, iron appears to be more common than bronze rivets.

There were not enough examples of Cretan knives to create a credible Crete-specific network. I used common attributes to create an overall network consisting of knives from both Crete and Cyprus, but the Cretan connections were so few that the network was virtually indistinguishable from the Cyprus-only knives network.
CONCLUSIONS

The strength of a network approach is in the ability of a network to organize data in a succinct and revealing manner. Network analysis can be used to highlight connections between objects and groups of objects that are difficult to observe otherwise. Subtle relationships underpinning several correlated factors are difficult to spot by visual inspection alone but can be borne out in network diagrams. Furthermore, networks are malleable and can be generated to organize different swaths of data. It is relatively easy to generate separate networks looking at objects from individual slices in time or from specific locations. These more specific representations of subsets of data can be used to highlight new features or refine overarching conclusions.

Network analysis presents a useful way of investigating communities of practice. In some cases, clustering methods were used to locate groups of objects that were made using similar forming techniques. In other cases, observing groupings by visual inspection of the graph was more effective. These two methods were used in combination with each other to observe significant groupings and sub-groupings in a network, relying on the organizational power of the network.

I was also interested in the relationship between different communities of practice and between sites on a regional level. Consequently, I sought to identify boundary objects that might have connected communities into “constellations” of practice. A traditional approach to these data sets has involved developing typologies and assigning individual objects to these types. This has the effect of flattening the data, since any features of the object that do not strictly conform to a standard type are effectively ignored in the analysis. Using a network approach allowed me to highlight the objects that bridge the
gap between types and use more information present in the object and its features. Boundary objects can be identified by looking at nodes with high centrality in the network or nodes which have strong ties to another community of practice or strong ties to objects from another site. For example, in the fibula network, two fibulae from Palaepaphos (P49.19 and P67.111) and two from Amathous (A331.37 and A23.63) differed from the most typical forms found at their respective sites but were similar to each other. I argue that they can be seen as brokers between communities of practice at the two sites.

Finally, when time-specific information is included, networks can be used to identify diffusion of innovation. In most of the networks that were generated there was temporal diffusion, meaning that objects were closer in time more often than would be expected by chance. It is possible to follow how the form and formation practices of objects changed through time by following time sequences in the network diagrams. I also looked to identify brokers in time, objects which, based on their features and chronology, seemed to be made at transitional points or moments of technological change. For instance, the only CG III knife with iron rivets (A313.1) sits at the center of a group of similar CA I knives (including 321.91, 222.69, 142.94, 346.5.1, and 202.7).

When considering the aggregate results all of the Cypriot networks, it is clear that there is a metallurgical “koine” on Cyprus that is evident in shared forms in bronze and iron. On the most basic level, similar assemblages are found at each site, including bronze ornaments (fibulae, pins, rings), vessels, needles, and spearheads, along with iron knives, spearheads, swords, daggers, and arrowheads. Furthermore, the typological distributions within object categories are similar for each site. For example, hemispheric
bowls are the most common bowls, asymmetrical beaded fibulae are the most common fibulae.

What accounts for this overall similarity in form? It could have been the result of centralized production and subsequent distribution throughout the island. In addition, some objects certainly travelled through trade. These explanations seem rather unlikely, however, since debris from metallurgical activity has been found at many sites.

Alternatively, the similarity in assemblages could be interpreted as a result of deeply entwined communities of practice, where metallurgical knowledge was shared across the island. If this were the case, we would expect ingrained similarities not only in the typology of objects but also in the forming techniques used to produce them. If people were sharing metallurgical knowledge between sites, how did the mechanics of the technological transfer actually function? Were metal workers travelling around the island, or apprenticing somewhere distinct from the area where they eventually practiced? In order to investigate these questions, it is vital to consider which stages of production rely on shared knowledge and which do not. Similarly, we can examine whether there are more similarities between nearby sites than between more distant ones.

In the LC III and CG IA there are similarities in both bronze and iron objects at Palaepaphos and Kourion. A fibula from LC IIIB Kourion has raised bands around the beads, which are rarely seen outside Palaepaphos. A bronze pin with an ivory head from LC III Kourion has parallels in iron in CG IA Palaepaphos (and Amathous). Very similar cast bronze rings have been found in LC III contexts at Kourion and LC III and CA IA contexts at Palaepaphos. Many of the iron knives from LC III and CG IA Kourion have concave backs and two bronze rivets (Bamboula 16.20, one from the settlement at
Bamboula, Kaloriziki 19.32, 39.31). A similar form emerges in CG IA Palaepaphos that features a concave back, but with iron instead of bronze rivets (84.15, 89.112, 144.64). There are far fewer tombs from LC III and CG IA Amathous and Lapithos, so it is difficult to compare them.

In the CG IA and CG IB periods, Palaepaphos provides by far the most evidence of fibulae and, perhaps relatedly, the most variety in form. Other sites are producing particular forms that are also found at Palaepaphos, but no other site is producing the full range of fibulae that Palaepaphos is. At Palaepaphos both 2 and 3 beaded asymmetrical fibulae were produced, with a variety of decorations, both incised and part of the mold. Fibulae from the other sites only have incised decoration if decorated at all, and there are several examples of incised decoration at Lapithos in particular.

Palaepaphos continues to produce both convex- and concave-backed knives. The concave-backed knives have iron rivets only, but the convex-backed have both bronze and iron rivets and with a wide variety of numbers of rivets and with different handle materials (wood, bone, and ivory). Convex-backed knives only are found at Lapithos and Amathous. Palaepaphos similarly is producing multiple spearhead types, including one that is a very tall, rolled piece of bronze that resembles a spike. Overall the variety of forms at Palaepaphos, and especially the two very distinct knife types, might suggest that multiple communities of practice were active there during the CGI period.

There are generally not large shifts in form between the CGIB period and the CGII period, but in some places smaller-scale trends emerge. Asymmetrical 3-beaded fibulae continue to be the most fibula common type, although 2-beaded fibulae also continue at Palaepaphos and Lapithos. More incised decoration, especially vertical lines
on the beads, is employed, particularly at Palaepaphos and Lapithos. Iron knives continue in the same traditions as the CG I. There are fewer examples of concave-backed knives in the CGII with examples found at Palaepaphos (77.50, 83.8, 83.72) as well as one at Amathous and one at Lapithos, which had not produced concave-backed knives before. Convex-backed knives also continue to be produced with both bronze and iron rivets at Palaepaphos. Finally, there is a substantial change in spearheads in the CGII period. In the CGI, it is predominantly bronze spearheads that are found. By the CGII period, spearheads are produced primarily in iron, rather than bronze.

The artifact evidence only presents a partial picture of the CGIII period, since the majority of evidence from this period comes from Amathous, largely precluding direct cross-site comparison. Fibulae forms change fairly significantly from predominantly asymmetrical with thinner arms to symmetrical with thicker arms. There are biconical and squat bead versions, some with incised decoration and the others without decoration. There are not many fibulae from other sites in this period, but there are a few from Palaepaphos with undecorated biconical beads, compared with several from Amathous with biconical beads. The majority of the convex-backed knives have bronze rivets in this period, although one knife with iron rivets precedes a group of CA I knives with iron rivets.

The forms of Cretan objects, in sharp contrast to the Cypriot examples, are quite heterogeneous. There is, for example, an enormous range of different fibula types that each contain only a few examples. Further analysis of the communities of practice beyond this overarching conclusion is not possible without further evidence. The lack of secure dating is an obstacle to analysis of the generated network diagrams, since
differences in communities of practice between sites cannot be easily separated from
general temporal differences across all sites. In the absence of secure dating, an
assemblage-based comparison would be most appropriate for trying to identify
communities of practice. My analysis only includes three sites, however, and many more
sites would be required in order to give assemblage-based comparison credibility. There
are clear examples of forms that are found at certain sites and not others, and perhaps are
examples of local metallurgical traditions, but the evidence does not appear in large
enough numbers. Objects from more sites or smaller time slices will be required to fully
investigate forming practices of Cretan artifacts.
CHAPTER 7: CONCLUSION

The final stages of this dissertation have coincided with the outbreak of the COVID-19 pandemic. The emergence of this virus and the adoption of unprecedented measures of social distancing have highlighted the interconnectedness of our social fabric and drawn attention to the challenges and limitations of learning at a distance. While Early Iron Age Cyprus and Crete are a far cry from the modern world, my project, which addresses how metallurgical knowledge was transferred in those regions both in-person and at a distance, has some timely resonances with the current environment.

As a result of the pandemic, University courses and K-12 education alike have moved entirely online. While the virtual world has presented some new pedagogical opportunities, it is clear that something quintessential is lost when we are not physically together. Lab-based instruction is at a particular disadvantage, since it relies upon training students to perform techniques that are based in the physical manipulation of materials. Developing these skills requires students and instructors to occupy a certain physical space together, often one containing expensive, immobile equipment.

For the craftspeople of the Early Iron Age Mediterranean, acquiring the physical skills needed for metallurgy would also have required access to immobile infrastructure, and long apprenticeships under experienced smiths. This presents a bit of a conundrum: in-person instruction was necessary to acquire metallurgical knowledge, yet, at the same time, it is clear that innovative techniques did travel over long distances. After all, this period of time is known in the Mediterranean as “the Iron Age” because of the
widespread adoption of iron smelting that took place throughout the region during this
time. So how were metallurgical techniques developed, shared, and transmitted across
space? My dissertation looks at this question in the context of Early Iron Age Cyprus and
Crete.

CYPRIOT SMITHS IN AEGEAN WATERS?
A long-standing view in scholarship of the Early Iron Age Mediterranean holds
that Cyprus was home to a more advanced metallurgical tradition than the Aegean and
that important innovations, especially iron smelting and intricate bronze casting, were
developed in Cyprus and then adopted by Aegean smiths. Many scholars posit the
presence of Cypriot craftsmen on Crete to explain how this kind of complex technical
knowledge could have been spread. Although recent studies have complicated this
narrative and have begun to chisel away many lines of evidence underpinning it, there
has yet to be a significant shift in perspective. In order to further this discussion, I
maintain that a different approach is needed: one that tries to characterize metallurgical
systems by drawing on anthropological theory, employing methods used by scholars
asking the same questions in other areas of the world, and expanding the available data
while making use of the evidence in its current state.

Before constructing arguments about the spread of technology on a pan-
Mediterranean scale, it is necessary to have a more complete understanding of the
regional technological systems in place in both Cyprus and the Aegean. There are still
many open questions about the organization of mining and smelting and their relationship
to later stages of production, as well as about the role of metallurgical smiths and
workshops. Furthermore, tackling the question of how innovation spread across the
Mediterranean without having a good sense of how metallurgical techniques might have been shared or non-shared locally or regionally seems premature.

The arguments that have been made about the transfer of technology have tended to focus on a few outstanding objects types, especially bronze stands and tripods and iron knives. There are good reasons for this, since these objects offer easily visible markers of technology in the archaeological record. When these objects are placed against the backdrop of the multitudes of mundane object types, such as fibulae or rings they do not seem as significant and do not constitute as credible a data set on their own. Furthermore, discussions of the transfer of technology have primarily focused on the development and popularization of iron smelting and innovative heating treatments such as carburization. In order to fully understand the metallurgical systems that were already in place and through which newer iron technology could spread, there must first be a better understanding of bronze metallurgy.

Ideally, a full program of study to understand the entire technological system of the Early Iron Age would include the investigation of mining sites, smelting sites, and workshops, and combined with archaeometallurgical study of slag from smelting and refining as well as petrographic study of technical ceramics and crucibles. Unfortunately, the available evidence for EIA Cyprus and the Aegean is famously limited, with the evidence coming predominantly from burials rather than settlements. The lack of settlement objects means that there is no slag or ceramics, and also obscures whether the objects were produced locally or imported. Nevertheless, I approach this question using scientific testing and network analysis, a combination which can make the best use of the limited evidence and legacy data that is available.
CHÂINE OPÉRATOIRE AND TECHNOLOGICAL STYLE

Châine opératoire and technological style provide a framework for understanding how craftsmen transform raw materials into finished objects. At each step in an object’s production, craftsmen make decisions which reflect their skill, experience, and training. These decisions are usually made in accordance with larger organizing principles that often reflect societal beliefs and values. Although craftsmen are constrained to some extent by these structuring principles, there is also room for improvisation and variation. Using techniques drawn from archaeological sciences, I was able to shed light on the decisions made by craftsmen at each step of production, and therefore to reconstruct the entire châine opératoire for each object.

Four needles from Lapithos serve as an example of the power of a châine opératoire approach. Needles 32-27-1195 and 32-27-1196 were likely made at the same time by a single craftsman, given that they are nearly identical in all of their characteristics. The same sequence of patterned action was performed at every stage in their production, from originating as a single batch of metal to the distinctive way they were hammered while the needle was turned. Needle 32-27-735 shares many similarities with the previously mentioned needles, particularly in the way it was alloyed, cast, and worked, but it diverges from them in the earlier stages of production (source, smelting, refining). Although it was likely not made at the same time, it could have been made by the same smith or by another smith trained in the same tradition. In particular, the similar pattern of the lamina in the microstructure reflects the direction of hammering, a gesture unlikely to change because it is part of embodied knowledge. Needle 32-27-745, on the other hand, is very distinct from the others in both its source metal and the techniques
used to form it. Nevertheless, it conforms to the same alloying practices as the other needles, since it contains more lead than other object types. The consistent addition of lead to needles and pins at Lapithos appears to be a deliberate choice, although there is no functional explanation for it. This needle appears to have been formed by a craftsman trained in a somewhat different tradition, although he was aware of some characteristics of the other Lapithos needles, such as the use of lead.

There are important distinctions among Cypriot samples, as seen above, but taken wholistically, they are more similar to each other than they are to Cretan samples. Samples from the Cypriot sites display consistency in their production sequence, from ore to object. The ore used for each of the objects appears to have been mined in Cyprus and smelted in more reducing atmospheres than the Cretan samples. This suggests a standard technique of processing ore at multiple smelting sites, perhaps indicating overall similarities in the styles of furnaces that were in use. I also identify similarities in how the raw metal was handled once it arrived in workshops in coastal centers. For example, it was typically alloyed with tin at levels of around 8-10% tin, with a few exceptions such as the high-tin bowl and low-tin needles. Later stages of production, especially working and annealing, are more difficult to compare across object types and techniques appear to be more locally distinct.

The samples from Vrokastro have more eclectic histories of production. Since there are no copper sources on Crete, all raw metal would have to have been imported. Smiths at Vrokastro appear to have been obtaining copper from a diverse range of sources. A couple of the objects likely originated from Cypriot ore, but the majority came from other sources. This imported metal was likely smelted near the mining sites and
unsurprisingly there is some variation in smelting practices. Most samples, however, were smelted in a less reducing atmosphere than the Cypriot examples. There is also significant variation in the later stages of production including alloying and working techniques. These steps were more likely to have been carried out at Vrokastro and might suggest it was not home to a very uniform or stable metallurgical system.

**COMMUNITIES OF PRACTICE**

The communities of practice approach emphasizes the socially embedded nature of learning, which occurs as a part of everyday life through the active participation of the learner in increasingly difficult tasks. Communities of practice are understood as small learning networks comprising members who are in regular face-to-face contact. They are characterized by a “shared repertoire” among other things (Wenger 1998, 73). Communities of practice are emerging and dynamic rather than static or fixed, and membership in one community does not preclude membership or participation in another.

In this study I have employed methods from network analysis and archaeometry to identify communities of practice operating at EIA sites on Crete and Cyprus. The foundational premise of these identifications is that similarities in the *châine opératoire* of objects from a single site can be considered indicative of a community of practice active at that site. I rely on two broad techniques to identify active communities of practice. First, I use archaeometric methods to reconstruct detailed *châine opératoire* for a representative group of samples from each site (see above). These *châine opératoire* can then be compared to look for similarities, which might indicate the objects were made by members of a single community of practice. Second, I use network analysis to identify and investigate clusters of objects, which are drawn together by similarities in
their attributes, and therefore represent groups of objects made with similar forming practices. Networks are particularly useful in identifying objects which are connected by an accumulation of many small similarities, which would not be as obvious to a human observer.

Archaeometric testing confirms that different sites are characterized by differences in the *châine opératoire* that can likely be attributed to the preferences and training of local communities of practice. I argue that the samples from Kourion can be attributed to a single community of practice, whereas the samples from Lapithos can be separated into two communities, which I label Lapithos A and Lapithos B. Each group can be differentiated from the others by (1) the specific ore body exploited, (2) the treatment of the ore during smelting and/or refining, (3) patterns of alloying, (4) the care taken during casting, and (5) the use of hammering and annealing to shape the objects. While the Lapithos A and Kourion groups are fairly distinct in each category, the Lapithos B group shares some characteristics with Kourion and others with Lapithos A (discussed below).

The presence of these distinct communities of practice on Cyprus demonstrates that most metallurgical training occurred within local communities. Since smiths learned to work metal from experienced members of local communities of practice, the objects they created display the same minor differences in technique as other objects made by members of the same community of practice. Even within the site of Lapithos, smiths displayed preferences for the techniques of their specific community of practice. While the samples included in the study suggest there was only one community of practice
active at Kourion, few samples from Kourion were analyzed. It is possible that additional 
samples from Kourion might reveal other communities of practice.

The Vrokastro samples are more difficult to assign to clearly defined communities 
of practice. While some objects, such as the two nails, can be attributed to a single 
community of practice, most show a great deal of variation in the ore bodies used, as well 
as in alloying and forming techniques. Imported metal and imported objects could 
account for some of this variation. Based on the network analysis of Cretan objects, 
however, I consider it likely that the majority of the Vrokastro objects were produced 
locally. This suggests that multiple communities of practice using a diverse range of 
practices were at work at Vrokastro. The heterogeneity of the objects therefore indicates 
that metallurgical production at Vrokastro was not as centralized or as stable as 
production on Cyprus, suggesting small-scale production by a number of groups or 
individuals.

The results of the network analysis confirm the general patterns seen in the 
scientific testing. Networks of Cypriot bronze objects show an overall similarity in form 
not seen in the Cretan networks, but local styles can still be discerned. For example, the 
fibulae network shows that assymetrical D-shaped fibula are common across Cyprus, but 
examples from each individual site cluster together due to similarities in their forming 
practices (Fig. 231). Local styles include, for example, a preference for incised decoration 
on fibulae from Lapithos in the CG I and II and springs that make two turns at Amathous 
in the CG III. Broad similarities between objects at Cypriot sites suggest a metallurgical 
industry that was fairly well-connected, where information was shared around the island.
Differences in the details of production, however, suggest most training took place on a local level.

The network analysis of Cypriot iron objects show that iron production was more locally distinct than bronze. For example, during the LC III – CG I period, iron knives with concave backs are produced exclusively using bronze rivets at Kourion and with exclusively iron rivets at Palaepaphos. Similarly, knives at Palaepaphos always have flat or round tangs, whereas at Amathous fishtail tangs become the dominant form in the CG III and CA I. Similarly, iron spearheads from Palaepaphos resemble bronze prototypes, whereas the Amathous iron spearheads take different forms, not seen in bronze.

The network analysis also reinforces the possibility of multiple communities of practice active at a site at one time. For example, in the CG I period Palaepaphos smiths produced iron knives in two quite distinct forms: concave-backed knives with iron rivets, which are only seen at Palaepaphos, and convex-backed knives with both bronze and iron rivets, which are seen at every site in the network. Similarly, smiths produced two very different types of spearheads: a very tall, round type that is only seen at Palaepaphos and another type with tall, narrow wings that is more commonly seen outside Palaepaphos. One of these groups seems to be a type fairly unique to Palaepaphos, while the other is more commonly found at other sites. This second group could consist of imported objects, but the frequency of the finds and overlap with other features common to Palaepaphos points toward local production. I suggest that these two groups could be representative of two different communities of practice active at Palaepaphos in the CG I, one of which had closer contact with smiths from the other sites in the network.
Network analysis also confirms that bronzeworking traditions on Crete were varied and that multiple communities of practice may have been active at each site. For example, the structure of the fibula network reflects the fact that Cretan smiths produced a wide variety of fibulae types, which relied on a diverse set of forming techniques. Multiple fibula types were in production at each site. Like on Cyprus, however, there are differences in local style between fibulae found at Knossos and those found at Vrokastro which suggest that most transfer of learning occurred on a local level (Fig. 284).

**CONSTELLATING PRACTICE AND KNOWLEDGE SHARING**

Constellations of practice provide a mechanism for addressing the scalar aspects of learning and the transmission of knowledge. Whereas communities of practice are understood as locally grounded, constellations of practice are more diverse or more diffuse configurations, often connected by boundary objects or brokers. Boundary objects link communities of practice together through their use of a common object, place, or other shared concepts.

In this study I have identified boundary objects both through network analysis and scientific testing. These are objects that exhibit attributes or forming practices that are a melding of attributes in two established communities of practice. In the scientific analysis, these objects often made use of some techniques that were common in one community of practice (for example, a certain percentage of lead used in alloying) and other techniques common in a different community (for example, extensive refining practices). In the context of network analysis, boundary objects were nodes with high centrality or in some cases, nodes that were embedded in a cluster with other nodes from a different site.
Scientific testing revealed connections between communities of practice at Kourion and Lapithos on Cyprus. Although the ores come from different sources on Cyprus, they were treated more similarly during smelting and alloying stages than the Cretan samples. This similarity of practice can be attributed to longstanding connections that led to a set of shared techniques, especially similarities in furnaces, in methods of refining, and in alloying. Similarities in the early stages of production, especially smelting, reflect knowledge sharing at mining and smelting sites in the interior of the island, whereas later stages including similarities in alloying reflect knowledge sharing between coastal centers.

Furthermore, connections between Lapithos and Kourion can be seen in examples of boundary objects which “constellate” practice by combining formation practices typical of different communities of practice. In particular, the Lapithos B samples make use of formation techniques typical of both Lapithos A and Kourion. For example, I interpret Lapithos B needle 32-27-745 as a boundary object, since it incorporates elements of both Lapithos A and Kourion objects, without fitting in neatly with either group. As stated above, it was carefully refined, like the Lapithos A samples. It is a low tin bronze, like the Kourion needles, yet it contains lead in a level more comparable to the Lapithos A needles. I argue that the employment of multiple local techniques in the formation boundary objects like this needle suggests that they were made by a smith familiar with the traditions with the typical châine opératoire of both Lapithos A and Kourion, perhaps having travelled to both places. These boundary objects therefore provide the best evidence for metallurgical specialists moving between the two sites.
Constellations of practice is a framework that could also be used to address connections between Cypriot and Cretan communities of practice. However, my research has demonstrated that it is much more difficult to find a clear connection between the Cypriot and Cretan samples. The samples show significant differences in many steps in the production sequence. Furthermore, no objects included in this study demonstrated a clear combination of techniques common on Cyprus and those common on Crete. This suggests that knowledge sharing did not follow similar patterns across large geographical space as it did on a regional level.

Network analysis also demonstrated connections between sites within Cyprus and Crete. Connectivity between sites can be seen in nodes from two sites clustering together or in a node from a single site that shares most of its connections with nodes from other sites. This type of node functions as a “boundary object” connecting communities of practice at the different sites. In some cases, geographical proximity has an impact on connectivity, as with the particularly close ties between Kourion and Palaepaphos in the LC IIIB and CG IA. On the other hand, Lapithos, on the north coast, shares similarities with the relatively distant sites of Palaepaphos, Kourion, and Amathous in the southwest. Lapithos is also marked by a number of distinctive features only seen there, which might be specific to the north coast.

The networks did not show strong connections between Cypriot and Cretan objects, however. Because of a lack of specificity in the Cretan object data, it was difficult to put the Cypriot and Cretan objects on the same graph, but in the several instances where it was possible, there were few points of overlap between Cretan and Cypriot objects.
CONCLUSIONS

The sharing of technological knowledge appears to have taken various forms at different geographical scales. The majority of learning occurred at a local level. For the most part, smiths learned their craft within locally grounded communities of practice. Each community of practice had its own unique ways of forming objects, which were passed down to new generations of smiths. These unique practices can be seen in the results of the scientific testing and also in network analysis. For example, SEM-EDS and microscopy show that objects from Lapithos A are more thoroughly refined than those from Kourion or Lapithos B, and network analysis shows that iron knives from Palaepaphos cluster together in the graphs.

These locally unique ways of making are present at every step of production but are particularly prominent in the transfer of gestural knowledge, which occurred exclusively on a local scale. For example, I found that examples of smiths handling and manipulating objects using a consistent pattern determined by gestural knowledge were confined to objects from the same site, such as the needles from Lapithos that were turned during hammering.

Knowledge was also shared between communities of practice at different sites within the same region. Most notably, the Cypriot sites of Kourion and Lapithos showed connections, which demonstrate a longstanding Cypriot copper industry where knowledge sharing was commonplace. This exchange of information appears to have taken place both at smelting sites in the interior of the island as well as in workshops located in the coastal centers. The Cretan site of Vrokastro similarly shows connections to other sites on Crete and other Aegean islands.
Overall, there seems to be no reason to suggest significant shared practices between the Cretan and Cypriot sites. Neither the scientific testing nor the network analysis shows strong connections between communities of practice on Cyprus and those on Crete. Although a small percentage of the ore used to form the Vrokastro objects originated on Cyprus, the majority did not. Cretan smiths appear to have been making use of a variety of sources. Beyond the imported ore, there are not significant overlaps in the techniques used to process the ore or form the objects.

Turning back to the question of long-distance transfer of technology from Cyprus to the Aegean, which has occupied much of the scholarly discussion, I argue that the role of Cypriot smiths in bringing metallurgical innovation to the Aegean has been overstated. While more expansive testing regime would be required to confirm these results and provide a definitive answer to the question of technological transfer, my research can shed some light on more or less likely possibilities.

Based on my initial findings, there is little to recommend connections between Cyprus and Crete. Although there may have been some Cypriot smiths who travelled to Crete, there is no strong evidence to support the claim that they had a longstanding or deep impact on the metallurgical system in place in Crete. It seems unlikely that they set up workshops and trained Cretan smiths. Contact between Cypriot and Cretan smiths was more likely to have been short-lived contact between trained smiths. Alternatively, iron smelting technology could have been passed along between neighboring communities, rather than making one large leap across the Mediterranean. In this scenario, ideas would be shared between communities that had already built a foundation of mutual trust.
DIRECTIONS FOR FUTURE RESEARCH

This dissertation has been a pilot study relying on scientific testing of only a small number of objects, and building a network from data from published works, the vast majority of which is legacy data. In order to substantiate and build on the conclusions presented here, further testing would be needed. One of the strengths of this study is that it has provided high-quality data that can be used as a baseline and a point of comparison for future research. Scientific testing of objects from EIA Crete would be very fruitful in that they could be compared with the Vrokastro samples. In particular, the results of the Vrokastro testing could be profitably supplemented by testing objects from other sites around the Bay of Mirabello, such as Kavousi and Azoria, as well as objects from Knossos and Eleutherna, where more Cypriot influence has been proposed. Cypriot objects from Palaepaphos and Salamis have been the subjects of p-XRF studies, but further (destructive) scientific testing would shed light on the elemental composition of and working techniques on objects. Results of scientific testing for objects from Palaepaphos and Amathous would be particularly interesting comparisons for Kourion, and similarly Ayia Irini would supplement Lapithos. Enkomi, Salamis, and Kition could form a separate region in eastern Cyprus and add a valuable further comparison point. If such studies were carried out and more data was available, a network similar to that in this study but much more expansive could be formed, and could include attributes such as “ore source,” “alloy composition,” and “inclusions,” fully combining the results of the scientific testing with a network approach. Of course, all of these further directions depend on getting permission to destructively sample objects, which is very difficult to obtain.
The network portion of this study could be expanded in a few different directions. Further research would likely include visual inspection of all of the objects rather than relying on publications. This would eliminate any false or omitted connections caused by differences in drawings or publications. Furthermore, the network would benefit from the incorporation of unpublished materials. Finally, it could be further expanded to include other areas of the Aegean, or even sites in the Levant and Anatolia.

Although the scientific testing and network analysis portions of my dissertation address the same questions and both shed light on the question of communities of practice and the transfer of knowledge, there are few points of intersection between them. Future study, with a much larger sample size and a similarly robust set of analyses, could profitably combine the two approaches. The network results could be used to strategically target specific objects for destructive testing (such as boundary objects) and the data from the scientific testing could be used as attributes to construct networks (for example, forming connections based on similarities in alloying practices). The results of the analyses would have reciprocal benefits.
<table>
<thead>
<tr>
<th>No.</th>
<th>Number</th>
<th>Material</th>
<th>Type</th>
<th>Site</th>
<th>Cemetery</th>
<th>Tomb</th>
<th>Period</th>
<th>Description</th>
<th>Measurements in cm</th>
<th>Complete</th>
<th>Conditions on Corrosion</th>
<th>Treated</th>
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<th>Corrosion Comments</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>49-12-6</td>
<td>Bronze</td>
<td>D</td>
<td>Kourion</td>
<td>Xerokhoini</td>
<td>2</td>
<td>CG</td>
<td>Asymmetrical D-shaped fibula with two beads. The clasp is tall and rounded and the arm is very flat and square in section. There are small round beads on each side of the bow with horizontal line decorations. The bow is round and swollen. The spring is small and the pin is round in section and partially preserved.</td>
<td>Asymmetrical</td>
<td>Nearly Complete</td>
<td>One join between the upper bead and the arm. Basis only partially preserved.</td>
<td>Chemically Treated</td>
<td>Surface is dark brown with some spots of bright green corrosion. Surface is covered with black deposits and displays some large areas of pitting.</td>
<td>Corrosion Visible</td>
</tr>
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<td>49-12-406</td>
<td>Bronze</td>
<td>D</td>
<td>Kourion</td>
<td>Xerokhoini</td>
<td>19</td>
<td>CG</td>
<td>Asymmetrical D-shaped fibula with two beads. The clasp is tall and rounded and the arm is very flat and square in section. There are round beads on either side of the bow. The bow is round and swollen. The spring is medium in size, and the pin is round in section.</td>
<td>Asymmetrical</td>
<td>Complete</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>3</td>
<td>49-12-21</td>
<td>Bronze</td>
<td>D</td>
<td>Kourion</td>
<td>Xerokhoini</td>
<td>19</td>
<td>CG</td>
<td>Asymmetrical D-shaped fibula with no discernable beads. Bow of an asymmetrical D-shaped fibula (?). The bow is very long and thin and is not very swollen. The clasp and arm are not preserved. There are beads on the side of the bow, and one is discernable round with horizontal line decoration on them. The bow is preserved in one piece. The clasp with part of the pin is preserved along with the small bead. The pin is only preserved in several fragments. One is attached to the clasp. L: 2.1; W: 5.4; T: 0</td>
<td>Asymmetrical</td>
<td>Incomplete Fragments</td>
<td>Bow preserved in one piece. Part of the spring and pin preservation in one piece.</td>
<td>Chemically Treated</td>
<td>Very dark brown in color. The surface is more irregularly shaped than others that have been treated the same way. The surface is pitted.</td>
<td>No Corrosion Visible</td>
</tr>
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<td>49-12-726</td>
<td>Bronze</td>
<td>D</td>
<td>Kourion</td>
<td>Xerokhoini</td>
<td>25</td>
<td>CG</td>
<td>Asymmetrical D-shaped fibula with unknown number of beads. The clasp and arm are not preserved. There are beads on the side of the bow, and one is discernable round with horizontal line decoration on them. The bow is round and swollen. The spring and pin are not preserved. The pin preserves an area.</td>
<td>Asymmetrical</td>
<td>Incomplete Fragments</td>
<td>Bow preserved in one piece. The small round bead and the arm are preserved.</td>
<td>Chemically Treated</td>
<td>Dark brown in color. Highly pitted and scratched surface. From large areas of surface loss.</td>
<td>No Corrosion Visible</td>
</tr>
<tr>
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<td>Bronze</td>
<td>D</td>
<td>Kourion</td>
<td>Kaloriziki</td>
<td>25</td>
<td>CG</td>
<td>Bow of an asymmetrical D-shaped fibula (?). The bow is very long and thin and not very swollen. The clasp and arm are not preserved. There are beads on the side of the bow, and one is discernable round with horizontal line decoration on them. The bow is very large. The clasp and arm are not preserved. Neither the clasp nor the arm is the sole.</td>
<td>Asymmetrical</td>
<td>Incomplete Fragments</td>
<td>Bow preserved in one piece. The small round bead and the arm are preserved.</td>
<td>Chemically Treated</td>
<td>Dark brown in color. Highly pitted and scratched surface. From large areas of surface loss.</td>
<td>No Corrosion Visible</td>
</tr>
</tbody>
</table>

Table 1: Table of Results from Visual Analysis
<table>
<thead>
<tr>
<th>#</th>
<th>Number</th>
<th>Material</th>
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<th>Cemetery</th>
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<th>Period</th>
<th>Description</th>
<th>Measurements (all in cm.)</th>
<th>Complete</th>
<th>Treatment</th>
<th>Comments on Treatment</th>
<th>Corrosion?</th>
<th>Corrosion Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>49-12-969</td>
<td>Bronze</td>
<td>Fibula</td>
<td>Kourion</td>
<td>Kaloriziki</td>
<td>33 CG II</td>
<td></td>
<td>Asymmetrical, D-shaped fibula with three beads. The clasp is tall and rounded. The beads on the foot are small and round. They have vertical line decoration. The bow is round and the pin is round in section. The pin is in two disconnected pieces.</td>
<td>L: 4.5; W: 5; T: 0.5</td>
<td>Nearly Complete</td>
<td></td>
<td>Untreated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>49-12-985</td>
<td>Bronze</td>
<td>Fibula</td>
<td>Kourion</td>
<td>Kaloriziki</td>
<td>33 CG II</td>
<td></td>
<td>Asymmetrical D-shaped fibula with three beads (?)</td>
<td>L: 1.5; T: 6</td>
<td>Incomplete</td>
<td>Mixed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>49-12-988</td>
<td>Bronze</td>
<td>Fibula</td>
<td>Kourion</td>
<td>Kaloriziki</td>
<td>36-W CG IB</td>
<td></td>
<td>Asymmetrical D-shaped fibula with three beads (?)</td>
<td></td>
<td>Incomplete</td>
<td>Mixed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>49-12-491</td>
<td>Iron</td>
<td>Knife</td>
<td>Kourion</td>
<td>Kaloriziki</td>
<td>19 CG IA</td>
<td></td>
<td>Iron knife with a slightly curved blade and one cutting edge. Two bronze rivets arranged vertically on one side of the blade.</td>
<td>L: 8.8 cm, W: 2 cm, tapers down to 0.8 cm</td>
<td>Complete</td>
<td>Joints 4 fragments joined.</td>
<td>Untreated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>49-12-493</td>
<td>Iron</td>
<td>Knife</td>
<td>Kourion</td>
<td>Kaloriziki</td>
<td>19 CG IA</td>
<td></td>
<td>4 fragments of an iron knife. The blade is fairly straight and rectangular in shape with 2 cutting edges. The blade is in two separate pieces.</td>
<td>H: 15.3; L: 2.8;</td>
<td>Nearly Complete</td>
<td></td>
<td>Untreated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>49-12-105</td>
<td>Iron</td>
<td>Knife</td>
<td>Kourion</td>
<td>Kaloriziki</td>
<td>39 CG IB</td>
<td></td>
<td>Fragment of an iron knife. Only the tang and base of the blade are preserved so it is impossible to say what the overall shape would have been.</td>
<td></td>
<td>Very Incomplete</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>49-12-105</td>
<td>Iron</td>
<td>Knife</td>
<td>Kourion</td>
<td>Kaloriziki</td>
<td>39 CG IB</td>
<td></td>
<td>Iron knife with a curved blade and one cutting edge. The tang is flattened and rectangular in shape. There is likely a wooden or bone handle and a small pin preserved.</td>
<td>L: 13.5 total length; 0.5 cm is the handle, and the blade is 6.8 cm to 10 cm wide on the edge.</td>
<td>Nearly Complete</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Table of Results from Visual Analysis
<table>
<thead>
<tr>
<th>Number</th>
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<th>Tomb</th>
<th>Period</th>
<th>Description</th>
<th>Measurements (all in cm.)</th>
<th>Complete</th>
<th>Restoration on Complete?</th>
<th>Comments on Treatment</th>
<th>Corrosion</th>
<th>Comments on Corrosion</th>
<th>Comments on Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Bronze</td>
<td>Needle</td>
<td>Kourion</td>
<td>Kaloriziki</td>
<td>25</td>
<td>CGII</td>
<td>Bronze needle with two joins. Eyelet is not preserved. Points are preserved.</td>
<td>L: 9.1; W: 0.2; D: 0.1</td>
<td>Complete</td>
<td>Untreated</td>
<td>Corrosion Stable</td>
<td>Corrosion Stable</td>
<td>One large healed corrosion</td>
<td>One large healed corrosion</td>
</tr>
<tr>
<td>17</td>
<td>Bronze</td>
<td>Needle</td>
<td>Kourion</td>
<td>Kaloriziki</td>
<td>27</td>
<td>CAF</td>
<td>One fragment of incomplete needle. Points are preserved. Points are preserved.</td>
<td>L: 4.5; W: 0.2; D: 0.1</td>
<td>Complete</td>
<td>Untreated</td>
<td>Corrosion Stable</td>
<td>Corrosion Stable</td>
<td>One large healed corrosion</td>
<td>One large healed corrosion</td>
</tr>
<tr>
<td>18</td>
<td>Bronze</td>
<td>Needle</td>
<td>Kourion</td>
<td>Kaloriziki</td>
<td>33</td>
<td>CGII</td>
<td>Two fragments of a needle. Bottom fragment is preserved. Points are preserved.</td>
<td>L: 14.7; W: 0.3; D: 0.1</td>
<td>Complete</td>
<td>Untreated</td>
<td>Corrosion Stable</td>
<td>Corrosion Stable</td>
<td>One large healed corrosion</td>
<td>One large healed corrosion</td>
</tr>
<tr>
<td>19</td>
<td>Bronze</td>
<td>Needle</td>
<td>Kourion</td>
<td>Kaloriziki</td>
<td>37</td>
<td>CGII</td>
<td>Four fragments of a needle. Bottom fragment is preserved. Points are preserved.</td>
<td>L: 6.9; W: 0.2; D: 0.1</td>
<td>Complete</td>
<td>Untreated</td>
<td>Corrosion Stable</td>
<td>Corrosion Stable</td>
<td>One large healed corrosion</td>
<td>One large healed corrosion</td>
</tr>
<tr>
<td>20</td>
<td>Bronze</td>
<td>Needle</td>
<td>Kourion</td>
<td>Kaloriziki</td>
<td>37</td>
<td>CGII</td>
<td>Pin with one large oval bead at the head and a boss and projection above it. Points are preserved.</td>
<td>L: 12.1; D: 0.3; D: 0.7</td>
<td>Complete</td>
<td>Untreated</td>
<td>Corrosion Stable</td>
<td>Corrosion Stable</td>
<td>One large healed corrosion</td>
<td>One large healed corrosion</td>
</tr>
<tr>
<td>21</td>
<td>Bronze</td>
<td>Pin</td>
<td>Kourion</td>
<td>Kaloriziki</td>
<td>56</td>
<td>CGIII</td>
<td>Bronze ring. Points and end of fillet are preserved, but does not form a complete circle.</td>
<td>L: 5.4; W: 1.9; D: 1.2</td>
<td>Complete</td>
<td>Untreated</td>
<td>Corrosion Stable</td>
<td>Corrosion Stable</td>
<td>One large healed corrosion</td>
<td>One large healed corrosion</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>#</th>
<th>Material</th>
<th>Type</th>
<th>Site</th>
<th>Completeness</th>
<th>Description</th>
<th>Measurements in cm</th>
<th>Comments on Treatment</th>
<th>Comments on Corrosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Bronze</td>
<td>Ring</td>
<td>Kaloi Salukei</td>
<td>Complete</td>
<td>Wide, thick band folded into a very small circle. Not big enough to be a finger ring.</td>
<td>W: 0.7; D: 1.1</td>
<td>Untreated</td>
<td>Corroded but green, corrosion, brown soil, and some irregular powdery substance.</td>
</tr>
<tr>
<td>27</td>
<td>Bronze</td>
<td>Ring</td>
<td>Kaloi Salukei</td>
<td>Complete</td>
<td>Band is round in section and of medium thickness. Two poorly joined fragments. One piece contains three pieces that were folded together.</td>
<td>W: 0.6; D: 2</td>
<td>Untreated</td>
<td>Corroded but green, corrosion and brown soil.</td>
</tr>
<tr>
<td>28</td>
<td>Bronze</td>
<td>Ring (or earring?)</td>
<td>Kaloi Salukei</td>
<td>Incomplete</td>
<td>Two fragments of an oval band that varies between semi-circular and circular in section. Doesn't form a circle.</td>
<td>W: 0.7; D: 1.1</td>
<td>Untreated</td>
<td>Corroded but green, corrosion and brown soil.</td>
</tr>
<tr>
<td>29</td>
<td>Bronze</td>
<td>Ring (or earring?)</td>
<td>Kaloi Salukei</td>
<td>Complete</td>
<td>Fragment of an iron spearhead. The spearhead is a leaf-shaped blade with a rounded protruding tang in the center. The spearhead is composed of several pieces.</td>
<td>W: 0.4; D: 1</td>
<td>Untreated</td>
<td>Corroded but green, corrosion and brown soil.</td>
</tr>
<tr>
<td>30</td>
<td>Bronze</td>
<td>Vessel</td>
<td>Kaloi Salukei</td>
<td>Complete</td>
<td>Fragment of an iron spearhead. The spearhead is a leaf-shaped blade with a rounded protruding tang in the center. The spearhead is composed of several pieces.</td>
<td>W: 0.4; D: 1</td>
<td>Untreated</td>
<td>Corroded but green, corrosion and brown soil.</td>
</tr>
<tr>
<td>31</td>
<td>Bronze</td>
<td>Vessel</td>
<td>Kaloi Salukei</td>
<td>Complete</td>
<td>Fragment of an iron spearhead. The spearhead is a leaf-shaped blade with a rounded protruding tang in the center. The spearhead is composed of several pieces.</td>
<td>W: 0.4; D: 1</td>
<td>Untreated</td>
<td>Corroded but green, corrosion and brown soil.</td>
</tr>
</tbody>
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Table 1: Table of Results from Visual Analysis
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<tr>
<th>Number</th>
<th>Material Type</th>
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<th>Intact</th>
<th>Comments on Treatment</th>
<th>Complete?</th>
<th>Intact?</th>
<th>Comments</th>
<th>Treatment</th>
<th>Comments on Treatment</th>
<th>Corrosion</th>
<th>Comments on Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>Bronze</td>
<td>Kourion</td>
<td>Kaloriziki</td>
<td>Tomb</td>
<td>CG IB</td>
<td>Hemispherical bowl with a thick rim.</td>
<td>H: 13.9; D: 30.9</td>
<td>Incomplete Fragments</td>
<td>Unstable</td>
<td>Green corrosion and brown soil.</td>
<td>Complete Fragments</td>
<td>Unstable</td>
<td>Comments on corrosion and brown soil.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Bronze Needle</td>
<td>Lapithos Lower</td>
<td>57 CG IIIA- B</td>
<td></td>
<td></td>
<td>Needle in two fragments. One fragment has a longer piece with a pointed tip. Another has a point. A third fragment has a square projection on the edge. A few bits of a coin.</td>
<td>H: 13.9; W: 16.</td>
<td>Incomplete Fragments</td>
<td>2 fragments</td>
<td>Unstable</td>
<td>Complete Fragments</td>
<td>Unstable</td>
<td>Comments on corrosion and brown soil.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Bronze Needle</td>
<td>Lapithos Lower</td>
<td>57 CG IIIA- B</td>
<td></td>
<td></td>
<td>Needle in three fragments. One fragment preserves the bottom half of an eyelet. The point is not preserved.</td>
<td>H: 7.5; D: 0.25</td>
<td>Complete</td>
<td>Intact</td>
<td>Unstable</td>
<td>Complete</td>
<td>Unstable</td>
<td>Comments on corrosion and brown soil.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Bronze Needle</td>
<td>Lapithos Lower</td>
<td>63 CG IIIA- B</td>
<td></td>
<td></td>
<td>Needle in five fragments. One fragment preserves the bottom half of an eyelet. Another has a point. A third fragment has a square projection on the edge. Perhaps a bit of a coin.</td>
<td>H: 5.5; D: 0.1</td>
<td>Incomplete Fragments</td>
<td>3 fragments</td>
<td>Unstable</td>
<td>Complete</td>
<td>Intact</td>
<td>Comments on corrosion and brown soil.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>Bronze Needle</td>
<td>Lapithos Lower</td>
<td>66 CG IIIA- B</td>
<td></td>
<td></td>
<td>Needle in three fragments. One fragment preserves the bottom half of an eyelet. The point is not preserved.</td>
<td>H: 3.5; D: 0.25</td>
<td>Incomplete Fragments</td>
<td>3 fragments</td>
<td>Unstable</td>
<td>Complete</td>
<td>Intact</td>
<td>Comments on corrosion and brown soil.</td>
<td></td>
<td></td>
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<tr>
<td>42</td>
<td>Bronze Needle</td>
<td>Lapithos Lower</td>
<td>66 CG IIIA- B</td>
<td></td>
<td></td>
<td>Needle in four fragments. One fragment preserves the bottom half of an eyelet. The point is not preserved.</td>
<td>H: 2.3; D: 0.2</td>
<td>Incomplete Fragments</td>
<td>3 fragments</td>
<td>Unstable</td>
<td>Complete</td>
<td>Intact</td>
<td>Comments on corrosion and brown soil.</td>
<td></td>
<td></td>
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<tr>
<td>43</td>
<td>Bronze Needle</td>
<td>Lapithos Lower</td>
<td>67 CG IIIA- B</td>
<td></td>
<td></td>
<td>Needle in four fragments. One fragment preserves the bottom half of an eyelet. The point is not preserved.</td>
<td>H: 4.3; D: 0.25</td>
<td>Incomplete Fragments</td>
<td>3 fragments</td>
<td>Unstable</td>
<td>Complete</td>
<td>Intact</td>
<td>Comments on corrosion and brown soil.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Bronze Needle</td>
<td>Lapithos Lower</td>
<td>67 CG IIIA- B</td>
<td></td>
<td></td>
<td>Needle in five fragments. One fragment preserves the bottom half of an eyelet. The point is not preserved.</td>
<td>H: 5.7; D: 0.3</td>
<td>Incomplete Fragments</td>
<td>4 fragments</td>
<td>Unstable</td>
<td>Complete</td>
<td>Intact</td>
<td>Comments on corrosion and brown soil.</td>
<td></td>
<td></td>
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<td>45</td>
<td>Bronze Needle</td>
<td>Lapithos Lower</td>
<td>70 CG IIIA- B</td>
<td></td>
<td></td>
<td>Needle in four fragments. One fragment preserves the bottom half of an eyelet. One may be the point, but it is difficult to say for sure.</td>
<td>H: 5.0; D: 0.25</td>
<td>Incomplete Fragments</td>
<td>4 fragments</td>
<td>Unstable</td>
<td>Complete</td>
<td>Intact</td>
<td>Comments on corrosion and brown soil.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>Bronze Needle</td>
<td>Lapithos Lower</td>
<td>57 CG IIIA- B</td>
<td></td>
<td></td>
<td>Needle in five fragments. One fragment preserves the bottom half of an eyelet. One may be the point, but it is difficult to say for sure.</td>
<td>H: 5.5; D: 1.2</td>
<td>Incomplete Fragments</td>
<td>4 fragments</td>
<td>Unstable</td>
<td>Complete</td>
<td>Intact</td>
<td>Comments on corrosion and brown soil.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>Bronze Needle</td>
<td>Lapithos Lower</td>
<td>59 CG IIIA- B</td>
<td></td>
<td></td>
<td>Needle in four fragments. One fragment preserves the bottom half of an eyelet. One may be the point, but it is difficult to say for sure.</td>
<td>H: 3.4; D: 0.2</td>
<td>Incomplete Fragments</td>
<td>4 fragments</td>
<td>Unstable</td>
<td>Complete</td>
<td>Intact</td>
<td>Comments on corrosion and brown soil.</td>
<td></td>
<td></td>
</tr>
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</table>

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<th>Description</th>
<th>Measurements</th>
<th>Complete</th>
<th>Intact</th>
<th>Comments on Completeness</th>
<th>Treatment</th>
<th>Comments on Treatment</th>
<th>Comments on Corrosion</th>
<th>Corrosion Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>32-27-741</td>
<td>Bronze</td>
<td>Pin/Needle</td>
<td>Lapithos</td>
<td>Lower 67</td>
<td>CG IIB-IIIA</td>
<td>Pin (or needle), broken on one end. The point is preserved and it is very long and gradually tapering. The head is not preserved. It is round in section. L: 10; D: 0.2; Incomplete</td>
<td>Intact</td>
<td>Unsampled</td>
<td>It has been cleaned to a brown/orange color which may be from chemical or electrolytic treatment. It appears to be a part of a larger category within item.</td>
<td>Chemically Treated</td>
<td>It has a dark edge of green corrosion with a highly irregular surface that the external burial soil and conditions caused.</td>
<td>Corrosion Visible</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>32-27-742</td>
<td>Bronze</td>
<td>Pin/Needle</td>
<td>Lapithos</td>
<td>Lower 67</td>
<td>CG IIB-IIIA</td>
<td>Pin (or needle) in four fragments. No clear point or eyelet preserved. Round in section. L: 7; D: 0.3; Incomplete</td>
<td>Fragments</td>
<td>3 small fragments.</td>
<td>Untreated</td>
<td>Corrosion Unstable</td>
<td>They are covered in burial soil and conditions and there are several spots of bright green, very powdery appearance.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>32-27-745</td>
<td>Bronze</td>
<td>Pin/Needle</td>
<td>Lapithos</td>
<td>Lower 67</td>
<td>CG IIB-IIIB</td>
<td>One fragment of a pin (or needle). No clear point or eyelet preserved. Round in section. L: 5; D: 0.2; Incomplete</td>
<td>Intact</td>
<td>Untreated</td>
<td>Corrosion Unstable</td>
<td>Covered in green corrosion and brown soil</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>51</td>
<td>32-27-611</td>
<td>Bronze</td>
<td>Toe Ring</td>
<td>Lapithos</td>
<td>Lower 53A</td>
<td>CG IIB-IIIB</td>
<td>2 fragments of thin, round band with round section. D: 0.2; Incomplete</td>
<td>Fragments</td>
<td>1 larger and 1 smaller fragment.</td>
<td>Untreated</td>
<td>Corrosion Stable</td>
<td>Covered in green corrosion and brown soil with some large encrustations.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>32-27-635</td>
<td>Bronze</td>
<td>Vessel</td>
<td>Lapithos</td>
<td>Lower 53A</td>
<td>CG IIIA-III B</td>
<td>Hemispherical bowl. Elongated shape. H: 5.4; D: 12.3; Incomplete</td>
<td>Joins</td>
<td>2 large fragments that have been joined to form most of the rim and sides. Many smaller fragments in a separate bag (over 10).</td>
<td>Untreated</td>
<td>Corrosion Unstable</td>
<td>Covered in green corrosion and brown soil with some bright green corrosion on the break edges.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>32-27-619</td>
<td>Bronze</td>
<td>Vessel</td>
<td>Lapithos</td>
<td>Lower 63</td>
<td>CG IIB-IIIB</td>
<td>Hemispherical bowl with a thick rim. H: 5.8; D: 13; Complete</td>
<td>Intact</td>
<td>Rim is preserved but most of the interior is not.</td>
<td>Chemically Treated</td>
<td>Brown in color and surface is highly polished</td>
<td>Corrosion Visible</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>32-27-620</td>
<td>Bronze</td>
<td>Vessel</td>
<td>Lapithos</td>
<td>Lower 63</td>
<td>CG IIB-IIIB</td>
<td>Hemispherical bowl with a thick rim. H: 6.1; D: 13.6; Incomplete</td>
<td>Intact</td>
<td>Hemispherical bowl with a slightly thick rim. D: 6.1; 14.5</td>
<td>Chemically Treated</td>
<td>Brown in color and surface is highly polished</td>
<td>Corrosion Visible</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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<table>
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<tr>
<th>ID</th>
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<th>Measurements (all in cm.)</th>
<th>Complete</th>
<th>Comments on Completeness</th>
<th>Treatment</th>
<th>Comments on Treatment Corrosion</th>
<th>Corrosion Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>58</td>
<td>Bronze</td>
<td>Vessel</td>
<td>Lapithos</td>
<td>Lower</td>
<td>53B</td>
<td>CG III-III</td>
<td>Hemispherical bowl with a thick rim. H: 5.6; D: 13.2; Incomplete</td>
<td>Incomplete</td>
<td>Joins</td>
<td>The rim has a crack. The bottom of the bowl is not preserved. Untreated</td>
<td>Dark brown in color. Yellow surface. Does not appear coated.</td>
<td>Corrosion Unstable</td>
<td>No Corrosion Visible</td>
</tr>
<tr>
<td>59</td>
<td>Bronze</td>
<td>Fibula</td>
<td>Lapithos</td>
<td>Upper</td>
<td>73</td>
<td>CG II-III</td>
<td>Bow of an asymmetrical, D-shaped Fibula with an unknown number of beads. The bow is preserved with a large, round bead on either side. The beads are incised horizontally. The bow is not preserved.</td>
<td>Only the bow with two beads is preserved</td>
<td>Dark brown in color. Highly polished surface. Does not appear coated.</td>
<td>Chemically Treated</td>
<td>Dark brown in color. Highly polished surface. Does not appear coated.</td>
<td>Corrosion Visible</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Bronze</td>
<td>Fibula</td>
<td>Lapithos</td>
<td>Upper</td>
<td>73</td>
<td>CG II-III</td>
<td>Bow of an asymmetrical D-shaped Fibula. The bow is very long and thin and not very swollen. The beads on either side of the bow have two raised bands on either side of the bead. W: 8.2; T: 0.9; Incomplete.</td>
<td>Only the bow with two beads is preserved</td>
<td>Chemically Treated</td>
<td>Brown/yellow in color. Carved inscription is visible on the surface.</td>
<td>No Corrosion Visible</td>
<td>Corrosion Visible</td>
<td></td>
</tr>
<tr>
<td>61</td>
<td>Bronze</td>
<td>Fibula</td>
<td>Lapithos</td>
<td>Upper</td>
<td>79</td>
<td>CGII-III-CA</td>
<td>Assymetrical D-shaped Fibula with 3 beads. The bow is preserved. There is a small bead on the base, with incised horizontal decoration on the bow and incised rings above and below the bow. The bow makes a gradual angle at the top. There are medium-sized beads on either side of the bow. The beads are decorated with incised grooves on either side of the bowl. The spring and pins are not preserved. W: 4.3; T: 0.9; Incomplete.</td>
<td>Preserved to the base of the spring and clasp.</td>
<td>Chemically Treated</td>
<td>Brown/yellow in color. Carved inscription is visible on the surface.</td>
<td>No Corrosion Visible</td>
<td>Corrosion Visible</td>
<td></td>
</tr>
<tr>
<td>62</td>
<td>Bronze</td>
<td>Fibula</td>
<td>Lapithos</td>
<td>Upper</td>
<td>80</td>
<td>CGII-III</td>
<td>Bow of an asymmetrical D-shaped Fibula with 3 beads. The bow is preserved. There are medium-sized beads on either side of the bow. The bow is not preserved.</td>
<td>Complete</td>
<td>Untreated</td>
<td>Corrosion Unstable</td>
<td>No Corrosion Visible</td>
<td>Corrosion Visible</td>
<td></td>
</tr>
<tr>
<td>63</td>
<td>Bronze</td>
<td>Fibula</td>
<td>Lapithos</td>
<td>Upper</td>
<td>88</td>
<td>CGII</td>
<td>Assymetrical D-shaped Fibula with 3 beads. The bow is preserved. There is a small bead on the base, with incised horizontal decoration on the bow and incised rings above and below the bow. The bow makes a gradual angle at the top. There are medium-sized beads on either side of the bow. The beads are decorated with incised grooves on either side of the bowl. The spring and pins are not preserved. W: 4.3; T: 0.9; Incomplete.</td>
<td>Complete</td>
<td>Untreated</td>
<td>Corrosion Unstable</td>
<td>No Corrosion Visible</td>
<td>Corrosion Visible</td>
<td></td>
</tr>
</tbody>
</table>

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<th>Number</th>
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<th>Description</th>
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<th>Complete</th>
<th>Comments on Completeness</th>
<th>Treatment</th>
<th>Corrosion</th>
<th>Treatment Comments</th>
<th>Comments on Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>Bronze</td>
<td>Knif</td>
<td>Lapithos</td>
<td>Upper</td>
<td>Three fragments of a knife. One fragment preserves an eyelet. One to the point, and one to the beginning of an eyelet. The other with blade.</td>
<td>11.5; D: 0.2; Complete</td>
<td>Intact;</td>
<td>another fragment intact</td>
<td>Untreated</td>
<td>Unstable</td>
<td>Copper corrosion, bronze ad, and encrustations.</td>
<td>The metals showed red and bright green corrosion. The copper corrosion is unstable, with several edges showing light green corrosion.</td>
</tr>
<tr>
<td>65</td>
<td>Bronze</td>
<td>Needle</td>
<td>Lapithos</td>
<td>Upper</td>
<td>Three fragments of a needle.</td>
<td>6 fragments; Complete</td>
<td>Intact;</td>
<td>Untreated</td>
<td>Unstable</td>
<td>Corrosion Stable</td>
<td>Copper corrosion, bronze ad, and encrustations.</td>
<td>Corrosion Stable</td>
</tr>
<tr>
<td>66</td>
<td>Bronze</td>
<td>Needle</td>
<td>Lapithos</td>
<td>Upper</td>
<td>Complete, intact needle. Eyelet is flattened and pointed. Needle is round in section, wider in the eyelet. The metal corrosion is unstable, with several edges showing light green corrosion.</td>
<td>5.5; D: 0.2; Complete</td>
<td>Intact;</td>
<td>Untreated</td>
<td>Unstable</td>
<td>Corrosion Stable</td>
<td>Copper corrosion, bronze ad, and encrustations.</td>
<td>Possible light green corrosion, undetermined.</td>
</tr>
<tr>
<td>67</td>
<td>Bronze</td>
<td>Needle</td>
<td>Lapithos</td>
<td>Upper</td>
<td>Complete needle with many joins. Very long and oval in section. The needle is bent at an almost 90 degree angle. Untreated</td>
<td>6 fragments, 1 slightly longer than others. Complete</td>
<td>Intact;</td>
<td>Stable;</td>
<td>Untreated</td>
<td>Unstable</td>
<td>Corrosion Stable</td>
<td>There are spots of possible green corrosion on some break edges indicating corrosion is unstable.</td>
</tr>
<tr>
<td>68</td>
<td>Bronze</td>
<td>Needle</td>
<td>Lapithos</td>
<td>Upper</td>
<td>Short needle with an eyelet on one side, but no point preserved.</td>
<td>6.5; D: 0.2; Complete</td>
<td>Intact;</td>
<td>Untreated</td>
<td>Unstable</td>
<td>Corrosion Stable</td>
<td>Copper corrosion, bronze ad, and encrustations.</td>
<td>Corrosion Stable</td>
</tr>
<tr>
<td>69</td>
<td>Bronze</td>
<td>Pin/Needle</td>
<td>Lapithos</td>
<td>Upper</td>
<td>Pin (or needle) in two small fragments. No clear point or eyelet preserved. Round in section.</td>
<td>1.9; D: 0.2; Complete</td>
<td>Intact;</td>
<td>stable;</td>
<td>Untreated</td>
<td>Unstable</td>
<td>Corrosion Stable</td>
<td>Bright green corrosion, which is powdery at break edges. They do not have any interior metal preserved.</td>
</tr>
<tr>
<td>70</td>
<td>Bronze</td>
<td>Pin/Needle</td>
<td>Lapithos</td>
<td>Upper</td>
<td>Pin (or needle) in two small fragments. No clear point or eyelet preserved. Round in section.</td>
<td>1.9; D: 0.2; Complete</td>
<td>Intact;</td>
<td>stable;</td>
<td>Untreated</td>
<td>Unstable</td>
<td>Corrosion Stable</td>
<td>Copper corrosion, bronze ad, and encrustations.</td>
</tr>
<tr>
<td>71</td>
<td>Bronze</td>
<td>Pin/Needle</td>
<td>Lapithos</td>
<td>Upper</td>
<td>Pin (or needle) in two small fragments. No clear point or eyelet preserved. Round in section.</td>
<td>1.9; D: 0.2; Complete</td>
<td>Intact;</td>
<td>stable;</td>
<td>Untreated</td>
<td>Unstable</td>
<td>Corrosion Stable</td>
<td>Copper corrosion, bronze ad, and encrustations.</td>
</tr>
<tr>
<td>72</td>
<td>Bronze</td>
<td>Ring</td>
<td>Lapithos</td>
<td>Upper</td>
<td>Spiral ring. Flat sheet wrapped in one and half rotations. Tips of either end are tapered. Small gap between the two ends. From the side it is ovular (maybe mishapen post-deposition?). W: 1; D: 2; Complete</td>
<td>Complete</td>
<td>Intact;</td>
<td>Untreated</td>
<td>Unstable</td>
<td>Corrosion Stable</td>
<td>There are spots of possible green corrosion on some break edges indicating corrosion is unstable.</td>
<td></td>
</tr>
<tr>
<td>73</td>
<td>Bronze</td>
<td>Ring</td>
<td>Lapithos</td>
<td>Upper</td>
<td>Spiral ring. Flat sheet wrapped in one and half rotations. Tips of either end are tapered. Small gap between the two ends. Not quite circular (maybe mishapen post-deposition?).</td>
<td>14.5; W: 11.5; Complete</td>
<td>Intact;</td>
<td>Untreated</td>
<td>Unstable</td>
<td>Corrosion Stable</td>
<td>Copper corrosion, bronze ad, and encrustations.</td>
<td></td>
</tr>
<tr>
<td>74</td>
<td>Bronze</td>
<td>Ring</td>
<td>Lapithos</td>
<td>Upper</td>
<td>Spiral ring in three fragments. Flat sheet wrapped probably in one and half rotations. Tips of either end are tapered.</td>
<td>14.5; W: 11.5; Complete</td>
<td>Intact;</td>
<td>Untreated</td>
<td>Unstable</td>
<td>Corrosion Stable</td>
<td>Copper corrosion, bronze ad, and encrustations.</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>Bronze</td>
<td>Ring</td>
<td>Lapithos</td>
<td>Upper</td>
<td>Spiral ring in three fragments. Flat sheet wrapped probably in one and half rotations.</td>
<td>14.5; W: 11.5; Complete</td>
<td>Intact;</td>
<td>Untreated</td>
<td>Unstable</td>
<td>Corrosion Stable</td>
<td>Copper corrosion, bronze ad, and encrustations.</td>
<td></td>
</tr>
<tr>
<td>76</td>
<td>Bronze</td>
<td>Ring</td>
<td>Lapithos</td>
<td>Upper</td>
<td>Spiral ring in three fragments. Flat sheet wrapped probably in one and half rotations.</td>
<td>14.5; W: 11.5; Complete</td>
<td>Intact;</td>
<td>Untreated</td>
<td>Unstable</td>
<td>Corrosion Stable</td>
<td>Copper corrosion, bronze ad, and encrustations.</td>
<td></td>
</tr>
<tr>
<td>77</td>
<td>Bronze</td>
<td>Ring</td>
<td>Lapithos</td>
<td>Upper</td>
<td>Spiral ring in three fragments. Flat sheet wrapped probably in one and half rotations.</td>
<td>14.5; W: 11.5; Complete</td>
<td>Intact;</td>
<td>Untreated</td>
<td>Unstable</td>
<td>Corrosion Stable</td>
<td>Copper corrosion, bronze ad, and encrustations.</td>
<td></td>
</tr>
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<th>Treatment</th>
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<th>Corrosion Comments</th>
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<tbody>
<tr>
<td>78</td>
<td>Bronze</td>
<td>Ring</td>
<td>Lapithos</td>
<td>Upper</td>
<td>73</td>
<td>CGIII</td>
<td>Spiral ring, only partially preserved. Flat sheet wrapped probably in one and a half rotations initially. Irregular in shape. H: 11; D: 9.5;</td>
<td>Intact</td>
<td>Nearly Intact</td>
<td>Coppered bronze corrosion</td>
<td>Intact</td>
<td>Nearly Intact</td>
<td>Coppered bronze corrosion</td>
<td>Stable</td>
<td>Coppered bronze corrosion</td>
<td></td>
</tr>
<tr>
<td>79</td>
<td>Bronze</td>
<td>Ring/Toe</td>
<td>Lapithos</td>
<td>Upper</td>
<td>73</td>
<td>CGIII</td>
<td>Wide and very flat sheets that have been loosely curved and twisted, but do not form closed circles. W: 0.8; D: 8.5; T:</td>
<td>Incomplete</td>
<td>Fragments: 6 pieces, 4 medium to large, several small fragments.</td>
<td>Intact</td>
<td>Intact</td>
<td>Intact</td>
<td>Coppered bronze corrosion</td>
<td>Intact</td>
<td>Coppered bronze corrosion</td>
<td>Intact</td>
</tr>
<tr>
<td>80</td>
<td>Bronze</td>
<td>Ring/Toe</td>
<td>Lapithos</td>
<td>Upper</td>
<td>73</td>
<td>CGIII</td>
<td>Wide and very flat sheets that have been loosely curved and twisted, but do not form closed circles. Some have visible curvatures. W: 0.8; D: 8.5; T:</td>
<td>Incomplete</td>
<td>Fragments: 4 large, several small fragments.</td>
<td>Intact</td>
<td>Intact</td>
<td>Intact</td>
<td>Coppered bronze corrosion</td>
<td>Intact</td>
<td>Coppered bronze corrosion</td>
<td>Intact</td>
</tr>
<tr>
<td>81</td>
<td>Bronze</td>
<td>Ring/Toe</td>
<td>Lapithos</td>
<td>Upper</td>
<td>73</td>
<td>CGIII</td>
<td>Wide and very flat sheets that have been loosely curved and twisted, but do not form closed circles. H: 9; D: 13.8;</td>
<td>Incomplete</td>
<td>Fragments: 2 large, curved and twisted fragments.</td>
<td>Intact</td>
<td>Intact</td>
<td>Intact</td>
<td>Coppered bronze corrosion</td>
<td>Intact</td>
<td>Coppered bronze corrosion</td>
<td>Intact</td>
</tr>
<tr>
<td>82</td>
<td>Bronze</td>
<td>Vessel</td>
<td>Lapithos</td>
<td>Upper</td>
<td>73</td>
<td>CGIII</td>
<td>Shallow bowl with carinated edge. H: 4; D: 12.5;</td>
<td>Incomplete</td>
<td>Fragments: 3 pieces, 1 in the base, the other two on the edge.</td>
<td>Intact</td>
<td>Intact</td>
<td>Intact</td>
<td>Coppered bronze corrosion</td>
<td>Intact</td>
<td>Coppered bronze corrosion</td>
<td>Intact</td>
</tr>
<tr>
<td>83</td>
<td>Bronze</td>
<td>Vessel</td>
<td>Lapithos</td>
<td>Upper</td>
<td>80</td>
<td>CGIII</td>
<td>Hemispherical bowl with thick rim. H: 5.5; D: 13;</td>
<td>Incomplete</td>
<td>Fragments: 10 medium to large fragments, 4 large and 2 medium pieces. Over 10 small pieces in a bag.</td>
<td>Intact</td>
<td>Intact</td>
<td>Intact</td>
<td>Coppered bronze corrosion</td>
<td>Intact</td>
<td>Coppered bronze corrosion</td>
<td>Intact</td>
</tr>
<tr>
<td>84</td>
<td>Bronze</td>
<td>Vessel</td>
<td>Lapithos</td>
<td>Upper</td>
<td>80</td>
<td>CGIII</td>
<td>Hemispherical bowl with thick rim. H: 5.2; D: 13.8;</td>
<td>Intact</td>
<td>Fragments:</td>
<td>The fragment may not be any metal left. It is comprised of dark green corrosion and has some burial soil on the surface. The end of the vessel may have a patch of powdery corrosion.</td>
<td>Intact</td>
<td>Intact</td>
<td>Intact</td>
<td>Coppered bronze corrosion</td>
<td>Intact</td>
<td>Coppered bronze corrosion</td>
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</tbody>
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<th>Corrosion</th>
<th>Treatment</th>
<th>Treatment</th>
<th>Corrosion/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Bronze</td>
<td>Fibula</td>
<td>Karavolaki</td>
<td>Antigokhi</td>
<td>CT IV</td>
<td>SM - N</td>
<td>Bow fibula with twisted wire bow. Clasp not preserved. Bow is square in section and twisted. It is more tightly twisted than others. The spring and pin are not preserved.</td>
<td>L: 4.7</td>
<td>Incomplete</td>
<td>Untreated</td>
<td>Chemically Treated</td>
<td>Visible</td>
<td>Stiff light and dark green. Surface is lightly pitted, not as much as others. Appears to be coated.</td>
</tr>
<tr>
<td>27</td>
<td>Bronze</td>
<td>Fibula</td>
<td>Karavolaki</td>
<td>Karavolaki</td>
<td>ENC V</td>
<td>EG / BR</td>
<td>Small fibula from a fibula. No clasp, spring, pin or beads preserved.</td>
<td>L: 3.5</td>
<td>Incomplete</td>
<td>Untreated</td>
<td>Only 2 fragments of the bow are preserved.</td>
<td>Visible</td>
<td>Stiff light and dark green. Surface is lightly pitted, not as much as others. Appears to be coated.</td>
</tr>
<tr>
<td>28</td>
<td>Iron</td>
<td>Fibula</td>
<td>Karavolaki</td>
<td>Procopoula</td>
<td>CT I</td>
<td></td>
<td>Fragmentary bow, heavily corroded. Approximate shape is square when twisted, but the corrosion makes it difficult to judge.</td>
<td>L: 105 x 15 - 35 wide x 5-10 deep; Mid piece – 50 x 30 x 4 - 7; Near the handle – 25 x 13 and 17 x 8</td>
<td>Incomplete</td>
<td>3 large fragments and 2 small flakes</td>
<td>Untreated</td>
<td>Corrosion Stable</td>
<td>Browned corrosion and white encrustations</td>
</tr>
<tr>
<td>29</td>
<td>Iron</td>
<td>Knife</td>
<td>Vrokastro</td>
<td>Kopranes</td>
<td>ENC IX</td>
<td></td>
<td>Fragments of an iron dagger. The dagger has a raised central tang and the section is eye-shaped. The handle bulges out in a biconical shape and there are smaller fragments of the blade.</td>
<td>L: 107 x 15 – 35 wide x 5-10 deep; Mid piece – 50 x 30 x 4 - 7; Near the handle – 25 x 13 and 17 x 8</td>
<td>Incomplete</td>
<td>3 large fragments and 2 small flakes</td>
<td>Untreated</td>
<td>Corrosion Stable</td>
<td>Browned corrosion and white encrustations</td>
</tr>
<tr>
<td>30</td>
<td>Iron</td>
<td>Spear</td>
<td>Vrokastro</td>
<td>Kopranes</td>
<td>ENC V</td>
<td></td>
<td>Spear head with round / conical area for attachment and spear point. The conical area seems more like it would have been bent into the shape vs cast? And the spear point area is less defined.</td>
<td>L: 22 cm. Whole length is 22 cm wide and .2 thick at the edges (thicker in the middle, .4) ;</td>
<td>Complete</td>
<td>Untreated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Iron</td>
<td>Blade</td>
<td>Kopranes</td>
<td>Kopranes</td>
<td>ENC I</td>
<td></td>
<td>Fragmentary blade. No clasp, spring, pin or beads preserved. L: 2.3; Incomplete</td>
<td>Complete</td>
<td>Untreated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Iron</td>
<td>Spear</td>
<td>Kopranes</td>
<td>Kopranes</td>
<td>ENC I</td>
<td></td>
<td>Spear head with round / conical area for attachment and spear point. The conical area seems more like it would have been bent into the shape vs cast? And the spear point area is less defined.</td>
<td>L: 5.5; Incomplete</td>
<td>Complete</td>
<td>Untreated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Iron</td>
<td>Blade</td>
<td>Kopranes</td>
<td>Kopranes</td>
<td>ENC I</td>
<td></td>
<td>Spear head with round / conical area for attachment and spear point. The conical area seems more like it would have been bent into the shape vs cast? And the spear point area is less defined.</td>
<td>L: 5.5; Incomplete</td>
<td>Complete</td>
<td>Untreated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Iron</td>
<td>Blade</td>
<td>Kopranes</td>
<td>Kopranes</td>
<td>ENC I</td>
<td></td>
<td>Spear head with round / conical area for attachment and spear point. The conical area seems more like it would have been bent into the shape vs cast? And the spear point area is less defined.</td>
<td>L: 5.5; Incomplete</td>
<td>Complete</td>
<td>Untreated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Iron</td>
<td>Blade</td>
<td>Kopranes</td>
<td>Kopranes</td>
<td>ENC I</td>
<td></td>
<td>Spear head with round / conical area for attachment and spear point. The conical area seems more like it would have been bent into the shape vs cast? And the spear point area is less defined.</td>
<td>L: 5.5; Incomplete</td>
<td>Complete</td>
<td>Untreated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Iron</td>
<td>Blade</td>
<td>Kopranes</td>
<td>Kopranes</td>
<td>ENC I</td>
<td></td>
<td>Spear head with round / conical area for attachment and spear point. The conical area seems more like it would have been bent into the shape vs cast? And the spear point area is less defined.</td>
<td>L: 5.5; Incomplete</td>
<td>Complete</td>
<td>Untreated</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Table of Results from Visual Analysis
<table>
<thead>
<tr>
<th>#</th>
<th>Number</th>
<th>Material</th>
<th>Type</th>
<th>Site</th>
<th>Cemetery</th>
<th>Tomb</th>
<th>Period</th>
<th>Description</th>
<th>Measurements in cm</th>
<th>Complete</th>
<th>Treatment</th>
<th>Comments on Treatment</th>
<th>Comments on Treatment</th>
<th>Corrosion/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>97</td>
<td>MS4584.1</td>
<td>Bronze</td>
<td>Nail</td>
<td>Vrokastro</td>
<td></td>
<td></td>
<td></td>
<td>Nail with a large round head. The top of the head is flat. The edges of the head are folded over forming a narrow edge. The pin tapers gradually and is round in section, but with some flatter lines where it has been hammered. There is also a small groove on the head of the nail. The nail is also bent nearly at a 90 degree angle, maybe postdepositional.</td>
<td>Length: 8.0; Head Diameter: 1.6; Pin Diameter: 5.5-6.5</td>
<td>Incomplete</td>
<td>Intact</td>
<td>Sample taken from the head.</td>
<td>Chemically Treated</td>
<td>Surface is brown and dark green and pitted in some places.</td>
</tr>
<tr>
<td>98</td>
<td>MS4584.2</td>
<td>Bronze</td>
<td>Nail</td>
<td>Vrokastro</td>
<td></td>
<td></td>
<td></td>
<td>Nail with a large round head. The top of the head is flat. The edges of the head are folded over forming a wide edge. The pin tapers quickly after the head and is ovular in section. The pin of the nail is also bent in three places, maybe postdepositional.</td>
<td>Length: 10.7; Head Diameter: 1.9; Head Thickness: 0.2-0.3; Pin Diameter: 0.3-0.6</td>
<td>Incomplete</td>
<td>Intact</td>
<td>Chemically Treated</td>
<td>Surface is brown and dark green and pitted in some places.</td>
<td></td>
</tr>
<tr>
<td>99</td>
<td>MS4584.3</td>
<td>Bronze</td>
<td>Nail</td>
<td>Vrokastro</td>
<td></td>
<td></td>
<td></td>
<td>Nail with a small round/ovular head. The top of the head is flat. The edges of the head are folded over forming a wide edge. The pin tapers quickly after the head and is irregular in section. The pin of the nail is also bent in several places, maybe postdepositional.</td>
<td>Length: 7.8; Head Diameter: 1.5; Pin Diameter: 0.3-0.6</td>
<td>Incomplete</td>
<td>Intact</td>
<td>Chemically Treated</td>
<td>Surface is brown and dark green and pitted in some places.</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>MS4584.4</td>
<td>Bronze</td>
<td>Nail</td>
<td>Vrokastro</td>
<td></td>
<td></td>
<td></td>
<td>Nail with a small round head. The top of the head is flat. The edges of the head are not folded over. The pin does not taper significantly. The pin of the nail is also bent to almost a 90 degree angle, maybe postdepositional.</td>
<td>Length: 10.5; Head Diameter: 1.3; Pin Diameter: 10.5</td>
<td>Incomplete</td>
<td>Intact</td>
<td>Sample taken from the head.</td>
<td>Chemically Treated</td>
<td>Surface is brown and dark green and pitted in some places.</td>
</tr>
<tr>
<td>101</td>
<td>MS4584.5</td>
<td>Bronze</td>
<td>Nail</td>
<td>Vrokastro</td>
<td></td>
<td></td>
<td></td>
<td>Nail with a small round head. The top of the head is curved slightly. The edges of the head are folded over forming a very wide edge. The pin tapers quickly after the head and is ovular in section. The pin of the nail is also bent in several places, maybe postdepositional.</td>
<td>Length: 10.5; Head Diameter: 1.3; Pin Diameter: 10.5</td>
<td>Incomplete</td>
<td>Intact</td>
<td>Sample taken from the head.</td>
<td>Chemically Treated</td>
<td>Surface is brown and dark green and pitted in some places.</td>
</tr>
<tr>
<td>102</td>
<td>MS4584.6</td>
<td>Bronze</td>
<td>Nail</td>
<td>Vrokastro</td>
<td></td>
<td></td>
<td></td>
<td>Very large nail or stake, with faceted pin and a conical head. The pin is square in section and tapers evenly. The pin has a circular base but it rises to a point. The edges of the head do not appear to be folded over slightly. This nail seems to have bent out at one place.</td>
<td>Length: 16.5; Head Diameter: 1.3; Pin Diameter: 16.5</td>
<td>Incomplete</td>
<td>Intact</td>
<td></td>
<td>Chemical Treated</td>
<td>Surface is bright green and tan and pitted in some places.</td>
</tr>
<tr>
<td>103</td>
<td>MS4584.7</td>
<td>Bronze</td>
<td>Pin</td>
<td>Vrokastro</td>
<td></td>
<td></td>
<td></td>
<td>Very large nail or stake, with four little bulbs near the head and a little knob on the head itself. Come to a point at the toe. Appears to be cast. The bulb is irregular in shape. Two are close to the pin. One is out of the pin.</td>
<td>18.5</td>
<td>Complete</td>
<td>Intact</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>104</td>
<td>MS4584.8</td>
<td>Bronze</td>
<td>Pin</td>
<td>Vrokastro</td>
<td></td>
<td></td>
<td></td>
<td>Very large nail or stake, with four little bulbs near the head and a little knob on the head itself. Come to a point at the toe. Appears to be cast. The bulb is irregular in shape. Two are close to the pin. One is out of the pin.</td>
<td>18.5</td>
<td>Complete</td>
<td>Intact</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Table of Results from Visual Analysis
<table>
<thead>
<tr>
<th>No.</th>
<th>Material</th>
<th>Site</th>
<th>Period</th>
<th>Loc. of Sample</th>
<th>Corrosion</th>
<th>Inclusions</th>
<th>Porosities</th>
<th>Grains / Dendrites</th>
<th>Working Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bronze</td>
<td>Kourion</td>
<td>CG IA</td>
<td>E 49-12-721</td>
<td>Cross-section not etched</td>
<td>Very small areas of intact metal in mass of corrosion. Intergranular corrosion at the edges of the sample.</td>
<td>Inclusions are infrequent, very small, and round.</td>
<td>Portions are very infrequent and small.</td>
<td>Possibly shaped through a cycle of hammering and annealing.</td>
</tr>
<tr>
<td>2</td>
<td>Bronze</td>
<td>Kourion</td>
<td>CG IB</td>
<td>E 49-12-988</td>
<td>Cross-section not etched</td>
<td>Very small areas of intact metal in mass of corrosion. Intergranular corrosion at the edges of the sample.</td>
<td>Inclusions are infrequent, very small, and round.</td>
<td>Portions are very infrequent and small.</td>
<td>The microstructure of this piece is difficult to interpret due to the corrosion. It was likely heavily cold-worked, because the grains are so small.</td>
</tr>
<tr>
<td>3</td>
<td>Bronze</td>
<td>Kourion</td>
<td>CG II</td>
<td>E 49-12-545</td>
<td>Cross-section not etched</td>
<td>Very small areas of intact metal in mass of corrosion. Intergranular corrosion at the edges of the sample.</td>
<td>Inclusions are infrequent, very small, and round.</td>
<td>Portions are very infrequent and small.</td>
<td>The microstructure of this piece is difficult to interpret due to the corrosion. It was likely heavily cold-worked, because the grains are so small.</td>
</tr>
<tr>
<td>4</td>
<td>Bronze</td>
<td>Kourion</td>
<td>CG II</td>
<td>E 49-12-982</td>
<td>Cross-section not etched</td>
<td>Very small areas of intact metal in mass of corrosion. Intergranular corrosion at the edges of the sample.</td>
<td>Inclusions are infrequent, very small, and round.</td>
<td>Portions are very infrequent and small.</td>
<td>The microstructure of this piece is difficult to interpret due to the corrosion. It was likely heavily cold-worked, because the grains are so small.</td>
</tr>
<tr>
<td>5</td>
<td>Bronze</td>
<td>Kourion</td>
<td>CG II</td>
<td>E 49-12-986</td>
<td>Cross-section not etched</td>
<td>Very small areas of intact metal in mass of corrosion. Intergranular corrosion at the edges of the sample.</td>
<td>Inclusions are infrequent, very small, and round.</td>
<td>Portions are very infrequent and small.</td>
<td>The microstructure of this piece is difficult to interpret due to the corrosion. It was likely heavily cold-worked, because the grains are so small.</td>
</tr>
<tr>
<td>6</td>
<td>Bronze</td>
<td>Kourion</td>
<td>CG II</td>
<td>E 49-12-544</td>
<td>Cross-section</td>
<td>Intermittent corrosion products and corrosion of the surface. Intergranular corrosion around the edges of the sample as well as some voids resulting from differential corrosion of grain boundaries.</td>
<td>Frequent, very small, round and irregularly shaped inclusions. Most are located on grain boundaries.</td>
<td>Frequent, very small round inclusions.</td>
<td>The microstructure reflects a cycle of annealing and hammering. The object appears to have been left in an annealed state, because the annealing twins are straight and because they seem to overlay the slip lines. The visibility of the strain lines, however, suggests that the object may only have been annealed for a short time in its final stage of production.</td>
</tr>
</tbody>
</table>

Table 2: Table of Results from Microscopy
<table>
<thead>
<tr>
<th>#</th>
<th>No.</th>
<th>Material Type</th>
<th>Site</th>
<th>Loc. of Sample</th>
<th>Corrosion</th>
<th>Inclusions</th>
<th>Porosities</th>
<th>Grains / Dendrites</th>
<th>Working Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>69-12-0915</td>
<td>Bronze Ring</td>
<td>Kourion</td>
<td>Kalogera</td>
<td>Folded edge</td>
<td>Entirely corroded with some ghost structures visible</td>
<td>Inclusions are infrequent, small, and round</td>
<td>Porosities are very frequent and large in size. They are elongated in the direction of working and distributed in a somewhat linear fashion.</td>
<td>Recrystallized grain structure with small twinned grains. The recrystallization twins are straight and are visible near the edges of the sample. The microstructure reflects a cycle of annealing and hammering. The annealing twins are straight and because they seem to overlap the slip lines. The visibility of the strain lines, however, suggests that the object may only have been annealed for a short time after the final stage of production.</td>
</tr>
<tr>
<td>8</td>
<td>12-27-755</td>
<td>Bronze Needle</td>
<td>Lapithos</td>
<td>Lower</td>
<td>Cross-section</td>
<td>Corrosion products and disruption of the surface. Intergranular corrosion around the edges of the sample. Corrosion products are highlighted by internal voids formed where the corrosion has attacked weak spots in the metal.</td>
<td>Inclusions are infrequent, small, and round</td>
<td>Porosities are very frequent and large in size. They are elongated in the direction of working and distributed in a somewhat linear fashion.</td>
<td>Recrystallized grain structure with small twinned grains. The recrystallization twins are straight and because they seem to overlap the slip lines. The visibility of the strain lines, however, suggests that the object may only have been annealed for a short time after the final stage of production.</td>
</tr>
<tr>
<td>9</td>
<td>12-27-745</td>
<td>Bronze Needle</td>
<td>Lapithos</td>
<td>Lower</td>
<td>Cross-section</td>
<td>Corrosion products and disruption of the surface. Intergranular corrosion around the edges of the sample. Corrosion products are highlighted by internal voids formed where the corrosion has attacked weak spots in the metal.</td>
<td>Inclusions are infrequent, small, and round</td>
<td>Porosities are very frequent and large in size. They are elongated in the direction of working and distributed in a somewhat linear fashion.</td>
<td>Recrystallized grain structure with small twinned grains. The recrystallization twins are straight and because they seem to overlap the slip lines. The visibility of the strain lines, however, suggests that the object may only have been annealed for a short time after the final stage of production.</td>
</tr>
<tr>
<td>10</td>
<td>12-27-733</td>
<td>Bronze Toe Ring</td>
<td>Lapithos</td>
<td>Lower</td>
<td>Cross-section</td>
<td>Corrosion products and disruption of the surface. Intergranular corrosion at the edges of the sample. Corrosion products are highlighted by internal voids formed where the corrosion has attacked weak spots in the metal.</td>
<td>Inclusions are infrequent, small, and round</td>
<td>Porosities are very frequent and large in size. They are elongated in the direction of working and distributed in a somewhat linear fashion.</td>
<td>Recrystallized grain structure with small twinned grains. The recrystallization twins are straight and because they seem to overlap the slip lines. The visibility of the strain lines, however, suggests that the object may only have been annealed for a short time after the final stage of production.</td>
</tr>
<tr>
<td>11</td>
<td>12-27-789</td>
<td>Bronze Bowl</td>
<td>Lapithos</td>
<td>Upper</td>
<td>Cross-section</td>
<td>Corrosion products and disruption of the surface. Intergranular corrosion at the edges of the sample. Corrosion products are highlighted by internal voids formed where the corrosion has attacked weak spots in the metal.</td>
<td>Inclusions are infrequent, small, and round</td>
<td>Porosities are very frequent and large in size. They are elongated in the direction of working and distributed in a somewhat linear fashion.</td>
<td>Recrystallized grain structure with small twinned grains. The recrystallization twins are straight and because they seem to overlap the slip lines. The visibility of the strain lines, however, suggests that the object may only have been annealed for a short time after the final stage of production.</td>
</tr>
</tbody>
</table>

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<tr>
<th>#</th>
<th>No.</th>
<th>Material</th>
<th>Type</th>
<th>Site</th>
<th>Conv.</th>
<th>Trim.</th>
<th>Period</th>
<th>Loc. of Sample</th>
<th>Cem.</th>
<th>Tomb</th>
<th>Corrosion products and disruption of the surface. Large voids between corrosion products and firm intact metal as well as smaller voids where corrosion has been diffusively corroded. Intergranular corrosion especially near the edges of the sample and some annulling lines mid/large lines outlined in corrosion.</th>
<th>Inclusions</th>
<th>Pores/voids</th>
<th>Grains/Dendrites</th>
<th>Working Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>32-27-1045 Bronze</td>
<td>Bowl</td>
<td>Lapithos</td>
<td>Upper</td>
<td>80</td>
<td>CG II-III</td>
<td>Rem. not etched</td>
<td>Extensive corrosion products over the original surface. Stress relieving corrosion. Extensive intergranular corrosion can be seen in the sample.</td>
<td>Inclusions are frequent and medium in size. They are mostly round. Some are located at the grain boundaries and others have been displaced by working.</td>
<td>Pores/voids are fairly infrequent and medium to large. Slip lines are visible in corrosion.</td>
<td>Grains are heavily deformed and medium to large. Slip lines are visible.</td>
<td>Grains are heavily deformed from extensive cold-working. There are extensive slip lines. The grains are quite large, potentially due to a long annealing time.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>32-27-1301 Bronze</td>
<td>Fibula</td>
<td>Lapithos</td>
<td>Upper</td>
<td>88</td>
<td>CG II II</td>
<td>Fr. not etching</td>
<td>Extensive corrosion products over the original surface. Stress relieving corrosion. Extensive intergranular corrosion can be seen in the sample.</td>
<td>Inclusions are located mostly at the grain boundaries.</td>
<td>Pores/voids are frequent and small.</td>
<td>Grains are heavily deformed with medium to large slip lines/dendrites.</td>
<td>Shaped through cycle of hammering and annealing. Probably annealing occurred the last step since annealing twins are straight.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>32-27-1193 Bronze</td>
<td>Needle</td>
<td>Lapithos</td>
<td>Upper</td>
<td>88</td>
<td>CG II II</td>
<td>Cross-section</td>
<td>Extensive corrosion products over the original surface. Stress relieving corrosion. Extensive intergranular corrosion can be seen in the sample.</td>
<td>Inclusions are very infrequent if present at all.</td>
<td>Pores/voids are very frequent and medium/large in size. In a few areas they appear to be somewhat elongated in the direction of working and aligned in a linear fashion, but in the whole they are not.</td>
<td>Recrystallized grain structure with medium-sized, twinned grains. Slip lines are visible within some grains, but the corroding twins appear to cut through them.</td>
<td>The microstructure reflects a cycle of annealing and hammering. The object appears to have been left in an annealed state, because the annealing twins are straight and because they seem to overlap the slip lines. The visibility of the strain lines, however, suggests that the object may only have been annealed for a short time in its final stage of production.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>32-27-792 Bronze</td>
<td>Needle</td>
<td>Lapithos</td>
<td>Upper</td>
<td>73</td>
<td>CG II-III</td>
<td>Cross-section, not detailed</td>
<td>Remnant metallic grains in a mass of corrosion.</td>
<td>Large round or irregularly shaped pores/pustules, primarily located at the grain boundaries outlining corrosion.</td>
<td>Two areas of the sample display quite different grain structures. One area shows very elongated grains in a laminated pattern. The other shows a recrystallized grain structure with very heavy slip lines outlined in corrosion.</td>
<td>The microstructure reflects a cycle of annealing and hammering. The object appears to have been left in an annealed state, because the annealing twins are straight and because they seem to overlap the slip lines. The visibility of the strain lines, however, suggests that the object may only have been annealed for a short time in its final stage of production.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>32-27-1196 Bronze</td>
<td>Pin</td>
<td>Lapithos</td>
<td>Upper</td>
<td>88</td>
<td>CG II II</td>
<td>Cross-section</td>
<td>Extensive corrosion products over the original surface. Stress relieving corrosion. Extensive intergranular corrosion can be seen in the sample.</td>
<td>Inclusions are very infrequent if present at all.</td>
<td>Pores/voids are very frequent and medium/large in size. In a few areas they appear to be somewhat elongated in the direction of working and aligned in a linear fashion, but in the whole they are not.</td>
<td>Recrystallized grain structure with medium-sized, twinned grains. Slip lines are visible within some grains, but the corroding twins appear to cut through them.</td>
<td>The microstructure reflects a cycle of annealing and hammering. The object appears to have been left in an annealed state, because the annealing twins are straight and because they seem to overlap the slip lines. The visibility of the strain lines, however, suggests that the object may only have been annealed for a short time in its final stage of production.</td>
<td></td>
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<td></td>
</tr>
</tbody>
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<tr>
<th>#</th>
<th>No.</th>
<th>Material</th>
<th>Type</th>
<th>Site</th>
<th>Tomb No.</th>
<th>Loc. of Sample</th>
<th>Epigraphic Data</th>
<th>Microstructural Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>MS4798</td>
<td>Bronze</td>
<td>Ibkliao</td>
<td>Vrokastro</td>
<td>Tomb 16</td>
<td>SM / PG Pin</td>
<td></td>
<td>Corrosion products and disruption of the surface, extensile intergranular and intergranular corrosion around the edges of the sample, and in some cases penetrating into the interior. There are also significant internal welds caused by corrosion. Inclusions are frequent, medium-sized inclusions. Some are elongated in the direction of working and some are still fairly round. There is extensive recrystallized, twinned grains. There are frequent small, round intragranular corrosion around the edges of the sample. There are no slip lines.</td>
</tr>
<tr>
<td>18</td>
<td>MS4798</td>
<td>Bronze</td>
<td>Ibkliao</td>
<td>Vrokastro</td>
<td>Tomb 16</td>
<td>SM / PG Pin</td>
<td></td>
<td>Corrosion products and disruption of the surface, but the object appears to have been electrolytically cleaned, removing much of the corrosion. Interganular and intergranular corrosion around the edges of the sample. Inclusions are frequent and round. There are frequent small, round inclusions. Most are located at the grain boundaries, but many are also located inside the grains. The are somewhat frequent small, round porosities, along with intergranular medium-sized inclusions. There are no slip lines.</td>
</tr>
<tr>
<td>19</td>
<td>MS4799</td>
<td>Bronze</td>
<td>Ibkliao</td>
<td>Vrokastro</td>
<td>Tomb 16</td>
<td>SM / PG Pin</td>
<td></td>
<td>Corrosion products and disruption of the surface, but the object appears to have been electrolytically cleaned, removing much of the corrosion. Interganular and intergranular corrosion around the edges of the sample. Inclusions are frequent and medium in size. They are round or irregular in shape and are mostly located at grain boundaries. There is a concentration of large, irregularly shaped inclusions clustered in the center of the sample and frequent small round porosities throughout the rest of the sample. Microstructure shows recrystallized, twinned grains that are medium to large in size. There is a localized area with some slip lines, but on the whole there are not many.</td>
</tr>
<tr>
<td>20</td>
<td>MS4622</td>
<td>Bronze</td>
<td>Ibkliao</td>
<td>Vrokastro</td>
<td>Tomb 16</td>
<td>SM / PG Pin</td>
<td></td>
<td>There are two areas of heavy external corrosion, but the object appears to have been electrolytically cleaned, removing much of the corrosion. There is extensive intergranular and intergranular corrosion around the edge of the sample, as well as welds caused by differential corrosion of inner grains. Finally, there is prominent corrosion at the center of the object, perhaps from an area that was already weak. Inclusions are frequent, medium-sized inclusions. Some are elongated and some are still fairly round. There is extensive recrystallized, twinned grains. There are frequent small, round intragranular corrosion around the edges of the sample. There are no slip lines.</td>
</tr>
<tr>
<td>21</td>
<td>MS4797</td>
<td>Bronze</td>
<td>Ibkliao</td>
<td>Vrokastro</td>
<td>Tomb 16</td>
<td>SM / PG Pin</td>
<td></td>
<td>Corrosion products and disruption of the surface, extensile intergranular and intergranular corrosion around the edges of the sample, and in some cases penetrating into the interior. There are also significant internal welds caused by corrosion. Inclusions are frequent, medium-sized inclusions. Some are elongated in the direction of working and some are still fairly round. There is extensive recrystallized, twinned grains. There are frequent small, round intragranular corrosion around the edges of the sample. There are no slip lines.</td>
</tr>
</tbody>
</table>

**Table 2: Table of Results from Microscopy**
<table>
<thead>
<tr>
<th>No.</th>
<th>Material Type</th>
<th>Site</th>
<th>Loc. of Sample</th>
<th>Corrosion</th>
<th>Inclusions</th>
<th>Porosities</th>
<th>Grains / Dendrites</th>
<th>Working Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>Bronze Fibula</td>
<td>Vrokastro</td>
<td>PG B / EG Spring</td>
<td>Thick corrosion products and disruption of the surface. Very prominent stress cracking along vertical lines where the needle was bent. Extensive intergranular corrosion deep into the metal. Many voids from corrosion.</td>
<td>Inclusions are frequent. There are dark grey inclusions that are very elongated in the direction of working and lighter grey inclusions that are distributed in a linear fashion, but are not elongated. The very elongated inclusions indicate that the metal was extensively cold-worked in a consistent direction, without annealing.</td>
<td>Porosities are frequent and very elongated in the direction of working. Annealing twins are visible.</td>
<td>The metal has been very heavily worked. It is difficult to say, but it was probably left in an annealed state.</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Bronze Nail</td>
<td>Vrokastro</td>
<td>Unclear Pin</td>
<td>There are some corrosion products and disruption to the surface, but the object appears to have been electrolytically cleaned, removing much of the corrosion.</td>
<td>Inclusions are frequent and medium-sized. Some are slightly elongated in the direction of working and distributed in a somewhat linear fashion. They are mostly located at the grain boundaries.</td>
<td>Porosities are frequent and large. Some are slightly elongated in the direction of working and distributed in a somewhat linear fashion.</td>
<td>Grains are lightly deformed and medium in size (but varying). Annealing twins are apparent, but there are no slip lines. There are localized areas of heavy deformation near the edge of the sample, suggesting purposeful edge hardening.</td>
<td>The metal has been heavily worked, but left in the annealed state. Deformation is concentrated in a few places, especially near the edges.</td>
</tr>
<tr>
<td>24</td>
<td>Bronze Nail</td>
<td>Vrokastro</td>
<td>Unclear Blind</td>
<td>There are some corrosion products and disruption to the surface, but the object appears to have been electrolytically cleaned, removing much of the corrosion.</td>
<td>Inclusions are frequent and medium-sized. Some are elongated in the direction of working, but others are not. They are not all located at the grain boundaries.</td>
<td>Porosities are frequent and varying in size from small to medium. Annealing twins are apparent, but there are no slip lines.</td>
<td>Grains are heavily deformed and varying in size from small to medium. Annealing twins are apparent, but there are no slip lines.</td>
<td>The metal has been heavily worked, but left in the annealed state with no evidence of cold working subsequent to annealing.</td>
</tr>
</tbody>
</table>

Table 2: Table of Results from Microscopy
Figure 1: Map of the Eastern Mediterranean (courtesy of Eli Storch)
**Figure 2**: Chronological Chart, After Dickinson (2006) and Gjerstad (1948) with updates from Smith (2009)
Figure 3: Map of Cyprus with Kourion and Lapithos (courtesy of Eli Storch)
Figure 4: Map of Crete with Vrokastro (courtesy of Eli Storch)
Figure 5: Site Map of Kourion (Steel 1996)
Figure 6: Site Map of Episkopi-Kaloriziki (Benson 1973)
Figure 8: Site Map of Lapithos, Upper Geometric and Kastros Tombs (Diakou 2013)
Figure 9: Site Map of Lapithos, Upper Geometric Cemetery (Djakou 2013)
Figure 10: Site Map of Vrokastro (Dohan 1914)
## The elemental composition (% mass) and inclusion information of SEM-tested artifacts

<table>
<thead>
<tr>
<th>Site</th>
<th>Type</th>
<th>Reference</th>
<th>Period</th>
<th>Cu</th>
<th>Sn</th>
<th>S</th>
<th>Fe</th>
<th>Sulfide</th>
<th>Iron</th>
<th>Sulfide</th>
<th>Lead</th>
<th>Selenium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kourion</td>
<td>Fibula</td>
<td>49-12-721</td>
<td>CG IA</td>
<td>90.7 ± 0.4</td>
<td>93 ± 0.1</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kourion</td>
<td>Fibula</td>
<td>49-12-988 *</td>
<td>CG IB</td>
<td>62.2 ± 1.8</td>
<td>37.8 ± 0.9</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
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</tr>
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<td>49-12-545</td>
<td>CG II</td>
<td>95.5 ± 0.3</td>
<td>45 ± 0.1</td>
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<td>Kourion</td>
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<td>49-12-982</td>
<td>CG II</td>
<td>93.3 ± 0.3</td>
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<tr>
<td>Kourion</td>
<td>Needle</td>
<td>49-12-986 *</td>
<td>CG II</td>
<td>87.4 ± 0.3</td>
<td>12.6 ± 0.1</td>
<td></td>
<td></td>
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<tr>
<td>Kourion</td>
<td>Ring</td>
<td>49-12-1005 *</td>
<td>CG IB</td>
<td>99.2 ± 0.4</td>
<td>0.8 ± 0.1</td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>Lapithos</td>
<td>Bowl</td>
<td>32-27-789</td>
<td>CG II</td>
<td>90.0 ± 0.2</td>
<td>98 ± 0.1</td>
<td>0.3 ± 0.1</td>
<td>X</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Lapithos</td>
<td>Bowl</td>
<td>32-27-1045</td>
<td>CG II / CG III</td>
<td>86.4 ± 0.3</td>
<td>13.6 ± 0.1</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
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<tr>
<td>Lapithos</td>
<td>Fibula</td>
<td>32-27-1201</td>
<td>CG II</td>
<td>91.7 ± 0.8</td>
<td>8.3 ± 0.2</td>
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<tr>
<td>Lapithos</td>
<td>Pin</td>
<td>32-27-1195</td>
<td>CG II</td>
<td>90.4 ± 0.4</td>
<td>9.7 ± 0.1</td>
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<tr>
<td>Lapithos</td>
<td>Pin</td>
<td>32-27-1196</td>
<td>CG II</td>
<td>90.4 ± 0.3</td>
<td>9.6 ± 0.1</td>
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<tr>
<td>Lapithos</td>
<td>Needle</td>
<td>32-27-745</td>
<td>CG IIIA</td>
<td>95.6 ± 0.2</td>
<td>4.2 ± 0.1</td>
<td>0.1 ± 0.1</td>
<td>0.1 ± 0.1</td>
<td>X</td>
<td>X</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Lapithos</td>
<td>Needle</td>
<td>32-27-735</td>
<td>CG IIIA</td>
<td>89.3 ± 0.2</td>
<td>10.7 ± 0.1</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
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</tr>
<tr>
<td>Lapithos</td>
<td>Needle</td>
<td>32-27-792 *</td>
<td>CG IIIA</td>
<td>80.4 ± 0.3</td>
<td>19.6 ± 0.1</td>
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<td></td>
<td>X</td>
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<tr>
<td>Lapithos</td>
<td>Ring</td>
<td>32-27-733</td>
<td>CG IA</td>
<td>83.0 ± 0.3</td>
<td>17.0 ± 0.1</td>
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<td></td>
<td>X</td>
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<tr>
<td>Vrokastro</td>
<td>Fibula</td>
<td>VK4758</td>
<td>SM / PG</td>
<td>95.6 ± 0.2</td>
<td>4.2 ± 0.1</td>
<td>0.2 ± 0.1</td>
<td>0.1 ± 0.1</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Vrokastro</td>
<td>Fibula</td>
<td>VK4622</td>
<td>PG B / EG</td>
<td>89.6 ± 0.3</td>
<td>10.0 ± 0.1</td>
<td>0.3 ± 0.1</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vrokastro</td>
<td>Fibula</td>
<td>VK4756</td>
<td>PG B / EG</td>
<td>89.0 ± 0.2</td>
<td>9.0 ± 0.1</td>
<td>0.4 ± 0.1</td>
<td>1.6 ± 0.1</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Vrokastro</td>
<td>Fibula</td>
<td>VK4757</td>
<td>PG B / EG</td>
<td>88.8 ± 1.9</td>
<td>11.2 ± 0.5</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vrokastro</td>
<td>Fibula</td>
<td>VK4759 **</td>
<td>LG / EO</td>
<td>100.0 ± 7.1</td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>Vrokastro</td>
<td>Fibula</td>
<td>VK4760</td>
<td>LG / EO</td>
<td>88.3 ± 0.2</td>
<td>11.7 ± 0.1</td>
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</tr>
<tr>
<td>Vrokastro</td>
<td>Nail</td>
<td>VK4584-1</td>
<td>SM / EO</td>
<td>99.6 ± 0.3</td>
<td>0.4 ± 0.1</td>
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<td>X</td>
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<tr>
<td>Vrokastro</td>
<td>Nail</td>
<td>VK4584-4</td>
<td>SM / EO</td>
<td>100.0 ± 0.6</td>
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<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Object is too corroded to say anything quantitative

**Machine error in the SEM, consult LA-ICP-MS results

---

**Figure 11: Results of the SEM Analysis**

---
306

Fibula
Needle
Needle
Ring
Bowl
Bowl
Fibula
Needle
Needle
Pin
Pin
Ring
Fibula
Fibula
Fibula
Fibula
Fibula
Fibula
Nail
Nail

Type
49-12-721
49-12-545
49-12-982
49-12-544
32-27-1045
32-27-789
32-27-1201
32-27-735
32-27-745
32-27-1195
32-27-1196
32-27-733
VK4622
VK4756
VK4757
VK4758
VK4759
VK4760
VK4584-1
VK4584-4

Reference
CG IA
CG II
CG II
CG II
CG II / CG III
CG II
CG II
CG IIIA
CG IIB / CG IIIA
CG II
CG II
CG IA
PG B / EG
PG B / EG
PG B / EG
SM / PG
LG / EO
LG / EO
unknown
unknown

Period
90.4%
93.8%
93.3%
90.0%
83.0%
90.4%
91.3%
88.4%
95.2%
88.6%
89.6%
72.8%
92.9%
88.3%
90.0%
95.4%
95.3%
88.7%
99.2%
99.4%

Cu63

Kourion
Kourion
Kourion
Kourion
Lapithos
Lapithos
Lapithos
Lapithos
Lapithos
Lapithos
Lapithos
Lapithos
Vrokastro
Vrokastro
Vrokastro
Vrokastro
Vrokastro
Vrokastro
Vrokastro
Vrokastro

Site

Fibula
Needle
Needle
Ring
Bowl
Bowl
Fibula
Needle
Needle
Pin
Pin
Ring
Fibula
Fibula
Fibula
Fibula
Fibula
Fibula
Nail
Nail

Type
49-12-721
49-12-545
49-12-982
49-12-544
32-27-1045
32-27-789
32-27-1201
32-27-735
32-27-745
32-27-1195
32-27-1196
32-27-733
VK4622
VK4756
VK4757
VK4758
VK4759
VK4760
VK4584-1
VK4584-4

Reference
CG IA
CG II
CG II
CG II
CG II / CG III
CG II
CG II
CG IIIA
CG IIB / CG IIIA
CG II
CG II
CG IA
PG B / EG
PG B / EG
PG B / EG
SM / PG
LG / EO
LG / EO
unknown
unknown

Period

7

1,740
5,000
4,730
1,270
1,960
5,460
519
2,790
1,210
822
742
3,150
1,400
19,140
307
343
382
110
178
2,020

Fe57

0.01

273
49.9
40.5
59.8
257
77.1
31.2
102
192
148
142
735
145
638
55.1
219
108
96.7
207
294

Co59

0.07

464
551
278
436
321
312
327
373
531
414
417
437
308
318
287
621
357
241
212
263

Ni60

0.11

12.1
36.7
35.4
18.7
12.1
44.6
7.01
10.8
52.3
10.0
8.76
48.7
141
106
10.1
75.6
23.6
143
88.8
80.5

Zn66

1,920
5,330
5,070
1,410
2,370
6,040
569
3,150
1,270
928
828
4,330
1,500
21,700
340
359
400
124
179
2,030

Fe57
302
53.2
43.4
66.4
310
85.3
34.1
115
202
167
158
1,010
156
723
61.2
230
113
109
209
295

Co59
513
587
298
484
386
345
358
421
557
467
466
600
332
360
319
651
375
272
214
264

Ni60

13.4
39.1
37.9
20.7
14.6
49.4
7.68
12.2
54.9
11.3
9.77
66.9
152
120
11.2
79.3
24.8
161
89.5
81.0

Zn66

Ratio of each trace element to copper (as ppm)

0.1

8.76%
4.17%
5.77%
8.45%
15.7%
7.99%
8.00%
7.69%
3.23%
9.41%
8.22%
25.1%
6.36%
9.21%
9.34%
3.73%
3.98%
10.5%
0.443%
0.0738%

Sn120

3,210
8,710
1,490
6,680
4,970
4,500
2,390
1,530
866
1,330
1,180
10,700
566
1,390
1,340
2,220
1,040
1,910
1,880
1,850

As75

0.62

2,900
8,170
1,390
6,020
4,130
4,070
2,190
1,350
824
1,180
1,050
7,810
526
1,230
1,210
2,110
995
1,690
1,870
1,840

As75

166
35.4
30.6
177
67.7
25.3
33.3
82.4
14.9
49.8
48.2
148
26.3
105
34.6
15.7
21.3
14.8
30.0
29.4

Se82

31.14

150
33.2
28.5
160
56.2
22.9
30.4
72.9
14.2
44.2
43.2
108
24.4
92.7
31.2
15.0
20.3
13.1
29.8
29.2

Se82

95.0
227
152
978
120
80.8
151
96.1
29.3
57.4
56.2
150
76.1
32.3
154
426
133
514
181
187

Ag107

0.02

85.8
213
142
881
100
73.0
138
85.0
27.9
50.9
50.4
109
70.7
28.5
138
406
127
456
179
186

Ag107

Figure 12: Results of the LA-ICP-MS Analysis

*note: Cu63 and Sn120 are % weight, and all of the other elements are PPM

Limits of Detection (PPM)

Kourion
Kourion
Kourion
Kourion
Lapithos
Lapithos
Lapithos
Lapithos
Lapithos
Lapithos
Lapithos
Lapithos
Vrokastro
Vrokastro
Vrokastro
Vrokastro
Vrokastro
Vrokastro
Vrokastro
Vrokastro

Site

The elemental composition of LA-ICP-MS-tested artifacts

1,540
699
935
1,490
3,220
1,340
1,320
1,320
779
1,690
1,460
5,470
1,410
1,760
2,140
898
719
2,440
82.1
13.0

Cd113

0.03

1,390
656
872
1,350
2,670
1,210
1,210
1,170
741
1,500
1,310
3,980
1,310
1,550
1,920
857
685
2,170
81.4
12.9

Cd113

156
693
147
563
173
167
411
357
39.6
177
167
485
52.0
64.6
114
1,550
155
629
196
175

Sb121

2

141
650
137
507
144
151
376
316
37.7
157
150
353
48.3
57.1
103
1,480
148
558
195
174

Sb121

160
16.3
3.89
115
61.5
2.16
15.2
16.0
0.122
22.1
22.8
240
0.512
53.4
2.72
9.04
10.5
7.17
36.2
26.0

Te128

0.03

145
15.3
3.63
104
51.0
1.95
13.9
14.2
0.116
19.5
20.5
175
0.476
47.1
2.45
8.62
10.0
6.36
35.9
25.8

Te128

1,460
5,000
1,830
4,590
3,790
4,950
2,000
36,600
13,000
17,100
19,800
4,510
3,540
1,870
2,380
3,010
4,510
2,490
504
362

Pb208

0.06

1,320
4,690
1,710
4,130
3,150
4,470
1,830
32,350
12,340
15,160
17,750
3,280
3,290
1,650
2,140
2,870
4,300
2,210
500
360

Pb208

6.59
4.78
2.80
27.2
13.2
4.04
4.01
19.8
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5.34
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17.7

Bi209

0.007

5.95
4.49
2.61
24.5
10.9
3.66
3.67
17.5
2.57
7.36
7.41
10.60
2.17
8.78
4.81
32.6
10.2
24.9
23.8
17.6

Bi209


Figure 13: Results of the LA-ICP-MS Analysis
Figure 14: Châine Opératoire Diagram (Ottaway 2001)
Image of object showing sample location.

Overview of sample.
Center of the sample. Medium and large, irregularly shaped porosities and recrystallized grains with annealing twins. Etched with FeCl$_3$. x800.

Recrystallized grains with annealing twins. Etched with FeCl$_3$. x800.
Image of object showing sample location.

Overview of sample.
Elongated inclusions. Polished. x400.

Elongated inclusions. Polished. x800.
Stress cracking. Polished. x400.

Stress cracking. Polished. x800.
Small, heavily worked grains. Elongated inclusions. Etched with FeCl₃. x800.

Small, heavily worked grains. Elongated inclusions. Stress cracking. Etched with FeCl₃. x800.
Image of object showing sample location.

Overview of sample.
Polished. x400.

Polished. x800.
Edge of the sample. Recrystallized grains with annealing twins.
Etched in FeCl$_3$. x400.

Edge of the sample. Recrystallized grains with annealing twins.
Etched in FeCl$_3$. x800.
Image of object showing sample location.

Overview of sample.
Polished. x400.

Polished. x800.
Recrystallized grains with annealing twins. Etched in H$_2$O$_2$. x400.

Recrystallized grains with annealing twins. Etched in H$_2$O$_2$. x800.
Image of object showing sample location.

Overview of sample.
Polished. x400

Polished. x800
Intergranular corrosion. Recrystallized grains with annealing twins. Etched in H\textsubscript{2}O\textsubscript{2}. x400
Image of object showing sample location.

Overview of sample.
Porosities. Light grey inclusions. Intergranular corrosion. Polished. x400.

Porosities. Light grey inclusions. Intergranular corrosion. Polished. x800.
Center of sample. Recrystallized grains with annealing twins. Light grey high tin phases. Etched with FeCl₃. x400.

Center of sample. Recrystallized grains with annealing twins. Light grey high tin phases. Etched with FeCl₃. x800.
Edge of sample. Recrystallized grains with annealing twins. Etched with FeCl$_3$. x400.

Edge of sample. Recrystallized grains with annealing twins. Etched with FeCl$_3$. x800.
Image of object showing sample location.

Overview of sample.
Small, frequent porosities. Polished. x400.

Small, frequent porosities. Polished. x800.
Intergranular corrosion. Polished. x400.

Intergranular corrosion. Polished. x800.
Recrystallized grains with annealing twins. Slip lines and specific areas of deformation. Etched with FeCl₃. x800.

Recrystallized grains with annealing twins. Slip lines and specific areas of deformation. Etched with FeCl₃. x800.
Image of object showing sample location.

Overview of sample.
Small area of intact metal in corrosion. Polished. x400.

Small area of intact metal in corrosion. Ghost structures visible in corrosion. Polished. x800.
Polished. x400.

Ghost structures with slip lines visible in corrosion. Polished. x800.
Image of object showing sample location.

Overview of sample.
Small, frequent porosities. Intergranular corrosion at edge of sample. Polished. x400.

Small, frequent porosities. Polished. x800.
Recrystallized grains with frequent slip lines. Etched with FeCl₃. x800.
Area.

Inclusions.

Pb →

CuFeS →
Area.

Inclusions.

CuFeS
Area.
Area.

Inclusions.
Area.
Inclusions. Tin bronze showing a typical eutectoid phase.
Area.

Inclusions.
Area.

Inclusions.

CuFeS
Frequent porosities. Intergranular corrosion at edge of sample. Polished. x400.

Frequent porosities. Intergranular corrosion at edge of sample. Polished. x800.
Deformed grains with bent annealing twins. Etched in HCl. x800.

Deformed grains with bent annealing twins. Etched in HCl. x1000.
Recrystallized grains. Slip lines. Etched in FeCl₃, x800.

Recrystallized grains. Slip lines. Etched in FeCl₃, x1000.
Frequent porosities. Polished. x400.

Frequent porosities. Polished. x800.
Corrosion at edge of sample. Polished. x400.

Corrosion at edge of sample. Polished. x400.
Recrystalized grains with annealing twins and slip lines. Etched in FeCl$_3$. x800.

Recrystalized grains with annealing twins and slip lines. Etched in FeCl$_3$. x1000.
Polished. x400.

Polished. x400.
Polished. x400.

Polished. x800.
Frequent, small porosities. Polished. x400.

Frequent, small porosities. Polished. x800.
Ghost structures visible in corrosion. Polished. x400.

Ghost structures visible in corrosion. Elongated inclusions. Polished. x800.
Corrosion at edge of sample. Frequent porosities. Polished. x400.

Frequent porosities. Polished. x800.
Corrosion at edge of sample. Polished. x400.
Recrystallized grains with annealing twins. Slip lines. Etched in FeCl₃. x800.

Recrystallized grains with annealing twins. Slip lines. Etched in FeCl₃. x1000.
Frequent porosities. Polished. x400.

Frequent porosities. Polished. x800.
Corrosion at edge of sample. Polished. x400.

Corrosion at edge of sample. Polished. x800.
Area.

Inclusions.
Area.

Inclusions.

Pb

CuFeS
Area.

Inclusions.
Area.

Inclusions.
Area.

Inclusions.

Pb  →

CuFeS  →
Area.

Inclusions.

Pb

CuFeS
Extensive intergranular corrosion. Polished. x400.

Extensive intergranular corrosion. Polished. x800.
Porosities and light grey inclusions. Polished. x400.

Porosities and light grey inclusions. Polished. x800.
Recrystallized grains with annealing twins. Some areas of deformation. Etched in FeCl₃. x800.
Corrosion. Polished. x400.

Corrosion. Polished. x800.
Ghost structures visible in corrosion. Cast structure. Polished. x800.
Area.

Inclusions.
Area.

Inclusions.

CuFeS
Figure 165: Images of front and back of 32-27-633
Figure 166: Images of front and back of 32-27-633
Figure 167: Images of front and back of 32-27-634
Figure 168: Images of front and back of 32-27-634
Figure 169: Images of front and back of 32-27-648
Figure 170: Images of front and back of 32-27-648
Figure 171: Images of front and back of 32-27-719
Figure 172: Images of front and back of 32-27-719
Figure 175: Images of front and back of 32-27-1046
Figure 176: Images of front and back of 32-27-1046
Figure 177: Images of front and back of 49-12-1051
Figure 178: Images of front and back of 49-12-1051
Figure 179: Images of front and back of 49-12-1052
Figure 180: Images of front and back of 49-12-1052
Figure 182: Images of front and back of 49-12-1055
Figure 183: Images of front and back of 49-12-1055
Figure 184: Images of front and back of 49-12-1055
Figure 185: Images of front and back of 49-12-1029
Figure 18: Images of front and back of 49-12-1029
Figure 187: Images of front and back of 49-12-1029
Porosities and light grey inclusions. Intergranular corrosion. Polished. x400.

Porosities and light grey inclusions. Intergranular corrosion. Polished. x800.
Extensive slip lines. Polished. x400.

Extensive slip lines. Polished. x800.
Recrystallized grains with annealing twins. Etched in FeCl$_3$. x800.

Recrystallized grains with annealing twins. Etched in FeCl$_3$. x1000.
Large, deformed grains. Intergranular corrosion. Light grey inclusions. Polished. x400.
Area.

Inclusions.
Area.

Inclusions.

CuFeS

Pb
Figure 196: Images of front and back of VK4584.1
Figure 197: Images of front and back of VK4584.2
Figure 198: Images of front and back of VK4584.3
Figure 199: Images of front and back of VK4584.4
Figure 200: Images of front and back of VK4584.5
Figure 201: Images of front and back of VK4584.6
Frequent, large porosities. Polished. x400.

Frequent, large porosities. Polished. x800.
Recrystallized grains with annealing twins. Etched in HCl. x800.

Deformed grains with bent annealing twins. Etched in HCl. x800.
Frequent inclusions. Polished. x400.

Frequent inclusions. Polished. x800.
Small, worked grains. Etched in HCl. x800.

Recrystallized grains with annealing twins. Etched in HCl. x800.
Area.

Inclusions.

Cu$_2$S
Area.

Inclusions.

Cu$_2$S
Figure 210: Images of front and back of 49-12-1053
Figure 211: Images of front and back of 49-12-1053
Figure 212: Images of front and back of 49-12-1053
Sb121 vs As57

Site
- Kourion
- Lapithos A
- Lapithos B
- Vrokastro

Type
- Bowl
- Fibula
- Nail
- Pin/Needle
- Ring

Sb121 vs As57
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<th>CGIII</th>
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<th>CGII</th>
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<td>11</td>
<td>37</td>
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<td>Shape of Wings</td>
<td>Palaepaphos</td>
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<td>19</td>
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<td>29</td>
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<td>Shape of Shoulder</td>
<td>Lapithos</td>
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<td>0</td>
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<td>2</td>
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<td>Taper</td>
<td>Kourion</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<td>Height of Midrib</td>
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<td>20</td>
<td>15</td>
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<tr>
<td>Width of Midrib</td>
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<tr>
<td>Shape of Midrib</td>
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Figure 233: Objects in the Network Database and Their Attributes
Cypriot Bronze and Iron Objects: Sites and Tombs

### Objects by Site

<table>
<thead>
<tr>
<th>Site</th>
<th># of Objects</th>
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<tbody>
<tr>
<td>Amathus</td>
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<td>Salamis</td>
<td>382</td>
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<td>Lapithos</td>
<td>202</td>
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<td>Kourion</td>
<td>154</td>
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<tr>
<td>Enkomi</td>
<td>111</td>
</tr>
<tr>
<td>Alaas</td>
<td>12</td>
</tr>
<tr>
<td>Kition</td>
<td>8</td>
</tr>
<tr>
<td>Idalion</td>
<td>4</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>2147</strong></td>
</tr>
</tbody>
</table>

### Number of Tombs by Site

<table>
<thead>
<tr>
<th>Site</th>
<th># of Tombs</th>
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</thead>
<tbody>
<tr>
<td>Amathus</td>
<td>164</td>
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<tr>
<td>Palaeapaphos</td>
<td>52</td>
</tr>
<tr>
<td>Salamis</td>
<td>47</td>
</tr>
<tr>
<td>Lapithos</td>
<td>43</td>
</tr>
<tr>
<td>Kourion</td>
<td>39</td>
</tr>
<tr>
<td>Enkomi</td>
<td>43</td>
</tr>
<tr>
<td>Alaas</td>
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</tr>
<tr>
<td>Kition</td>
<td>2</td>
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<tr>
<td>Idalion</td>
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### Objects by Cemetery

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<tr>
<td>Amathus</td>
<td>Swedish</td>
<td>206</td>
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<tr>
<td>Amathus</td>
<td>Diplostrati</td>
<td>4</td>
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<tr>
<td>Amathus</td>
<td>Western Necropolis</td>
<td>2</td>
</tr>
<tr>
<td>Palaeapaphos</td>
<td>Skales</td>
<td>233</td>
</tr>
<tr>
<td>Palaeapaphos</td>
<td>Palaepaphos-Plakes</td>
<td>106</td>
</tr>
<tr>
<td>Palaeapaphos</td>
<td>Terato Saudiha</td>
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<td>Palaeapaphos</td>
<td>Eliomyla</td>
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<td>Palaeapaphos</td>
<td>Kouklia-Xylinos</td>
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<td>Palaeapaphos</td>
<td>Kouklia-Hadjji Abdullah</td>
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<td>Royal Tombs</td>
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<td>Kouformeron</td>
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<tr>
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<td>Non-RT</td>
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<td>Alaas</td>
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</tr>
<tr>
<td>Kition</td>
<td>Kition</td>
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<tr>
<td>Idalion</td>
<td>Idalion</td>
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<td><strong>Grand Total</strong></td>
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Figure 234: Cypriot Bronze and Iron Objects in the Network Database
Cypriot Bronze and Iron Objects: Object Types

Objects by Type

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<td>Blade</td>
<td>284</td>
</tr>
<tr>
<td>Fibula</td>
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</tr>
<tr>
<td>Bowl</td>
<td>162</td>
</tr>
<tr>
<td>Ring</td>
<td>147</td>
</tr>
<tr>
<td>Nail/Punch</td>
<td>105</td>
</tr>
<tr>
<td>Pin</td>
<td>97</td>
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<tr>
<td>Needle</td>
<td>69</td>
</tr>
<tr>
<td>Spearhead</td>
<td>63</td>
</tr>
<tr>
<td>Dagger</td>
<td>16</td>
</tr>
<tr>
<td>Tripod</td>
<td>9</td>
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<td>Grand Total</td>
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Object Types by Site

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<th>Amathus</th>
<th>Palae</th>
<th>Lapithos</th>
<th>Salamis</th>
<th>Kourion</th>
<th>Enkomi</th>
<th>Alaus</th>
<th>Kition</th>
<th>Idalion</th>
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<td></td>
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<tr>
<td>Bowl</td>
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<td>64</td>
<td>22</td>
<td>3</td>
<td>11</td>
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<td>3</td>
<td></td>
<td>162</td>
</tr>
<tr>
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<td>24</td>
<td>40</td>
<td>50</td>
<td>17</td>
<td>4</td>
<td>1</td>
<td>1</td>
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<td>147</td>
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<tr>
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<td>3</td>
<td>3</td>
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<td>2</td>
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<td>4</td>
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Figure 235: Cypriot Bronze and Iron Objects in the Network Database
Cretan Bronze and Iron Objects

Object Types by Site

<table>
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<th>Knossos</th>
<th>Vrokastro</th>
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<tr>
<td>Bowls and Vessels</td>
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<td>91</td>
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<td>42</td>
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<td>7</td>
<td>82</td>
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<tr>
<td>Pins</td>
<td>167</td>
<td>6</td>
<td></td>
<td>173</td>
</tr>
<tr>
<td>Spearheads</td>
<td>2</td>
<td>76</td>
<td>4</td>
<td>82</td>
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<td></td>
<td>57</td>
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<tr>
<td>Total</td>
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<td>59</td>
<td>608</td>
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Figure 236: Cretan Bronze and Iron Objects in the Network Database
Figure 23.7: Map of Cyprus with Selected Sites (courtesy of Eli Storch)
Figure 238: Map of Crete with Selected Sites (courtesy of Eli Storch)
Fibulae – All Sites, All Dates, T=7
Fibulae – AllSites, AllDates, T=7, Spinglass Clustering
Importance of Attributes to the Shape of the Fibulae Network, AllSites, AllDates

<table>
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<tr>
<th>Attribute</th>
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<th>Possible</th>
<th>Probability</th>
<th>Relativity</th>
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<tr>
<td>Symmetrical / Asymmetrical</td>
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<td>453</td>
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<td>85.4%</td>
<td>2.016</td>
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<td>70.9%</td>
<td>1.672</td>
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<tr>
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<td>280</td>
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<td>61.8%</td>
<td>1.459</td>
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<tr>
<td>Spring shape</td>
<td>263</td>
<td>453</td>
<td>58.1%</td>
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<td>1st bead (on foot) shape</td>
<td>261</td>
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<td>1st bead (on foot) size</td>
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<td>Lower foot thickness</td>
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<td>Upper foot angle of curve</td>
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<td>Needle Holder Pinch</td>
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<td>Needle holder Shape</td>
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<td>105</td>
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<td>23.2%</td>
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The Probability Column represents the probability that two objects sharing a given attribute are also connected on the network. This is a proxy for the importance of the attribute to the shape of the network. Methodology taken from Östborn and Gerding (2015).
Fibulae – Palaepaphos, All Dates, T=7
Fibulae – Palaepaphos, AllDates, T=7, Spinglass Clustering
Fibulae – Amathous, All Dates, T=7
Fibulae – Amathous, AllDates, T=7, Spinglass Clustering
Fibulae – All Sites, CGI, T=6

[Diagram of Fibulae – All Sites, CGI, T=6]

- Amathous
- Kourion
- Lapithos
- Palaepaphos

541
Fibulae – AllSites, CGI, T=6, Spinglass Clustering
Fibulae – All Sites, CGII, T=6
Fibulae – AllSites, CGII, T=6, Greedy Clustering
Fibulae – All Sites, CGIII, T=6
Fibulae – AllSites, CGIII, T=6, Spinglass Clustering
Fibulae – AllSites, CAI, T=6, Spinglass Clustering
Bowls – All Sites, All Dates, T=3

---

**Diagram Information:**

- **Legend:**
  - Red: Amathous
  - Green: Kourion
  - Cyan: Lapithos
  - Purple: Palaepaphos

- **Nodes with Specific Values:**
  - Example values from the image include 5.41, 7.116, 7.242, 7.256, and others.

---

**Note:**

The values mentioned are illustrative and do not correspond to actual data points in the diagram. The diagram visualizes relationships and locations across sites and dates. The specific values are placeholders and should be replaced with actual data for analysis.
Bowls – AllSites, AllDates, T=3, Spinglass Clustering
Bowls – Palaepaphos, All Dates, T=2.5
Bowls – Palaepaphos, AllDates, T=2.5, Greedy Clustering
Bowls – Amathous, All Dates, T=3
Bowls – Amathous, AllDates, T=3, Greedy Clustering
Bowls – AllSites, LClIIIB–CGI, T=2.5, Greedy Clustering
Bowls – All Sites, CGII, T=2.5
Bowls – AllSites, CGII, T=2.5, Greedy Clustering
Bowls – AllSites, CGIII, T=2.5, Greedy Clustering
Knives – AllSites, AllDates, T=4, Greedy Clustering
Knives – Palaepaphos, All Dates, T=2.5

[Diagram showing relationships between various dates and contexts with labels such as LCIIIB, LCIIIB–CGI, CGI, CGI–CGII, CGII, CGII–CGIII, CGIII, CGIII–CAI, CAI, CAI–CAII, and CAII.]
Knives – Amathous, All Dates, T=4
Knives – Amathous, AllDates, T=4, Spinglass Clustering
Knives – All Sites, CGI–II, T=3
Knives – AllSites, CGI–II, T=3, Greedy Clustering
Knives – AllSites, CGIII, T=3, Greedy Clustering
Knives – AllSites, CAI, T=3, Greedy Clustering
Spearheads – All Sites, All Dates, T=4
Spearheads – All Sites, All Dates, T−4
Spearheads – AllSites, AllDates, T−4, Spinglass Clustering
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Figure 284: Cretan Fibulae Types by Site
Fibulae, Crete, AllDates, T=6, Spinglass Clustering
BIBLIOGRAPHY


Charalambous, A. 2016. “A Diachronic Study of Cypriot Copper Alloy Artefacts.” 
*JAS: Reports* 7: 566–73.

Charalambous, A., and V. Kassianidou. 2012. “Appendix I: Chemical Analyses of Metal Artefacts from Late Cypriote Tombs Excavated in the Limassol Area, with the Employment of PXRF.” In *Tombs of the Late Bronze Age in the Limassol Area Cyprus (17th -13th Centuries BC)*, edited by V. Karageorghis and Y. Violaris, 37–45. Limassol: Municipality of Limassol.


Figueiredo, E., R. J. C. Silva, J. C. Senna-Martinez, M. F. Araújo, F. M. Braz Fernandes, and J. L. Inês Vaz. 2010. “Smelting and Recycling Evidences from the


Gale, N. H. 1999. “Lead Isotope Characterization of the Ore Deposits of Cyprus and Sardinia and Its Application to the Discovery of the Sources of Copper for Late


———. 2013a. “The Exploitation of the Landscape: Metal Resources and the Copper Trade during the Age of the Cypriot City-Kingdoms.” *BASOR* 370: 49–82.


Kuijpers, M. H. G. 2018a. “A Sensory Update to the Chaîne Opératoire in Order to Study Skill: Perceptive Categories for Copper-Compositions in 611


Orfanou, S. 2015. “Early Iron Age Greek Copper-Based Technology: Votive Offerings from Thessaly.” University College London.


623


Tholander, E. 1971. “Evidence of the Use of Carburized Steel and Quench Hardening in Late Bronze Age Cyprus.” *Svenska Institutet i Athen, Skrifiner Utgivna* 18: 15–22.


