Toward a Theory of Social Stability:

Investigating Relationships among the

Valencian Bronze Age Peoples of Mediterranean Iberia

by

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ABSTRACT

What causes social systems to resist change? Studies of the emergence of social complexity in archaeology have focused primarily on drivers of change with much less emphasis on drivers of stability. Social stability, or the persistence of social systems, is an essential feature without which human society is not possible. By combining quantitative modeling (Exponential Random Graph Modeling) and the comparative archaeological record where the social system is represented by networks of relations between settlements, this research tests several hypotheses about social and geographic drivers of social stability with an explicit focus on a better understanding of contexts and processes that resist change. The Valencian Bronze Age in eastern Spain along the Mediterranean, where prior research appears to indicate little, regional social change for 700 years, serves as a case study.

The results suggest that social stability depends on a society's ability to integrate change and promote interdependency. In part, this ability is constrained or promoted by social structure and the different, relationship dependencies among individuals that lead to a particular social structure. Four elements are important to constraining or promoting social stability—structural cohesion, transitivity and social dependency, geographic isolation, and types of exchange. Through the framework provided in this research, an archaeologist can recognize patterns in the archaeological data that reflect and promote social stability, or lead to collapse.

Results based on comparisons between the social networks of the Northern and Southern regions of the Valencian Bronze Age show that the Southern Region's social structure was less stable through time. The Southern Region's social structure consisted

of competing cores of exchange. This type of competition often leads to power imbalances, conflict, and instability. Strong dependencies on the neighboring Argaric during the Early and Middle Bronze Ages and contributed to the Southern Region's inability to maintain social stability after the Argaric collapsed. Furthermore, the Southern Region participated in the exchange of more complex technology—bronze. Complex technologies produce networks with hub and spoke structures highly vulnerable to collapse after the destruction of a hub. The Northern Region's social structure remained structurally cohesive through time, promoting social stability.

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CHAPTER 1

INTRODUCTION AND BACKGROUND

'Stability,' insisted the controller,

'Stability, the primal and ultimate need.

***Stability.* Hence all this.'**

–*Brave New World*, Aldous Huxley (1932)

What causes social systems to resist change? Social systems, broadly defined, are the patterns of relationships of persons or groups. Archaeology has paid particular attention to examining change in political and economic social systems under the rubric of social complexity, looking for material indicators such as monumental architecture and standardization of production that mark a transition to new forms of hierarchization and centralization (Kohring 2012; Alt 2010; Price and Feinman 2010; Trigger 2006; Hayden 2001; Earle 1997; Crumley 1995; Yoffee 1979; Flannery 1972;). However, these studies of the emergence of social complexity in archaeology have focused primarily on drivers of change with much less emphasis on drivers of stability. Often, social stability is implicitly considered the norm, with little need to account for societies that do not change.

Social stability, or the persistence of social systems, is an essential feature without which human society is not possible. It is a quality that falls along a continuum, measurable by quantifying the endurance of social relationships (Patterson 2004). Social stability operates at a macro-individual scale, so while behaviors of individuals within a social system or exogenous environmental factors like climate change are assumed to be unceasingly dynamic, the overall properties of the social structure may remain stable. Archaeological models that address social change commonly assume that societies continue in a state of stability until a driver appears and forces a response (Redman 2005; Tainter 2004; Hayden 2001; Feinman and Neitzel 1984). A more realistic assumption may be that no such thing as a static, natural, or social environment exists in which a social system could be said to operate. Then the focus becomes what are the drivers of stability as well as change, and how do these impact some social systems more than others?

The maintenance of social stability is a challenge that crosscuts all societies, past and present. People require peace, economic security, environmental stability, and the stability of social relationships to survive. Social stability is so vital to a society that members will risk their lives to defend it when threatened. Durkheim (1960) identified social "cohesion" as a significant research topic decades ago. Unfortunately, the topic has fallen into disfavor in recent decades, due to criticisms launched against Durkheimian studies for inadequate accounting of individual agency and societal evolution.

While these criticisms may be fair, they do not negate stability as an essential social fact in the understanding of humanity. Stability is a basic human need, and most societies recognize that it must be actively preserved in the face of constant change. Decisions made in the name of social stability profoundly affect people's lives and the trajectories of societies, thus it is critical to understand it.

Archaeologists are often intrigued by periods of social stability and resistance to change in the trajectory of the past. For example, Rowlands (2005:54) notes several instances in Bronze Age Europe where its societies are characterized by "cyclical trends of evolution and devolution" and are "resistant against the formation of more rigid social differentiation and state formation." These occurrences where societies appear to be tradition-bound should not be hastily judged as backward, regressive, or devolutionary without a full understanding of why and how people preserve traditions. Social change and stability are two sides of the same coin, and without problematizing the processes that govern stability, our explanations will be deficient.

The Valencian Bronze Age (VBA) in eastern Spain is one such case where a social system lasted for nearly 700 years while surrounding regions with similar initial conditions traveled a path of change in social complexity (Figure 1.1). It is situated within broader trends of the European Bronze Age where archaeologists have noted major social transformations in some areas but a peculiar resistance to such processes as urbanization and state formation in others even though “the necessary building blocks were in place” (Kristiansen and Earle 2010). Consequently, the VBA is ideally suited for studying transition points in social complexity and serves as a case study for deciphering the social drivers responsible for social stability.

In addition, while archaeologists, overall, accept the general stability of the VBA, variations in time and space have been noted (see “Evidence for Stability in the Valencian Bronze Age” section for detail) especially leading into the Early Iron Age transition. In these contexts, the degree of stability and which aspects of society are stable have never been quantitatively assessed. This project measures multiple dimensions of the region's social stability spatially and temporally and then compares these measurements to the results of the modeling of social processes. It contributes to a growing body of research on diverse trajectories to social complexity in the ancient Mediterranean.

A general theory of social stability does not exist in archaeology, and there are few archaeological studies that first, try to identify archaeological indicators of social stability and second, capture dynamic processes behind why some societies remain stable. This research tests several hypotheses about drivers of social stability with an explicit focus on a better understanding of contexts and processes that resist change. Rather than looking at the presence or absence of material indicators to measure changes in social complexity, this project presents a new method for accounting for change or lack thereof in social complexity combining quantitative modeling and the comparative archaeological record where the social system is represented by networks of relations between settlements. Material proxies such as tools and adornments made from metal, bone, stone, and ceramics are utilized to infer these networks. This research concludes with a new and vital contribution toward a general theory of social stability in archaeology—a blueprint for the recognition of social stability in the archaeological record and the hypothesis testing of the causes of social stability in prehistoric societies.

Figure 1.1. The Iberian Peninsula with the Valencian Bronze Age region (País Valenciano) and relevant rivers highlighted.

The following sections of Chapter 2 begin with an overview of VBA prehistory contextualized within the context of how each aspect of its prehistory—spatial, cultural, and temporal—plays a role in constituting and reflecting social relationships. Chapter 3 begins with a discussion of the state of theory on social stability in both archaeology and sociology followed by the theory underlying social network analysis and Network Science. A discussion of prior explanations for the social trajectory of the VBA as provided by Iberian archaeologists follows. The theoretical framework employed in this research ends the chapter.

Chapter 4 provides a detailed explanation of the methodology employed in this project, from data collection to variable operationalization, to analysis and modeling. Chapter 5 presents results from exploratory data analysis, followed by results related to chronology building and social network analyses. This research concludes with a general theory of social stability and the four contextual elements that drive social stability based on evidence from the VBA.

CHAPTER 2

REGIONAL BACKGROUND

The Valencian Bronze Age

The Valencian Bronze Age (VBA) (ca. 2200-750 BCE), is an archaeological culture located in Mediterranean Spain geographically spanning approximately 20,000 square kilometers within the País Valenciano, which includes the modern provinces of Valencia, Alicante, Utiel-Requena, and Castellón. Organizationally, the VBA can be classified as small-scale, consisting of numerous small and self-sustaining agricultural villages. It is lesser-known than its Iberian contemporary, the Argaric (ca. 2300-1550 BCE), and other Bronze Age cultures flourishing contemporaneously in the Near East and the regions surrounding the Greek archipelago. Nevertheless, a substantial range of research addressing the VBA exists, going back to the late 1800s. The present discussion is the first English review of the literature of the VBA, with particular emphasis on up-to-date research on social organization.

The VBA is located between the Segura and Vinalopó Rivers in the south, and in the north between the *tierras castellonenses* and the Ebro River (de Pedro Michó and Martí Oliver 2004:299) (see Figure 1.1). During the latter half of the 19th century, the Siret brothers were the first to mention VBA materials (Siret and Siret 1889) who discuss bone tools, ivory and metal objects, tombs with burial goods, and adornments. Later in the 1930s, Furgús (1937) conducted and published results from excavations in the southern part of the province of Valencia, at the sites of San Antón near Orihuela, Spain and Laderas del Castillo near Callosa de Segura, Spain. San Antón and Laderas del Castillo produced an impressive collection of metal objects, bone tools, and ceramics, many of which suggested a perduring connection with the Argaric culture located to the south of the VBA. Early investigators thus interpreted the VBA as an extension of the Argaric culture.

Tarradell (1962) was the first researcher to demonstrate that the VBA is materially distinct from the Argaric culture. Tarradell noted the VBA's material uniformity and posited several, defining characteristics of the VBA: 1) numerous, small sites with rock walls and rectangular rock dwellings; 2) sites located on difficult to access elevated landforms and often fortified; 3) interments of single individuals, but sometimes in twos or threes, in nearby caves; 4) ceramics with little decoration; 5) lithics dominated by sickle blades; 6) rare instances of polished stone tools and the introduction of archers' wrist guards; 9) appearance of bronze halberds. (Martí Oliver and de Pedro Michó 1995; Gil-Mascarell and Aranegui 1981; Tarradell 1965). Additionally, when compared to the Argaric, the VBA tends to have a minimal and less diversified presence of metal objects, globular ceramics, and Argaric "copas" (a chalice-like form) (Jover Maestre and López Padilla 2009; Hernández Pérez 1985).

In the 1970s, Llobregat (1975) suggested an autochthonous origin for the VBA, demonstrating material continuity with previous periods. However, most archaeologists maintained that bronze technology must have come from the Argaric since the Valencian region contains no appropriate metal sources (Jover Maestre and López Padilla 2009; Navarro Mederos 1982). From the 1980s onward, there have been continual revisions to these hypotheses as more and more VBA sites are investigated and radiocarbon dated. Using radiocarbon and material evidence, Martí and Bernabeu (1992) demonstrated that the VBA is chronologically contemporaneous with the Argaric, overturning previous arguments that the VBA was an outgrowth of the more “advanced” Argaric.

Social Geography of the VBA

Despite earlier observations that the VBA is materially homogeneous, social and cultural aspects of the VBA vary in important ways across a quite heterogeneous physical space. However, certain geographic and climatic aspects characterize the region as a whole and are important to understanding VBA social organization. The next paragraphs first discuss the general physical characteristics of the VBA followed by a discussion of important sub-regional differences.

The VBA region is located on the eastern portion of the Iberian Peninsula, the westernmost major peninsula in southern Europe. The Peninsula is surrounded by the Atlantic Ocean to the west and the Mediterranean Sea to the east. The influence of the Atlantic Ocean and the Mediterranean Sea, as well as the Peninsula’s orographic characteristics, divide the region into two watersheds, one draining toward the Atlantic and the other draining to the Mediterranean. The VBA is wholly contained within the Mediterranean watershed. Although the Iberian Peninsula has a dense network of waterways, the Mediterranean watershed is located within one of the driest regions of Spain. Its rivers have low annual volume and irregular flow, especially during the long dry summers, and are subject to flash floods (Benito and Machado 2012). Even under these conditions, waterways within the region of the VBA have served as important natural travel corridors throughout history and prehistory.

The climate in Mediterranean Spain along the coastal plain is characterized by dry and warm to hot summers (22-30 degrees Celsius in July) and cool to mild and wet winters (8-17 degrees Celsius in January). Modern rainfall records indicate that areas in the north may receive a few more days of rain within the year than areas in the south. VBA settlements located in the interior foothills experienced a slightly different climate with lower temperatures on average (23 degrees Celsius in summer) and higher precipitation with more rainy days per year than along the coast. The vegetation within the region during the VBA is typical Mediterranean, with an array of plant varieties found in forested as well as marshy contexts. A paleobotanical study of the site of La Lloma de Betxí indicates that the following plants were present: the common olive (*Olea europaea*), Aleppo pines (*Pinus halepensis*), Holm oaks (*Quercus ilex*), heather (*Erica multiflora*), mastic trees (*Pistacia lentiscus*), plants in the rose family (*Rosaceae sp.*), legumes (*Leguminosae sp.*), and Raywood ash (*Fraxinus oxycarpa*) (de Pedro Michó 1998). To this list can be added palms and esparto grass, which inhabitants commonly used for weaving.

Some Iberian archaeologists attribute differences in social organization and social trajectories to the variable aridity of this region. Gilman (1981) postulated that the climate in the Argaric core was more arid than the climate of the VBA. According to Gilman, a more arid climate increases the competition for good land and increases the pace of agro-technological intensification. Competition spurs complexity, in other words. However, Chapman (2008:202) counters this by saying, “Our knowledge of the water and nutritional requirements of the exploited plants and animals, suggest that agricultural production was not as ‘risky’ as has been argued, nor did it require capital investment to reduce such risks in a so-called marginal environment.”

de Pedro Michó (1998) notes that the vegetation present during the Bronze Age is not representative of an arid climate but reflects a healthy vegetation cover in nearby river systems. The soils and climate were good enough for VBA people to grow most cereal crops employing dry farming, requiring land clearance and terracing. Thus, the species present today that grow in arid and eroded environments may be a product of some of the land modifications begun during the Bronze Age. For example, holm oaks common in this region tend to succeed Aleppo pines under a regime of agricultural intensification, and Barrachina (2012) believes this transformation occurred during the Late Bronze Age.

It is not clear whether or not the differences between the Argaric and the VBA are related to differences in their respective environments. It is interesting to note that similar diachronic changes to the settlements patterns of both the VBA and in the Argaric region occur during the Chalcolithic to Bronze Age Transition. Chalcolithic settlements were abandoned or remodeled into elevated and terraced sites with intensified farming (Chapman 2008). This change in the agricultural organization is pan-regional, thus micro-climatic, sub-regional differences appear to have little influence on settlement strategy. Something else overrode these micro-climatic differences and remade societies of the Southeast Iberian Peninsula.

The mountain ranges of the VBA region were consequential to the organization of social space and social exchange. The central portion of the Iberian Peninsula is dominated by a large plateau often referred to as the *Meseta Central*. Several mountain chains border the *Meseta*. The two mountain ranges relevant to this research are the *Sistema Ibérico* to the northeast, and in the southeast, the *Cordilleras Béticas*, running parallel to the coast. The *Cordilleras Béticas* are more fragmented and thus less of a physical barrier than other mountain ranges on the Iberian Peninsula such as the Pyrenees (Gibbons and Moreno 2002; Simón García 1998).

The mountain ranges of the *Sistema Ibérico* are important to the organization of the Northern regions of the VBA. In the north, there are important east-west river corridors, namely the Turia near modern Valencia and the Palancia near modern Sagunto, that extend to the low-lying mountain ranges of the *Sistema Ibérico*. The geography as one moves inland from the Mediterranean is a coastal plain (Figure 2.1) characterized by gradual undulations and loamy clay soil overlain by lacustrine limestone (de Pedro Michó 1998). The ranges of *La Serra Calderona* and *La Serra d'Espada* run in parallel to each other from the Mediterranean coast inland toward modern Aragon and surround the valley of the Palancia River. The two ranges create a significant geographic barrier with elevations at times reaching over 1000 meters.

The Palancia River corridor and its two surrounding mountain ranges make up an axis crosscut by small lateral valleys. Several important Northern VBA sites are located strategically on hills that control these lateral valleys, including the sites of Pico Nabo and Peña de la Dueña. While communications within the Palancia River corridor and its lateral tributaries appear to have been relatively easy, the mountain ranges inhibited north-south communication with the rest of the VBA. Instead, communication ran east-west, between the coast and Aragon, a region with significant mineral resources (Simón García 1998).

The Southern VBA is located within the *Cordilleras Béticas*, mountain ranges that extend from the Gulf of Cadíz to modern Alicante, running SW-NE. Geologists divide this geologic feature into two zones separated by the *surco intrabético*, a long fossa or depression. The *Cordilleras Béticas* are important to human habitation, providing fertile valleys for agriculture, access routes from Andalusia to Alicante, and ridges and hilltops along the *surco intrabético* for Bronze Age settlements (Gibbons and Moreno 2002; Simón García 1998). The inland, mountainous terrain is ideal for agro-pastoralism, as the site of Cabezo Redondo near modern-day Villena, Spain demonstrates. While the lands along the site's immediate margins are practically sterile today, residents at Cabezo Redondo could rely upon high-quality lands located less than a kilometer away and a nearby lake and a natural spring for water (Hernández Pérez et al. 2016:18).

The Vinalopó River and Segura River are the two important river corridors in the Southern Region of the VBA. The Vinalopó River corridor traverses the south and central parts of the province and connects the coast to the inland areas. The Segura River runs east-west along the southern coastal plain toward the mountains of the *Sistema Penibetico* and the *Meseta Central* (see Figure 1.1 for locations of rivers). The Segura River forms a depression extending from the coast and in the middle of this flat plain, mountains emerge near modern Orihuela, *las sierras de Orihuela* and *Callosa*. The mountains contain Triassic materials including limestone and slate, but also flint, copper, gold, iron, and mercury. Several important sites from the Southern VBA are located near this area including San Antón, Laderas del Castillo, Cueva de San Antonio de Padua, las Espeñetas, and Cabezo Pardo. The people at these sites exploited the rich minerals as well as a strategic position along the Segura River.

Figure 2.1. View of coastal plain looking toward the Mediterranean Sea from the northern site of Tossal de San Miquel near modern-day Llíria, Spain.

Chronology and Temporality

The material uniformity of the VBA has resulted in a lively discussion over how to chronologically divide the VBA (Hernández Pérez 1985; Navarro Mederos 1982; Enguix 1980; Aparicio 1976; Gusi 1975). Archaeologists now ascribe the cultural uniformity noted for the VBA to the Early and Middle VBA, a span that covers the 700 years between 2200-1500 BCE. The most recent studies show that the first VBA sites were an outgrowth of Bell Beaker cultures from the end of the Chalcolithic period. Several prominent VBA sites contain ceramics with Bell Beaker motifs and forms, marking a transition period between the Chalcolithic and Bronze Age.

Recently a group of 111 population geneticists and archaeologists sequenced the genomes of 271 ancient Iberians of which 47 are Calcolithic and 53 are Bronze Age and merged this with data from 1,100 other ancient remains and 2,862 present-day individuals (Olalde et al. 2019). Beginning during the transition period leading into the Early Bronze Age (ca. 2200 BCE), the gene pool changed dramatically with an influx of genes associated with the steppes near the Caspian and Black Seas. In fact, by 2000 BCE, about 40% of the local gene pool was supplanted, and the migrations almost entirely replaced the Y chromosomes of the local inhabitants. The researchers note that the archaeological evidence suggests that the replacement was not violent and posit that the steppe migrants eventually just genetically overwhelmed the smaller local population.

The steppe migrants likely brought bronze technology, including weaponry, to the Iberian Peninsula and were probably riding horses. The authors speculate that these characteristics conferred higher social status on males enforcing a patriarchal line of inheritance. These individuals would have higher reproductive success in replacing the local population (Olalde et al. 2019).

It is not entirely clear yet, what additional effects these migrations had on social organization. The archaeological sequence of the Valencian region is unique on the Iberian Peninsula, and researchers have conducted several studies on the origins of the VBA and its predecessor, the Chalcolithic. The Chalcolithic consists of a pre-Bell Beaker period and is followed by a transitional Bell Beaker period, known in Valencia as *el Horizonte Campaniforme de Transición a la Edad del Bronce* (HCT) (2600-2100 BCE) (García Borja 2008; Bernabeu 1984).

Archaeologists note that during the HCT transition, elements of the Chalcolithic continue to influence the development of the VBA. It is during the HCT that the steppe migrations occur. However, during his discussion of the origins of the VBA, Bernabeu

(1984) demonstrates that changes during the HCT coincide with the beginning phases of the Argaric. Interestingly, the transition from the Chalcolithic to the Argaric in the Southeast seems to have been rather quick, taking place over a few years. Argaric cylindrical beakers with high carinations, silver adornments, and ‘Palmela’ points appear in early sites in the VBA South near modern-day Orihuela. The Argaric may have inspired aspects of the VBA, but the coincidental beginnings of both cultures are not sufficient to explain the origins of the VBA and leads to a “turtles all the way down” dilemma. What caused the development of the Argaric? Is there a root cause for all of the HCT?

Most archaeological sites are located on medium elevation hilltops (200-600 meters above sea level.) The possibility that the introduction of bronze technology caused the settlement shift to hilltops is intriguing, but bronze and bronze technology are relatively scarce finds on VBA sites, indicating a low level of production. Technologies used in the making of bronze such as ovens, molds, and crucibles exist in low quantities and are not differentiated from domestic contexts. Maybe more striking is the fact that copper artifacts appear during the HCT and continue to outnumber bronze artifacts throughout the Early Bronze Age (Gonzalez-Blanco et al. 2018; Simón García1998). Access to copper and the knowledge of production expands during the HCT but this expansion could be a symptom of other drivers rather than a cause of the HCT.

The analysis of the cause of the HCT is a heady and multi-faceted endeavor. Until approximately 2400 BCE, Chalcolithic populations maintained a pan-regional suite of cultural, mortuary, and subsistence practices. During the HCT, societies near the Ebro River in Catalonia continued these same traditions while societies of the VBA reorganized. Through a summed radiocarbon date analysis, Blanco-González et al. (2018) conclude that this period coincides with a statistically significant increase in settlements between 2000 and 1600 BCE. There was a general movement of the population toward aggregation on hilltops. However, Iberian researchers note that this movement did not include accompanying evidence for the formation of social or site hierarchies.

Bernabeu (1984) and Martí (1983) propose two possible causes for the transition: 1) the pressure of population increase and 2) the inability of agriculture technology to keep up with increasing population thus forcing people to settle in previously unsettled areas such as hilltops. An early Bronze Age population boost is reported for all Mediterranean regions, except France (Weinelt et al. 2015). Blanco-Gonzalez et al. (2018) through a recent pan-regional analysis of environmental, material, demographic, and radiocarbon data discuss the 4.2 ky BP event as a possible cause for the transition to the Bronze Age and coincident demographic changes. The 4.2 ky BP event is a climate change event that generally resulted in colder and drier conditions in some areas. However, the coastal areas along the Mediterranean were less affected than more mountainous areas. Mountainous areas saw the expansion of evergreen forests and the intensification of pastoral activities. High charcoal concentrations indicate an increase in the clearance of forests during the 4.2 ky BP event, "undoubtedly related to human pressure and dry conditions" (Blanco-Gonzalez et al. 2018:36).

Other changes occurred during the HCT but not in a regionally homogenous fashion. Iberian researchers (Jover Maestre and López Padilla 1997; Hernández Pérez 1997; Jover Maestre and López Padilla 1995) argue for the existence of a frontier zone between Argaric and non-Argaric influenced VBA societies. Although the geographic boundaries of this frontier zone have not been fully resolved, in general, the zone consists of the Segura River corridor and the coastal areas of the Camp d'Alicant (de Pedro Michó 2010). With some exceptions, burials north of the frontier zone shift to individual or double burials located outside of the village in caves or bedrock fissures. Burials south of the frontier zone resemble Argaric burials in cists and within settlements.

This situation seems to demand a strict cultural division between Argaric and non-Argaric groups, and evidence within the frontier zone partially supports this interpretation. Argaric and non-Argaric groups co-existed within the frontier zone while maintaining their cultural distinctiveness and specific burial rituals. However, the division did not preclude interrelation between the zones and the sharing of ideas and material culture. The northern and southern VBAs have much in common, but the maintenance of differing burial traditions indicates that the south and north did not share the same exposure to the same spheres of influence. Additionally, it seems clear that some groups actively resisted influence from outsiders, maintaining traditions similar to those in the north. This difference is important to understanding the VBA's social stability and later chapters will return to this topic.

The transitional changes during the HCT did not affect all areas of the VBA equally, and the entire portrait of their influence is still unclear. We can say that introduction of bronze occurs, steppe males replace the local male population, decoration on pottery decreases, transitioning away from Bell Beaker styles, and sites tend to aggregate. Some change in burial rites also occurs with a shift toward individual burials in the northern areas of the VBA, but with no coeval change in burial goods. There is a reduction in the diversity of the lithic industry, an increase in polished stone archers' braces, the significant presence of ‘V’ perforated buttons, and an increase in copper items. Additionally, we can add that the peoples of the Early and Middle VBA were not operating in cultural isolation. Besides the genetic evidence cited earlier, archaeological evidence in the form of elephant ivory demonstrates that some degree of contact between the Iberian Peninsula and North Africa during the Chalcolithic and Bronze Ages (Olalde et al. 2019; Schuhmacher et al. 2009). Evidence from the Chalcolithic in Southeast Iberia also shows that people participated in exchanges for flint from distant sources in the Subbetic Mountains (Blanco-González et al. 2018).

It is also of note that compared to the HCT transition in other areas of Iberia, the VBA peoples along the Mediterranean coast tended to maintain their Neolithic traditions (Bernabeu and Orozco 2014). As Blanco-González et al. (2018:57) state, “These [communities] may be envisaged as more resilient or stable groups. However, these communities were not isolated; they participated in widespread exchange networks, were permeable to trans-Pyrenean cultural traditions and adopted some isolated technological improvements. However, their material culture and lifestyles did not transform abruptly…Shifts in social practices seemed to have pursued smooth pathways, which are elusive to archaeological tracking.” It appears that many fundamental aspects of the local culture persisted in the face of new cultural exposures, and it is the goal of this research to develop a theory as to why.

The Late Bronze Age (1500-1100 BCE) is marked by a change in most of the archaeological features noted above and others (i.e., new ceramic styles, new technologies, increasing site elevations, the spread of bronze technology, techno-economic changes from agriculture to livestock).

By the Late Bronze, VBA peoples were experiencing several external pressures, reviewed here. The first of these is the Late Bronze Age Collapse occurring between 1200 and 1150 BCE, a sudden disruption of the economy and trade routes of the Near East and the Eastern Mediterranean (Cline 2014). While the Iberian Peninsula did not directly participate in this economy, it is reasonable to argue that the collapse was responsible for several "shatter zones," a term used by Ethridge (2009) and others to describe the waves of destabilization in Native American communities caused by European contact. The first Europeans in North America destabilized the contacted societies, but they also inadvertently created a ripple effect of disruption to societies that had never even seen a European and would not for a century.

The timing of the Late Bronze Age Collapse is in line with several changes occurring on the Iberian Peninsula. The steppe migrations just mentioned in the previous section began before the collapse. It is possible that the effects of the migrations from Central Europe toward the Iberian Peninsula relate to the later collapse. By the Final Bronze Age, we see the appearance of the Urnfield Culture near the modern-day city of Sagunto, Spain, an Indo-European material culture characterized by inhumation in cremated remains urns buried in fields (Barrachina 2012; Ruiz Zapatero 1978; Arteaga 1976).

Additionally, the material culture of the Northern and later the Southern VBA exhibits an increased presence of Cogotas I materials, whose origins are in the Central Meseta of Spain (Barrachina 2012; Rodríguez Marcos 2012; Abarquero 2005; Picazo Millán 1993; Molina and Arteaga 1976). While not enough work has been done to support the hypothesis, the possibility exists that the peoples of the Central Meseta were migrating in response to pressures from migrations coming from beyond the Pyrenees Mountains.

By the Final Bronze, the material evidence attests contact with the Phoenicians and Greeks from the Eastern Mediterranean (Hernández Pérez 2001; Lerma 1981). The Phoenicians rose in power due to the decline of the Mycaeneans during the Late Bronze Age collapse. They founded their first colonies on the Iberian Peninsula in the 10th or 9th century BCE near modern Cádiz and areas along the Southern coast of Spain. Greek contact may have begun during the 9th century BCE, but the commercial trading post of Emporio was not established until ca. 600 BCE.

The Phoenicians brought iron and iron technology to the VBA as indicated by the piece of iron cached in the Tesoro de Villena. They also introduced the wheel and writing. They also fundamentally transformed the exchange patterns of the area in their quest for metals such as tin and other natural resources. Many Iberian researchers suspect that the aggregation of sites at higher elevations near the end of the VBA Bronze Age is due to the reorganization of polities along trade routes servicing the new Phoenician and Greek traders (Martí and de Pedro Michó 1997).

At approximately 1550 BCE, the Argaric culture collapsed (Lull et al., 2013). The collapse occurs before the accepted dates for the Late Bronze Age Collapse and may not be related to these events. Lull et al. (2013) make a convincing argument that agricultural intensification due to site centralization and social stratification of the Argaric core robbed the land of its nutrients and eventually led to the Argaric collapse. The authors believe that the collapse was violent; the Argaric is famous for its adoption of bronze halberds, weapons of war that must have conferred significant advantages on groups who had them (Figure 2.2). Inhabitants abandoned sites and reorganized both architecturally and around new burial rites.

The reasons for the collapse are fascinating but out of the scope of this current research. As already mentioned, sites in the Southern Region of the VBA show evidence of close ties to the Argaric culture with resemblances in burial rights, particular ceramics, especially in the exchange of bronze. The effects of the Argaric collapse would have rippled through the VBA trough interruptions in cultural and material exchanges.

All of these exogenous challenges contributed to a crisis point that both the Northern and Southern VBA had to face in differing degrees beginning at approximately 1550 BCE. As a result, the VBA is a perfect fishbowl for the investigation of the role that fundamental differences in social structures play in response to crises. In other words, how do structures of relationships maintain social stability, and how effective are they in crisis?

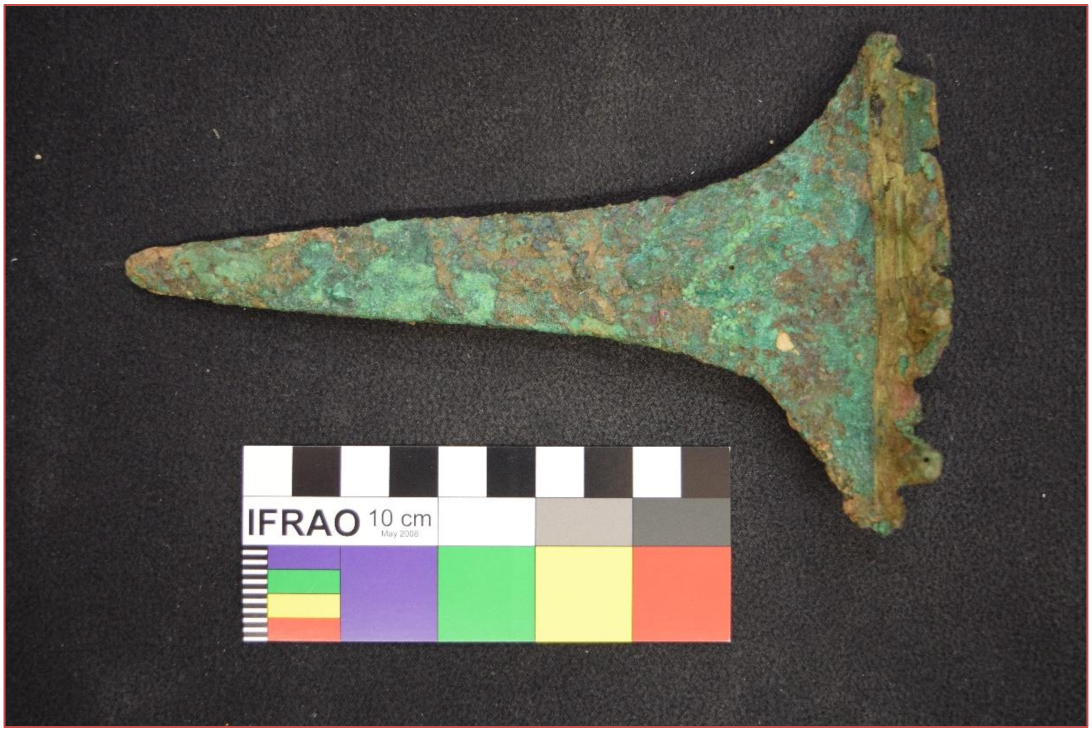


Figure 2.2. Example of a bronze halberd from the site of Laderas del Castillo or San Antón.

Life in the Valencian Bronze Age

This research takes an explicitly regional perspective, encompassing information from over 200 VBA sites from across the region. This type of approach is less common in Spanish archaeology, where research tends to be focused on individual sites and how conclusions can be scaled up to understand the VBA as a whole. As a result, conclusions that characterize the social life of the entire region are scant. Much of the discussion below is derived from site-level studies but with the critical stance that this type of generalizing is problematic. The discussion begins by critically evaluating the current, regional-scale research on the VBA and the social aspects that contextualize the current project.

Social organization

Evidence for this topic is limited due to the ambiguity of the archaeological record and relative lack of regional-scale studies. The VBA is a prehistoric culture; writing developed in the Iron Age after contact with the Phoenicians. Still, we can derive some characterizing statements with confidence.

Iberian archaeologists suggest that VBA societies may have been organized as tribal societies or as segmentary societies (small, autonomous groups usually of agriculturalists) (de Pedro and Martí 2004; Brodsky et al . 2013). Generally, VBA settlements consisted of small clay-walled dwellings, typically having two to four rooms each and with two to ten dwellings per settlement. The settlements may have housed five to 20 close families of agro-pastoralists. Since settlements are small, the inhabitants may have been related kin, although archaeological evidence to confirm this is lacking. However, recent investigations demonstrate that the nature of VBA settlements evolved through time (Jover Maestre et al. 2018). The earliest settlements consisted of large clay-walled structures with a few partitions separating activity areas. By 1800 to 1750 BCE, settlements demonstrate broad changes that suggest urban planning. These changes include the construction of small, attached habitations distributed along both sides of a central corridor. In addition to changes in urban planning, excavations have revealed that newer settlements tend to have ceramic storage vessels with greater volume and an increase in agricultural and grain processing implements.

VBA settlements typically are located on hilltops, although some are found in the plains. VBA peoples did not settle on the highest hilltops but instead chose elevations ranging between 200 and 600 meters. Nearby caves were used for burials but also possibly in a temporary way for pastoralism. Traditional interpretations like that of Tarradell suggest that these settlements were fortified and located on hilltops for defense. However, current research on this topic suggests that defense is not the exclusive reason.

In one of the few synthetic/regional studies of social organization available for the VBA, Jover Maestre and López Padilla (2005) used Theissen polygons and site size to understand land use patterns surrounding modern-day Villena, Spain. The authors note that through time, a distinct settlement pattern emerges where several smaller sites group around one or two larger sites. Larger sites are those with areas between 0.1 and 0.3 hectares. These sites are located not more than six to seven kilometers apart, interspersed with smaller settlements. Jover Maestre et al. (2018) updated these conclusions concerning the settlement organization of the region surrounding Villena. For the period between 2200/2150 BCE and 1500/1450 BCE, the settlement organization consists of three groupings. Groups 1 and 2 are the large settlements mentioned above that constitute ‘nuclei’ settlements (Jover Maestre et al. 2018:107). These larger settlements make up 15% of all settlements and have sequences of prolonged occupation (upwards of 600 to 700 years) often with several construction episodes.

Group 3 consists of small settlements of less than 300 m^2 and shorter spans of occupation. The typical occupation duration for small settlements throughout the VBA region may have been between 200 and 300 years (Bernabeu, email message to author, December 11, 2019). The function of the smaller sites is still unknown. However, Iberian archaeologists suggest that the more numerous smaller sites served a complementary role to the productive management of the larger sites (Jover Maestre et al. 2018). The limited number of people who would have occupied these small sites would still need to maintain relationships with larger nuclei sites for resources and exchange of mates. The larger sites contain evidence of scaled-up food production in the form of large terraces, cisterns, and silos as well as metal and ivory object production.

The social interactions between large and small sites do not indicate arrangement designed for defense. The elevations of most VBA sites are not especially intimidating. Instead, the evidence suggests that VBA peoples considered access to and control of natural resources and ease of communication. People at the largest sites took advantage of their landscape by locating on low hills that could visibly command up to two hectares for the production of cereal grains and pasturing of animals in nearby forested areas. In the region of Villena, the larger sites are situated near lakes and would have been able to control enough good farming land to maintain self-sufficiency for a small, pueblo-like community (Jover Maestre et al. 2016). de Pedro Michó (1998), from her research at the Northern site of La Lloma de Betxí, also speculates that the choice of elevated location may have been for visibility and control of farming/pasture lands (Figure 2.3). There are at least 800 known VBA sites, and many of them are easily visible to one another.

Little evidence exists for interpersonal violence, although some artifacts exist that could be classified as weapons (daggers, points, halberds) and some sites show evidence of burning (Barciela González et al. 2012). The majority of artifacts and settlements reflect use in agricultural or domestic contexts. Based on the lack of material evidence for specialized production at the site of La Lloma de Betxí, de Pedro Michó (1998) concludes that the society was not hierarchical during the Early and Middle Bronze Ages. Evidence from Villena shows the gradual development of organized enclaves for the facilitation of communication. These enclaves lacked labor specialization or "chiefs," resembling a tribal society. At the site of Terlinques, a large food processing room, as well as terraced lands constructed from large stone blocks, suggest the organization of labor for public benefit (Jover Maestre and López Padilla 2009). However, evidence for social differentiation in the Early and Middle VBAs, such as differentiation in burial treatment, is absent.

Jover Maestre and López Padilla's (2009) study of the frontier zone, outlines a "historical process" of social organization for the area surrounding Villena. Settlements near Villena operated between the Argaric zone of influence and the more northern, upper reaches of the Vinalopó River. The authors suggest that both the need for agricultural intensification to feed increasing populations as well as Argaric influence during the Early and Middle VBA's encouraged territorial organization and consolidated social dependencies. In particular, greater territorial organization may have been necessary to facilitate the exchange of metals originating from the Argaric. By the Middle

VBA, the social organization consisting of one large site associated with several small sites was established. Furthermore, the division of internal spaces within habitations increases alongside the dedication of spaces to grain storage and metal production.

At the beginning of the Late VBA, the social organization near Villena changes once again, in all probability, due to the collapse of the Argaric. The number of sites decreases, the distance between sites increases, and the location of sites appears to be determined by not only good agricultural land but also for control of travel corridors. The number and variety of materials (copper, tin, amber, pasta vitrea, and ivory) at VBA sites increase at this time, indicating a broadening of exchange on a macroregional scale (Jover Maestre and López Padilla 2009). The rise of sites like Cabezo Redondo with large caches and burials with gold and silver indicates a shift toward centralization. In fact, the centralization of Cabezo Redondo may be a direct result of the migration of ideas about hierarchical social organization piggybacking with the migration of Argaric peoples after the collapse.

Figure 2.3. View from the northern site of Tossal de San Miquel.

While the studies cited above utilize some regional data, it is important to remember that existing conclusions about the VBA tend to derive from site-level studies that may ignore regional variation. Social organizational patterns in Villena or La Lloma de Betxí in the North may not apply to all of the VBA. This project's unprecedented regional synthesis of social structure is critical for understanding the macroregional social scale to contextualize microscale differences between North and South.

Subsistence organization

VBA subsistence was agropastoral and self-sustaining at the community level. These were small communities, possibly 20 people or a couple of families. Traditionally, Iberian researchers thought that VBA peoples relied exclusively on dry farming of cereals. However, new isotope evidence from the site of Terlinques indicates some of the earliest uses of irrigation techniques in Europe (Mora-González et al. 2016). VBA peoples also actively terraced the low hills on which they located their habitations. Cereal remains at VBA sites include varieties of Triticum/durum wheat alongside leguminous plants such as lentils. Additionally, acorns are common, possibly as a dietary supplement or to feed livestock. We know that processing and consumption of cereal grains was a significant aspect of VBA life, evidenced by groundstone implements (i.e., *molinos* and *manos*), large storage vessels, high incidences of dental caries in human remains, and osteological wear and tear along the clavicle from grinding grain (Polo Cerdá and Casabó i Bernad 2004).Additionally, one of the hallmarks of the VBA is the high incidence of *dientes de hoz* or flint sickle blades for cutting cereal crops. Flint tools are mostly absent from Bronze Age sites, except for these blades. Excavations at Pic dels Corbs provide an exemplar of the region's agricultural production. Wheat (*Triticum aestivum-durum*), barley (*Hordeum vulgare*), *Cerealia sp*., and broad beans (*Vicia faba L.*) are documented along with groundstone and *dientes de hoz* (Barrachina 2012).

The variety of crops grown in the VBA diversified during the Final Bronze Age, possibly another reflection of the macroregional expansion of exchange relationships and the aggregation of populations. At this point, evidence suggests the cultivation of green peas, fava beans, flax, and short cycle cereals, including barley.

Generally, people of the VBA relied on domesticated animals more than wild animals. For example, at the site of Peña de Sax located in the Vinalopó valley, 82.1% of the faunal remains excavated were from domestic animals. Of the domestic animals, 48.2% were goats and sheep, followed by cattle at 20%. VBA peoples pastured goats, sheep, and cattle for meat and secondary products (Puigcerver Hurtado and López Padilla

2005). Besides these, they also kept horses and pigs. At some sites such as Barranco Tuerto, pig remains outnumbered cattle remains, yet sheep and goats still heavily dominate all assemblages.

Interestingly, the evidence for the use of the horse other than for consumption is scant and does not occur before the second millennium BCE. The introduction of the horse as a beast of burden and for travel must have had a significant impact on the pattern of exchange relationships, i.e. broadening social interchange over larger territories. However, this impact has not been quantified for the VBA. VBA peoples also kept domesticated dogs in small numbers. At Peña de Sax, dog remains comprised 0.8% of the faunal remains. Even though the evidence suggests that people did consume dogs, dogs may have been more critical for herding and hunting or as scavengers of waste; tooth marks pock the faunal remains at Peña de Sax.

VBA peoples relied on some wild game, the most important being deer and rabbits. Wild animals present at the site of Pic dels Corbs in order of frequency include red deer (*Cervus elaphus*), the European rabbit (*Orctolagus cuniculus*), a variety of wild cats, wild boar (*Sus scrofa*), and brown bear (*Ursus arctos*). Pic del Corbs has a long occupation beginning in the Middle VBA and ending in the Final Bronze Age. In contrast to the site of Peña de Sax, roughly 40% of the faunal remains throughout the occupation span of Pic dels Corbs are wild (Barrachina 2012). At La Lloma de Betxí along the Turia River, wild animals include rabbits, deer, foxes, numerous species of birds and fish, reptiles, rodents and wild boars (de Pedro Michó 1998). Interestingly, evidence for the exploitation of sea resources is scarce, mainly mollusks for adornment.

If we turn to a comparative study of sheep and goat production only, most sites favor sheep over goats (Puigcerver Hurtado and López Padilla 2005). Age-at-death patterns of faunal remains of sheep and goats attest to herd management strategies. Sheep and goats tended to be slaughtered at young ages, a mortality pattern arguing for an emphasis on secondary products like cheese, yogurt, and milk. *Queseras*, or ceramic cheese strainers, are standard on VBA sites. The presence of spindle whorls in some sites and a skein of wool thread at the site of Terlinques demonstrate textile production from sheep (Jover Maestre et al. 2001). However, evidence for textile production is scarce in comparison to the later Iberian Age, where spindle whorls are common (Antón Peset 2018). Therefore, production was probably limited to the community level.

In sum, agropastoralism was fundamental to the way VBA peoples organized themselves on the landscape and integral to the organization of social relationships between these communities. Settlements operated near other each within visible range, suggesting active communication between sites. However, sites were located just far enough away from each other for control of enough land to sustain 5 to 20 families with cereal farming and livestock (Jover Maestre and López Padilla 2009; Pérez Botí 2004). One can imagine the coexistence of both defensive and cooperative relationships with immediate neighbors.

Burial practices and social life

Although not central to the current project, studies of burial practices can extend our understanding of social life in the VBA. Generally, burials in the Early to Middle VBA are individual or double inhumations, often without grave goods, in caves or bedrock fissures located near villages. Customarily, archaeologists contrast these patterns with burial practices of the preceding Chalcolithic and the contemporaneous Argaric. Burials in the Chalcolithic are of multiple individuals in caves or bedrock fissures with a notable presence of grave goods. Argaric burials occur in multiples within the zone of habitation, in cists, pits, and urns. This difference in funerary practices has been used to distinguish between Argaric sites and VBA sites (de Pedro Michó 2010).

Burials across the Northern Region of the VBA contain similar types of grave goods and usually in small numbers, implying the exchange of a shared idea of a "proper" burial. The site of Muntanya Assolada contains a typical set of grave goods—a white flint point; 126 discoidal beads for a necklace, a necklace with tubular beads, a rectangular limestone pendant, a bone button with a V-shaped perforation, 15 perforated shells, some undecorated ceramic fragments, and various faunal remains. Figure 2.4 is an example of a typical set of perforated shells found at VBA sites. This set is from Laderas del Castillo or San Antón. Figure 2.5 is a set of stone discoidal beads from the Northern site of Els Germanells.

Figure 2.4. Set of perforated shells from the site of Laderas del Castillo or San Antón.

Figure 2.5. Set of stone discoidal beads from the site of Els Germanells.

Recent investigations reveal that the situation is more complicated in that burial practices across the VBA are quite mixed. In a 2010 review of burial practices and osteological data, de Pedro Michó concludes that burials do occur in multiples in the VBA and some have grave goods. Many of these "anomalous" burials occur along the frontier between the VBA and the zone of Argaric influence, suggesting a mixing of cultural practices. However, a burial with ten individuals is located near the site of Pic dels Corbs located well north of the Turia River near modern-day Sagunto, Spain. Furthermore, burials in cists occur within the Northern Region of the VBA.

Burials at the site of Cabezo Redondo near modern Villena, Spain offer insight into funerary practices within the cultural frontier zone and provide some of the clearest evidence of active resistance to change. At Cabezo Redondo, we see two burial practices combined, burials within caves but also burials under house floors in masonry cists and infant burials in ceramic urns. Some individuals have no grave goods while others have a few gold, silver, or shell adornments and double-bowled ceramic “gemini" vessels. This variability suggests differentiation among individuals in the form of unequal access to types of funerary containers and other grave goods, a practice seen in the Argaric core (Many Argaric tombs are rich in grave goods of gold, silver, and weapons, ceramic vessels made exclusively for burial, and food offerings likely for community feasting (Aranda and Esquival 2007). However, other Argaric burials have no goods, and still other individuals do not even merit burial.) Thus, two societies co-existed along this frontier zone and despite Argaric influence, one society actively retained much of its cultural traditions, economic practices, and ideologies.

Material Culture and Social Interaction

The production and exchange of materials play an important role in the structuring of social relationships and this research employs material exchange as a proxy for social relationships. For these reasons, the most prevalent material categories composing the archaeological record of the VBA are discussed in the following sections, beginning with the most important metals—copper, bronze, silver, and gold.

Copper

Copper is the primary metal in use during the VBA, based on frequency in the archaeological record. The same types of objects produced in bronze also are made in copper, including axes, punches, chisels, points, and adornments. These objects are found in small numbers and often in burial contexts. Copper is malleable and ductile and can be used in its native form or in combination with other materials. Most of the copper artifacts found in the VBA are thought to originate from local sources.

Copper metallurgy begins in the preceding Chalcolithic during the third millennium BCE and continues throughout the Bronze Age. The frequency of copper objects decreases through time, as bronze increases (Simón García 1998). Arsenical copper, which contains up to 0.5% arsenic, is dominant during the Chalcolithic in Iberia (Escanilla Artigas et al. 2016). When additional amounts of arsenic are added, arsenical copper becomes arsenical bronze, a material that can be hardened more than copper alone.

Bronze

The introduction of bronze is a significant technological advance, but how important was it to the pan-regional organization of the VBA? The picture surrounding the trade in metals and production processes in the VBA is murky, producing often contradictory conclusions. The geographical origin of bronze technology in Iberia is debatable, and the evidence controverts a local origin (Simón García 1998). Recent genetic evidence indicates that steppe peoples migrating from regions near the Caspian and Black Seas starting at 2500 BCE may have been the source of bronze technology on the Iberian Peninsula (Olalde et al. 2019). While bronze technology was adopted during the Early Bronze Age (ca. 2200 BCE) (Simón García 1998), finds of bronze and associated production tools are scarce, especially in the earliest portion of the VBA.

Figure 2.6 displays the nearest known locations of copper sources. Note the concentration of copper sources in three zones—*la Sierra de Orihuela* near the Segura River in the South, *la Sierra de Espadan y Calderona* near the Palancia River in the North, and *el Valle de Ayora y Requena* in the central interior. Archaeologists consider *la Sierra de Orihuela* to be an important source due to its proximity to Argaric communities. Some have theorized that metalsmithing must have spread from the more mineral-rich Argaric region to the rest of VBA territory. In other words, the Argaric region possessed the appropriate metal sources while the VBA did not, therefore, the technology must have spread from the Argaric region. The pattern of the earliest adoption of bronze technology in geographically southern locations at the sites of Serra Grossa and Terlinques supports this hypothesis. This hypothesis is not yet fully substantiated for a variety of reasons. Early excavations often attributed metal finds to the Argaric, and now provenance is lost. Other local copper sources may have existed but are unknown today, and chemical analyses of copper have not produced a geographical source to date (Simón García 1998).

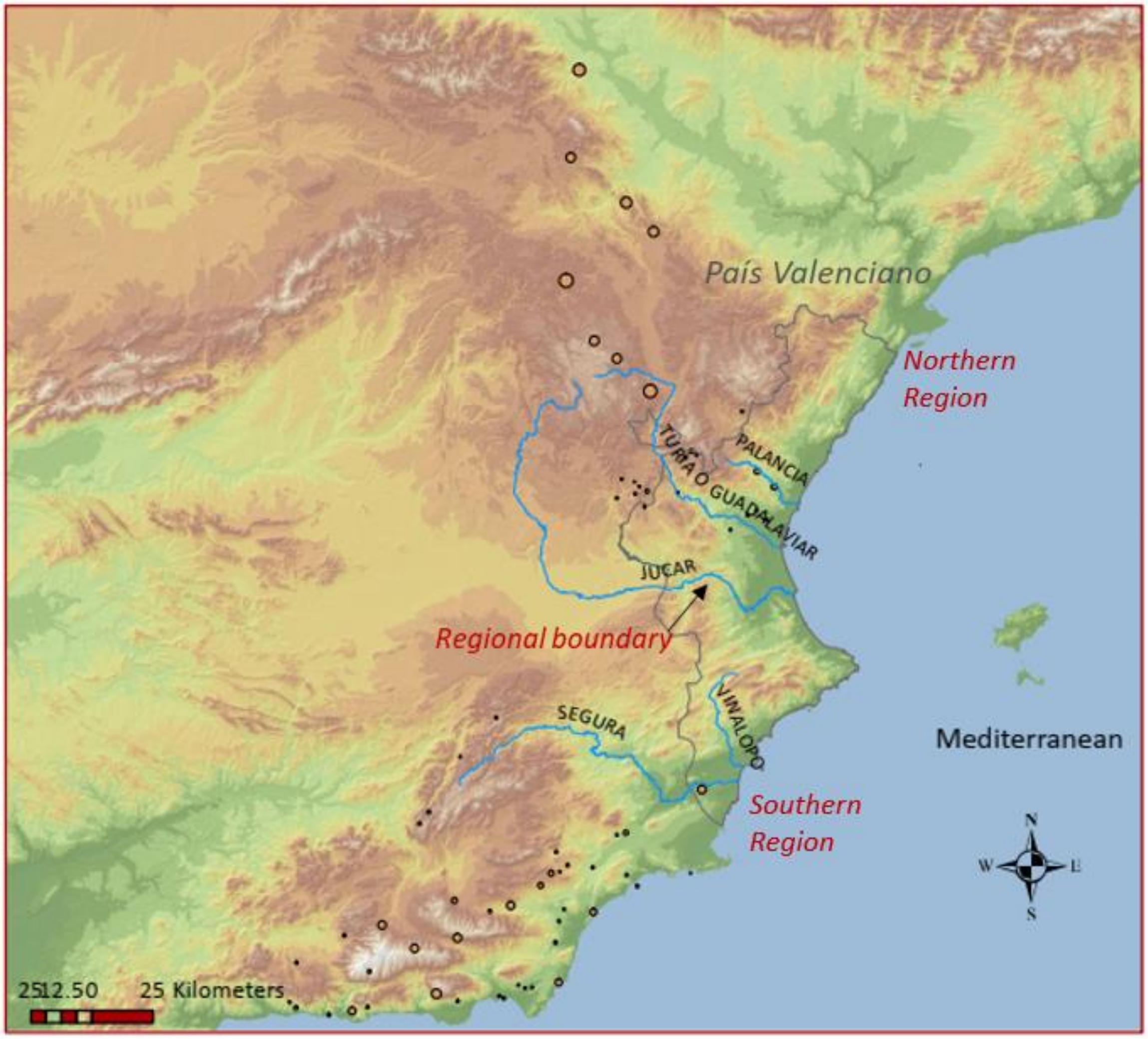


Figure 2.6. Map of nearest copper sources (copper-colored circles) to the VBA. Note the virtual absence of sources in the study region (País Valenciano). (source: *http://info.igme.es/cartografiadigital/tematica/Metalogenetico1500Elemento.aspx?Id=Cobre&language=es*).

VBA peoples used crucible-based methods to extract minerals from their metal ores, in contrast to the furnace-based techniques used in the Near East (Farci et al. 2017) (Figure 2.7). The melted ore was poured into stone molds to produce a variety of tools and weapons, including swords, daggers, halberds, and punches. The evidence concerning VBA bronze production and social exchange is difficult to interpret. For one, we do not know if bronze production was limited to the site level. Stone molds are scattered throughout the VBA leading to the conclusion, that each site produced its own bronze and had its own craftsperson or peoples. However, the level of bronze production is low and monotonic. All of the molds, except one, are of one morphological type—the monovalve—even though other types may have been available. (Archaeologists have found two other types in neighboring regions in Iberia) (Vicente 2008). Thus, one could imagine a few craftspeople or locales responsible for shaping the entire craft industry. Was bronze traded? Did metalsmiths travel and produce on-site? Did sites have their own metalsmiths?

These questions have yet to be answered. It is safe to conclude that the technological know-how of monovalve production spread throughout the VBA and that particular morphological forms also spread. The Argaric halberd is a prime example. It is also logical to conclude based on the low-level or production and rarity of bronze finds, that for most of the VBA, people did not rely heavily on bronze. Based on chemical analyses of Argaric bronze, Montero-Ruiz and Murillo-Barroso (2010) emphasize that the evidence for recycling is scant. High rates of recycling are more likely to be associated with a society that extensively relies on bronze. There are no tin sources in the VBA region, and so one must assume a shift in exchange relationships, albeit limited, if locals sought out tin or bronze through trade.

Alternatively, local VBA inhabitants could substitute arsenical bronze for tin bronze. This scenario does appear to have been the case during the Early and Middle Bronze Ages, after which tin bronze begins to replace arsenical bronze. The gradual replacement of arsenical bronze with tin bronze indicates that the availability of tin bronze increased through time. The availability could have increased due to increased production, trade, migration of peoples, recycling, and/or build-up of bronze over time. The dynamics of VBA bronze production and exchange need further research.

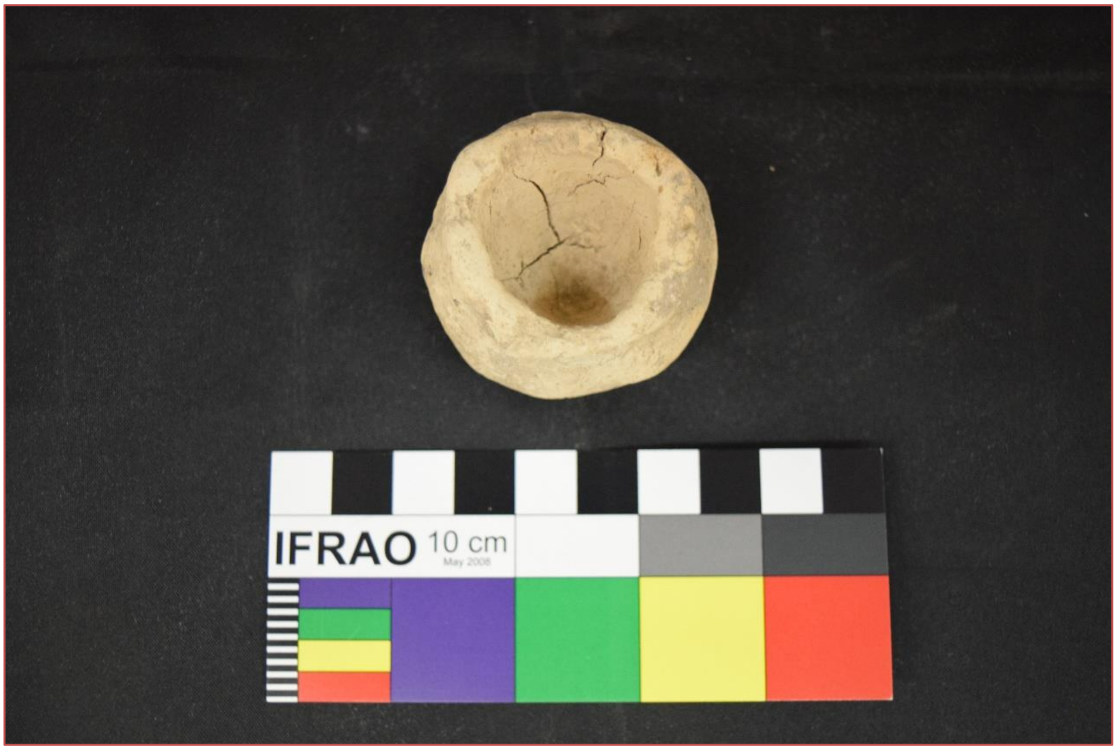


Figure 2.7. Example of a crucible from the site of Laderas del Castillo or San Antón.

Gold and silver

VBA peoples used gold and silver in the production of adornments like bracelets, pendants, earrings, rings, and fasteners. Silver ore is found natively in great masses interspersed with rocks containing copper and gold. The *Sierras d'Espada* in the Northern Region of the VBA contain outcroppings of silver ore. The *Sierras de Orihuela* in the Southern Region of the VBA constitute the only source of gold in the Valencian region, in the form of gold united with copper (Simón García 1998).

Although rare in archaeological contexts, the gold and silver of the *Tesoro de Villena* found near Villena, Spain, and investigated by Iberian archaeologist Soler in 1963, is spectacular (Soler García 2005). The *Tesoro de Villena* is a cache of 59 objects including ornate gold bowls, jars and bracelets, silver jars, amber, and one iron object (the oldest in Iberia.) It is attributed chronologically to the Final Bronze Age, and the hoarded piece of iron may have originated from contact with the Phoenicians. The decorative style of garlands and points is attributed to influence from the ceramic style of Cogotas I, a Late and Final Bronze Age culture originating from the Spanish Meseta to the west (Barciela 2017). However, archaeologists believe that the *Tesoro de Villena* objects were sourced and produced locally (Hernández Pérez et al. 2016). This "treasure" is the most significant find of metal objects from the VBA and possibly the entire Iberian Peninsula (Figure 2.8).

The treasure is a Final Bronze Age manifestation and suggests the development of socio-economic inequality during this period. After the Argaric collapse, increasing exposure to Cogotas I cultures from the Spanish Meseta, and later contact with the Phoenicians and Greeks, the socio-economic structure favoring equitable distribution appears to shift toward centralization and unequal distribution (Jover Maestre and López Padilla 2004). The nearby Late Bronze Age site of Cabezo Redondo also contains an impressive collection of gold. Based on current research, it is unknown how widespread this shift may have been but the treasure and Cabezo Redondo are located south of the Júcar River along the Vinalopó River. This has led some archaeologists to suggest that centers of power shifted northward along the Vinalopó after the Argaric collapse (Martí Oliver and de Pedro Michó 1997)

Silver is associated closely with Argaric culture and the presence of silver in Early and Middle VBA sites might indicate Argaric influence. While a relatively large amount of silver has been found at Argaric sites, most silver is present in the form of small rings and spirals. Lull et al. (2014) propose that these rings and spirals may have been used as standardized weights for exchange. Archaeologists have found silver rings and spirals at the sites of Laderas del Castillo, San Antón, Tabayá, Terlinques, and La Horna within the VBA/Argaric zone of influence and included in this study. Whether silver was used at these sites in the manner described by the authors has not been established, but its presence in the form of rings and spirals strongly indicates a relationship with the Argaric.

Figure 2.8. Tesoro de Villena (*https://creativecommons.org/licenses/by-sa/4.0/deed.en license*, author Superchilum 2014).

Rare and exotic finds

The VBA peoples used rare and exotic materials that would necessitate long-distance trade networks, the most important of which is ivory. There are multiple sources for the ivory in ancient Iberia: African steppe elephants, Asiatic elephants, sperm whales, and an extinct elephant called *Elaphus antiquus* or Straight-tusked elephant. Schuhmacher et al. (2009), based on chemical analyses, postulates that the ivory arriving during the Early Bronze Age near Argaric country derives mostly from African and Asiatic elephants.

We see the use of ivory for adornments throughout the region. However, more ivory has been found in the southern portion of the province (Pascual Benito 1995:20). Ivory is used in the production of the ‘V’ perforated button, a diagnostic of the VBA (Figure 2.9). These were produced by polishing, grinding, and trimming pyramidal ivory bars. Bars were cut in triangular cross-sections transversally to create pyramid shapes.

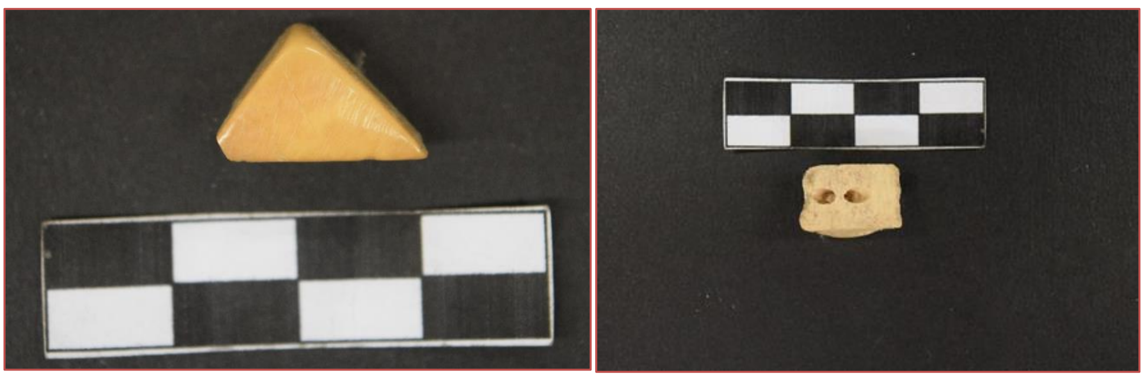


Figure 2.9. 'V' perforated button profile showing triangular shape (left); ‘V’ perforated button showing perforations (right).

Pieces of amber found at the sites of Pic dels Corbs and Penya Negra are another exotic find. The origins of this amber are unknown, but a Baltic source (or possibly France or Germany) is likely (Rovira and Port 1995). Amber of a different origin is also found in the Spanish region of Catalonia, just north of Pic dels Corbs.

Tin, ivory, and amber are exotics that necessitate wide-spread trading connections. Despite the existence of exotic, exchange networks for the trade of objects that must have come from outside the VBA, the VBA remained conservative materially, with little evidence for change during the 700 years of the Early and Middle Bronze Ages.

Ceramic vessel production

During the Valencian Bronze Age, all ceramic vessels are handmade except for a few examples from Pic dels Corbs from the Final Bronze Age that might be hand-turned (Barrachina 2012). Temper is coarse sand and used in both thick and thin-walled vessels. Some vessels are burnished; only a few in the Late to Final Bronze Ages are painted. Plainware dominates most assemblages (Figure 2.10).

Figure 2.10. Typical plainware ceramic from the northern site of Puntal de Cambra.

Chapter 3: Methods contains a more elaborated discussion on ceramic decorations, but general patterns of production and exchange are reviewed here. The relatively bounded regional patterning of ceramic types and styles, as well as evidence from a few technological ceramic studies, suggests that the production and use of most ceramic objects were local, with individual styles transmitted regionally along natural corridors and through extended social connections. Only a few archaeometric analyses of ceramic pastes exist, but a 1983 X-ray diffraction study of 64 samples from the Southern site of Peña Negra II classified ceramic pastes into two groups—one foreign and one local (González Prats and Pina Gosálbez 1983). Peña Negra II is a Bronze Age/Iron Age transition site, but the results for the local ceramics are still useful. The foreign ceramics are Phoenician in origin. VBA peoples created all local ceramics from nearby clay sources.

Ceramic forms are not a characteristic utilized in this research, but forms include open and closed mouth bowls and jars, carinated jars, large storage jars, and "gemini" vessels (two vessels joined together by a handle). Vessels with flat bases begin to appear in the Late Bronze Age along with an increase in the number and variety of decorations (Barrachina 2012). Gemini vessels are common in the territories north of the Ebro and provide further evidence of the fluidity of regional social relations during the Bronze Age (Soriano and Amorós 2014).

Regional Variation

The above patterns are general, and they reflect the traditional interpretations formulated at a time when systematic excavations and radiocarbon dates were few. Iberian researchers are now discovering new modes of diversity in VBA cultural practices through time and space. As López Padilla (2011:59) states (translated from Spanish), "To accept, however, *the dynamic character and the state of constant* *transformation of the societies* (emphasis added) implies that we also assume necessarily a diachronic perspective in the analysis of any social fact."

Several Iberian researchers mention a north/south divide with the Júcar River serving as a physical frontier and social frontier (Barrachina 2012; Gil-Mascarell 1995; Picazo Millán 1993; Tarradell 1965). Compelling upstream evidence for this division comes from historical records. Figure 2.11 shows a map, derived from later Roman classifications, of separate ethnolinguistic groups from around the period of the Carthaginian conquests some 400 years after the Final Bronze Age. Rome administratively divided the region that corresponds with the VBA into two ethnolinguistic groups—the *Contestani* and the *Edetani*. The frontier between these two groups is the Júcar River. It is not much of a stretch to conclude that the Romans utilized an established social division to administer its territories.

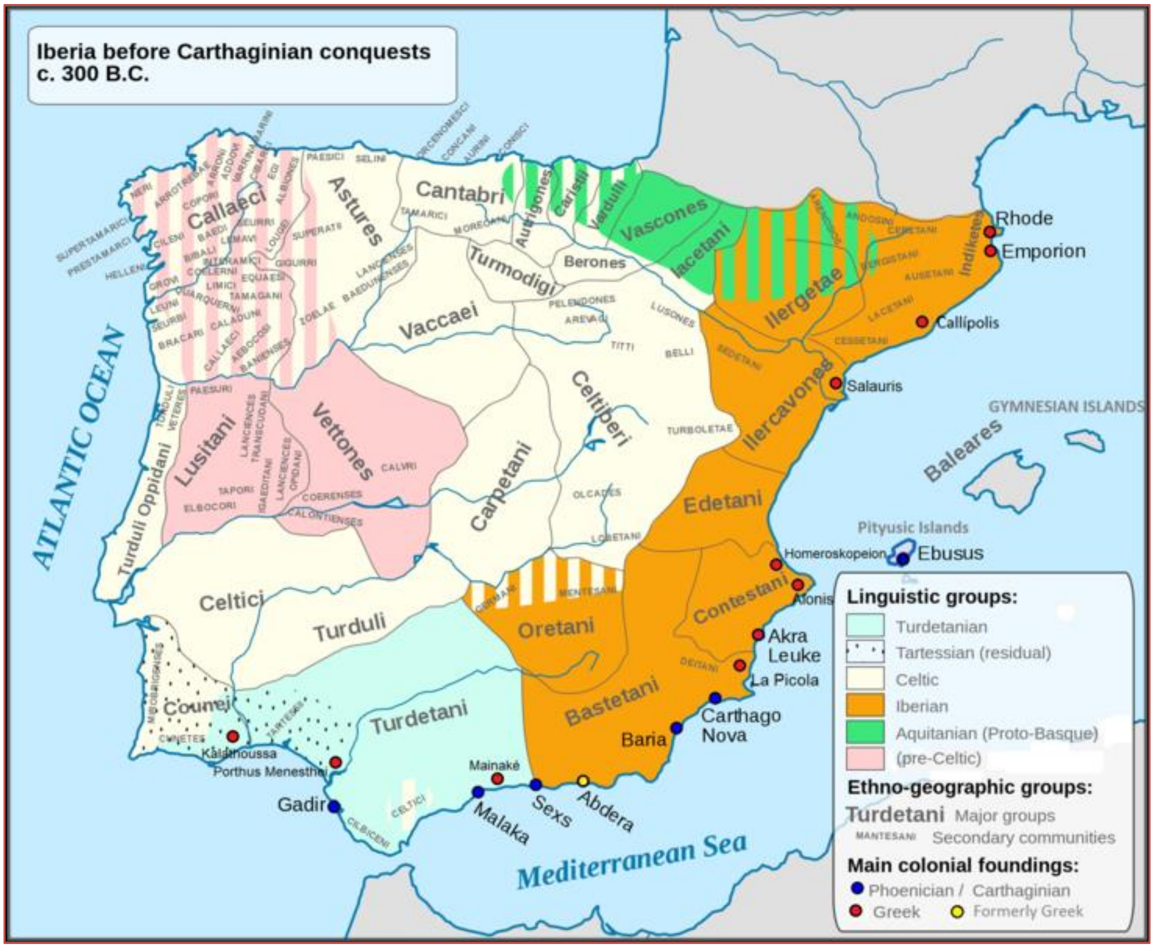


Figure 2.11. Map of Iberian ethnolinguistic groups from approximately 300 BCE. (*https://creativecommons.org/licenses/by-sa/4.0/deed.en license*, author CanBea87, 2016).

How did VBA peoples travel in order to maintain social and economic exchange relationships? There is no lasting physical evidence for the development of communication through maritime or frequent aquatic travel (neither boats nor boat iconography survives.) People may have been traveling in wooden or skin boats that did not survive centuries of exposure to an acidic environment, but this is only speculative. VBA peoples may have used horses for travel over land and horse remains are found in archaeological sites. However, the material evidence is lacking that would demonstrate precisely how horses were used. For the transport of goods, oxen may have served as burden animals.

The paramount influence of river corridors as conduits of exchange during the VBA cannot be understated. Five major rivers flow through the VBA and from north to south, these are the: 1) Palancia; 2) Turia; 3) Júcar; 4) Vinalopó; and 5) Segura. Iberian archaeologists, back to Tarradell, have recognized that these rivers are a useful analytical framework (Martínez Monleón 2014; Palomar Macián 2004; García Bebia1994; Soriano Sánchez 1985; Tarradell 1965). The following discussion summarizes aspects of regional differences between the northern and southern VBA through a review of the five corridors (Figures 2.12 and 2.13).

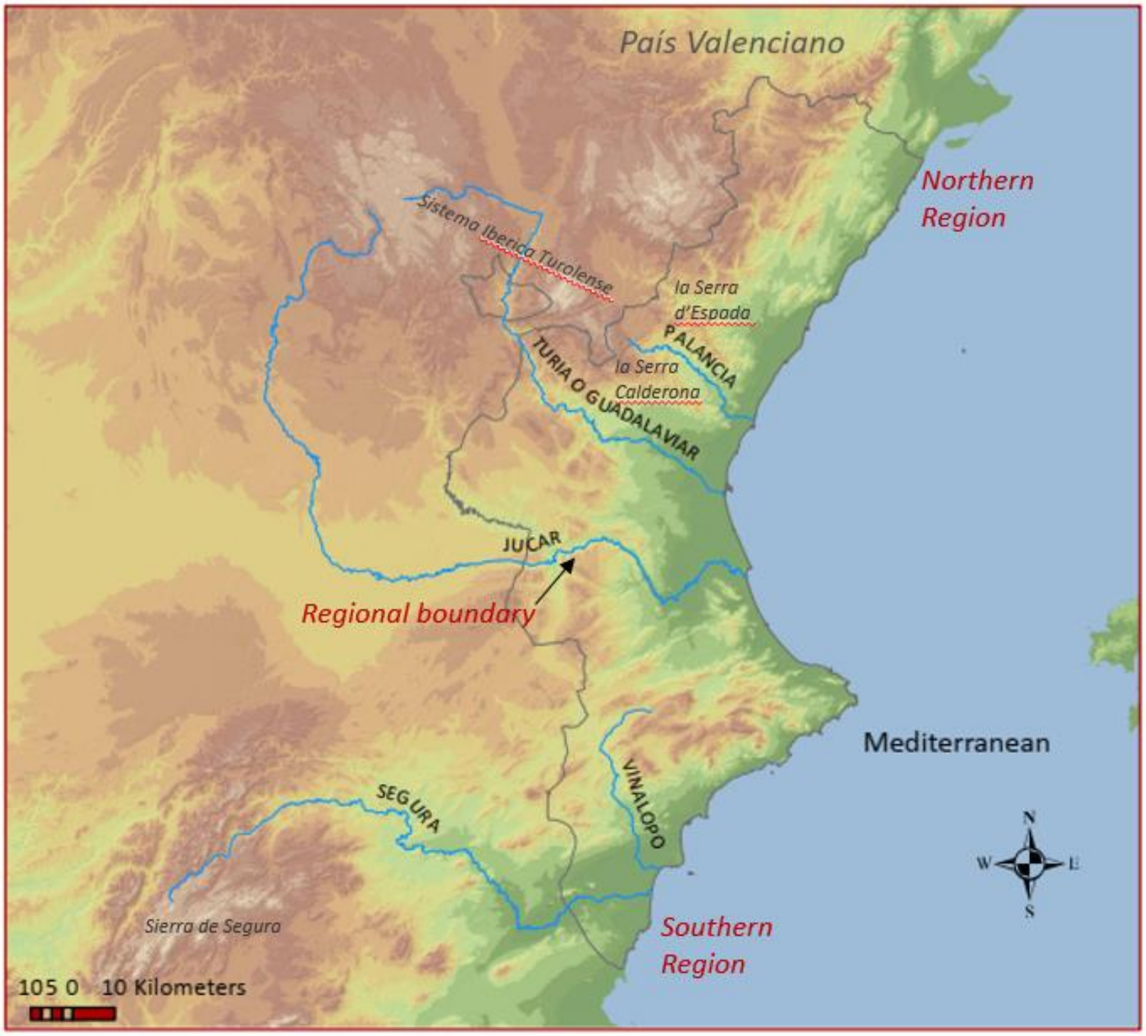


Figure 2.12. Map of VBA showing major river corridors, mountain ranges mentioned in the text, and Northern and Southern regions.

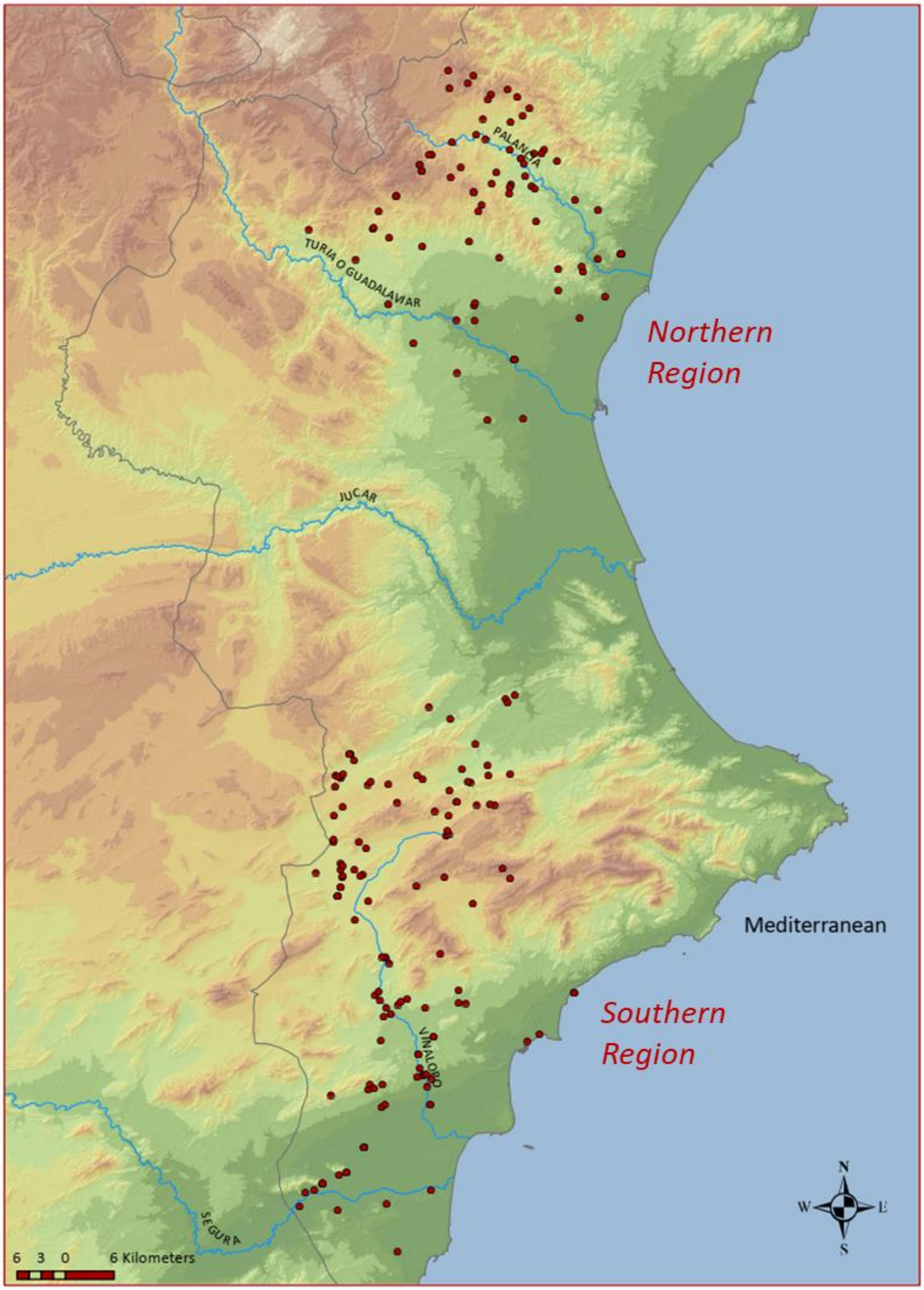


Figure 2.13. Map of locations of all VBA sites analyzed in this research.

Northern Region—Palancia River and Turia River corridors

The Palancia River corridor consists of the Palancia River itself coursing between two mountain ranges—*la Serra Calderona* to the south and *la Serra d'Espada* to the north. The maximum elevation in the mountains is approximately 700 meters, and the river creates a watershed with branching ravines and small tributaries. Just west of the modern town of Segorbe the two mountain ranges constrict, creating a basin or bounded region extending east to the Mediterranean Sea near Sagunto, Spain. The territory is 40-45% mountainous and 55-60% littoral plain (Barrachina 2012). This varied and rich environment has high agricultural and pastoral potential. VBA sites are positioned at medium elevations all along the corridor and along the tributaries.

Visibility between sites along the Palancia is excellent, but the basin is geographically bounded by mountains running east-west. This natural barrier served to promote travel between Aragon and the coast but restrict travel elsewhere. Picazo Millán (1993) suggests that sites in this Palancia River corridor show evidence of interaction with sites to the north in Catalonia and to the west in the *Meseta Central*. In common to these regions is a ceramic decoration style called *cordones*, a type of applique resembling cords or ropes (Figure 2.14). *Cordones* are concentrated heavily in this region and suggest that the Palancia River sites are part of a northern sphere of influence.

Figure 2.14. Examples of the ceramic style called "cordones."

In contrast, the Turia River corridor extends from the Mediterranean Sea near modern Valencia inland toward its source in the mountain ranges of the *Sistema Iberica Turolense* in Teruel Province. The country is gently undulating, with low-lying hills (de Pedro Michó 1998). The land surrounding the Turia is more open than that surrounding the Palancia with many more access points to surrounding regions. As such, the material culture reflects an admixture of northern and southern elements. For the most part, ceramics are undecorated until the Late and Final Bronze Ages. At this point, *cordones* appear at a few sites as well as decorations commonly associated with the Final Bronze Age, central Iberian Meseta culture of Cogotas I.

Southern Region—Júcar, Vinalopó, and Segura River corridors

The Júcar River corridor traditionally divides the Northern and Southern regions. However, based on geographic proximity as well as material similarity to the Southern Region, the Júcar is classified as part of the Southern Region in this analysis. The 498-kilometer river flows out of the Universales Mountains north of the modern city of Cuenca. It flows in a southeasterly direction through the Valencia provinces and into the Gulf of Valencia at Cullera.

The Vinalopó River corridor is the major north-south artery connecting territories south of the Júcar River to the Segura River and the Mediterranean (see Figure 2.12). The Vinalopó is the axis for a comprehensive network of paleo-canals attached to the Vinalopó's east and west banks (García Bebia 1994). Despite being a called a river, it is relatively shallow along its 81-kilometer course. Sites along the Vinalopó contain a great diversity of metal object types but a relative uniformity in ceramic types and styles. Again, ceramics do not exhibit decorations until the Late and Final Bronze Ages. Several sites located within the frontier zone along the Vinalopó contain Argaric specific vessels that northern VBA sites do not have, namely the *copas* mentioned earlier and highly polished tulip-shaped vessels with high carinations (Hernández Pérez 1997). In other words, some sites along the Vinalopó are tied in with Argaric influence.

The Segura River is the southernmost corridor in this study. It begins in the Sierra de Segura range, and after 325 kilometers it empties south of the city of Alicante at Guardamar del Segura. The Segura is another east-west travel corridor. Many of the sites along the Segura are classified as Argaric and contain Argaric elements such as bronze halberds, *copas*, burials within settlements, and tulip-shaped vessels. In general, sites located further south in the VBA region, contain more bronze and more evidence for metallurgy.

The differences between northern and southern VBA cultural contexts as well as the changes that evolve during the Late and Final Bronze Ages provide a rich foundation for the comparative study of social stability through time and space. The Northern and Southern Regions experience exogenous social pressure at approximately the same time, therefore, questions can be addressed such as: 1) In face of exogenous pressure, how did differences in social structure between the two regions affect the pace of socio-structural change?; 2) Did the north or the south remain more stable social stability after experiencing exogenous social pressure and why?; 3) What influence does the type of exogenous shock have on a society's ability to resist change? This research uses social networks and social theory to derive answers to these questions. The next chapter reviews and evaluates theory from archaeology, anthropology, and sociology on social stability as well as the theory underlying analysis of social processes using networks.

CHAPTER 3

THEORY AND CONCEPTUAL FRAMEWORK

Archaeological Perspectives on Social Stability

Sadly, there is little recent archaeological theory on the topic of social stability. A survey of major archaeology journal articles published after the 1990s for the terms "social stability," or "stability," produces few relevant results, none with a theoretical stance. Archaeology and the rest of the social sciences have a strained relationship with this topic. Often, anthropologists assess a research avenue using a normative and/or prescriptive lens. Beginning in the 1960s, many in anthropology actively shifted toward the perspective that the field should serve as a defender of the oppressed or unseen and an instigator of social change (i.e., Engle Merry 2005; Bourgois 1990). This is an important normative mission but its improper application has led to censoring of theoretical points of view and is problematic for the advancement of science (Kempner et al. 2011; Cowlishaw 2000). The abridged state of social stability studies is a case in point.

By the 1980's the study of social stability fell out of favor due to strong criticisms from researchers who argued that the overwhelming emphasis on structure justified the status quo and ignored issues of power and individual agency (Hodder 1985). The study of social structure was something normatively bad and the study of social stability possibly worse. Maintenance of social stability was equated to the maintenance of the power structure. This is an unfortunate false equivocation. The study of the existence of social stability and how it works is not equivalent to its "goodness" or "badness." The goodness or badness of it depends on goals or values. For example, if the goal is to maintain the stability of the American socio-economic power system, then preventing wealth redistribution is good. However, if the goal is to promote socio-economic equality, then stability is not so good. Our moral judgments about social stability do not affect the existence of social stability as an important, observable pattern and process.

This confusion has made social stability unpalatable to the social sciences and led to a lack of fulfilling research in recent years (Olsson et al. 2015). However, a few examples exist of archaeological theory that try to address social stability, if indirectly. These examples can be grouped into those that assume that societies are always changing versus those that assume that societies are inherently stable. Many of the sources employed within the following discussion are older than desired due to the dearth of research available for the reasons above described.

Societies are inherently changing

Several theories in anthropology that relate to social stability assume that societies are constantly changing. The three main theoretical perspectives in anthropology that operate under this assumption are Cultural Evolution, Complexity Science, and Resilience.

Cultural Evolution derives from an older theoretical model (19th century) based on explanations for social change inspired by the theories of Charles Darwin and appropriated by Herbert Spencer (Trigger 2006). Societies inherently progress unilinearly from less complex to more complex through time, although some societies remain stuck in their particular stage. Later anthropologists revised cultural evolution to acknowledge multilinear stages of evolution and different rates of development (i.e. Sahlins and Service 1960, White 1959, and Steward 1955.)

In recent years, the characterization of the transformation of societies and cultures has moved toward discussions of social complexity and the factors that affect the organizational trajectory of a society. Rather than identifying 'social complexity' as a framework that emphasizes the inevitability of social stratification, the latest theoretical models investigate decentralized hierarchies, heterarchy, and political or ethnic alliance formation/factionalization (Blitz 2010; Baden 2005; Feinman et al. 2000; Crumley 1995; Brumfiel and Fox 1994). In other words, they acknowledge the dynamic development of multiple, societal trajectories and the concomitant existence of multiple, often competing social structures within one society. The new emphasis on social complexity is promising, but most favor the study of causes of social change or resistance to the imposition of power, rather than drivers of social stability. In addition, even the more current theoretical threads within the study of social complexity focus on the classification of social organization rather than the processes underlying social organization.

Social stability in most of these works is the state preceding or succeeding increases in social complexity (Kirch 1990; Paynter 1989). The following are two illustrative excerpts of a discussion by Paynter:

> Regional culture histories should exhibit a shift from simple to complex societies. Strong theoretical bases for this expectation are found in appeals to general laws in physics or the notion that complexity enhances stability.

and

> In this program, the task of archaeology is to find the mechanism(s) that produce change from one form of social integration to the next. Such forces are usually exogenous to the culture. Certain problems make life miserable for members of a society; social change solves these problems.

> The most common source of misery is the productive system's inability to meet society's demand for matter and energy. Complex production systems remedy the supply-demand imbalance more efficiently than simple ones. [Paynter, 1989:373]

Social stability is enhanced by progress in the form of social transformation and adaptability in the face of change. The early cultural evolutionists are not completely off base, but their assumptions that progressive increases in social complexity promote social stability is problematic. Social complexity is not a necessary condition for social stability. Complex social configurations can increase vulnerability under the right conditions. Flannery (1972) and Rappaport (1979) argue that complexity breeds instability and that as complex societies become increasingly differentiated, their stability declines. Less complex societies are more autonomous and self-sufficient. They have less specialization, are more equally interconnected, and any disruptions diffuse more easily. In essence, Flannery and Rappaport believe that the maintenance of simpler social systems preserves social stability and that civilization is a "maladaptive" social experiment whose success or failure is yet to be determined (Tainter 1988). Their perspectives, if slightly undertheorized, treat social stability as something with underlying processes to be explained.

Most modern anthropologists recognize that early cultural evolutionists misappropriated Darwin’s theories and have updated evolutionary applications to the archaeological record. Dual Inheritance Theory (DIT) and Cultural Transmission are two related approaches relevant to social stability. DIT explains human behavior as the product of the coevolution of genes and culture (Richerson and Boyd 2005). Culture evolves through cultural transmission from generation to generation or horizontally between members of the same population. Culture is socially learned and transmitted through imitation. Certain mechanisms, akin to evolutionary theory, govern cultural evolution including selection, random variation, cultural drift, and biased transmission. DIT and Cultural Transmission theory treat stability as the persistence of traditions, a persistence that is the outcome of mechanisms of gene-culture evolution.

In archaeology, the application of Cultural Transmission is most commonly used to explain technological traditions. This approach has the explanatory power of evolutionary theory behind it, which makes it attractive. Additionally, it allows for the emergence of population-level patterns (i.e. tradition) from individual behaviors like selection (Eerkens and Lipo 2007). However, its application to archaeology has been relatively narrowly focused on technological traditions and with an emphasis on change rather than stability.

The study of the persistence of traditions has a long history in archaeology. Haury et al. (1956) published "An Archaeological Approach to Cultural Stability," in which they focus on the study of tradition. The approach consists of the identification of a typology of tradition segments used to inform theories about causes of cultural persistence and change. The authors emphasize the archaeologist's ability to track rates of material form, a "form-time" relationship generally referred to as culture history. The operational form of this relationship is the tradition—a "socially transmitted form unit" that persists in time (Haury et al. 1956:38).

Haury et al. (1956) share this research's emphasis on persistence as crucial to their definition of stability, however, their conceptualization focuses on the persistence of material traditions, not on the persistence of social relationships. Interestingly, they note that social structure may be a causal factor limiting or promoting cultural stability, however, their discussion is limited to the presence and nature of class or labor specialization and culture contact and diffusion. Their contribution to the operationalization of a concept like stability is still notable even when considering that many of their assumptions have been questioned more recently.

In recent decades, Complexity Science has developed to address the lack of good scientific systems models for human societies that are dynamic, interrelated, and continually changing. Complexity Science views human societies as incredibly complex systems with interconnected agents operating at multiple scales, influenced by a constant flux of matter and energy (Downey 2018; Byrne and Callahan 2014; Mitchell 2009; Kohring and Wynne-Jones 2007; Bentley 2003). It recognizes that equilibrium often is not the natural operating state of societies. In fact, social stability appears counterintuitive under these conditions, and also unpredictable. Hence, it is as necessary to explain periods of stability as intervals of rapid change. While this project does not adopt an explicitly Complexity Science approach, it is inspired by the necessity to explain social stability rather than assume its natural existence.

An important and relevant tenet of Complexity Science to the theorization of social stability is that of self-organization. Self-organizing systems are systems that are created and recreated by the individuals that make up the system. According to Accard (2018:1), "In a self-organizing system, agents make changes while preserving stability. When change does not preserve stability, chaos prevails, and there can be no recreation of the system. Thus, when addressing self-organizing, organization theorists have to focus on the issue of how change preserves stability." The current project takes a strikingly similar perspective, i.e. that agents operate within a system on the edge of chaos and that the changes that agents make can prevent chaos and promote stability (Accard 2018).

Furthermore, Accard (2018:4) argues that social stability results “because agents have codified knowledge in the form of rules; this codification typifies their interactions and limits the range of possible interactions. The interactions also stabilize because they are self-referent interactions: interacting agents have convergent cognitive orientations, and thus the range of possible interactions that they perform is limited. Permanent stabilization, however, cannot occur because agents are never totally constrained by rules. Rules are both enabling and constraining, and thus agents are always able to revise their knowledge and make changes in their interactions.”

From the perspective of the current research, social rules in the form of norms and institutions govern the social interactions of actors within the network. Through time, these constrained interactions produce a patterned, global social structure. Certain global structures are more stable than others are because of the opportunities or constraints available to individuals. This does not mean that agents cannot cause change. A small change, for example, the refusal to follow a rule, can lead to unforeseen consequences for the whole system. These changes diffuse within the global system, the system reacts by constantly self “reorganizing.” State transitions do occur from one organization to another, but change forces the system constantly to organize around some form of social stability.

Recently, Resilience theory, developed in the field of ecology, has been embraced by several archaeologists (Alcock 2017; Bicho et al. 2017; Bradtmöller et al. 2017; Peters and Zimmermann 2017; Rosen and Rivera-Collazo 2012; Weiberg 2012; Nelson et al.

2006; Redman 2005; Redman and Kinzig 2003). Resilience within socio-ecological systems is the ability to maintain structures and functions (Bradtmöller et al. 2017) and is sometimes envisioned as a system's ability to absorb shocks without crossing over into a new state. It is a conceptual framework for the study of cycling periods of stability and instability in the relationship between humans and their environment. In Redman's (2005:72) words, "Destabilizing forces are important in maintaining diversity, flexibility, and opportunity; stabilizing forces are important in maintaining productivity, fixed capital, and social memory" and "Neither stability nor transformation is assumed to be the norm; rather, systems are seen as moving between the two in what has been termed an adaptive cycle."

Resilience theory has better potential than other archaeological approaches because it has an explicit model, the Adaptive Cycle (AC) model and pre-defined parameters. In an AC model, the resilience of a socio-ecological system can be a high or low result of archaeological proxies for *connectedness* (a measure of the degree of flexibility of internal system controls) and *potential* (the number and kinds of future options available often governed by social networks) (Brandtmöller et al. 2017). However, as Brandtmöller et al. (2017) state, this kind of framework has not yet been fully actualized within an archaeological case study. Also, resilience theory describes the processes that might create and maintain stability but does not explain why stability exists. In this sense, it lacks the explanatory power necessary for a dissertation that is interested in cause.

A couple of researchers outside the field of archaeology discuss an additional problem plaguing Resilience Theory. In their article, Jannsen et al. (2006:1) note that “formal models used to study the resilience of social-ecological systems have not explicitly included important structural characteristics of this type of system.” The authors recognize that network analysis is a promising avenue for operationalizing structural characteristics for use in understanding resilience. More specifically, network analyses by focusing on the structure of interactions between the components of social-ecological systems can be used to understand how these structures influence the behavior of the system. Resilience Theory developed out of the field of Ecology to address cycling, stability, and change in natural systems. In a recent paper by Rogers (2017), the author recognizes the need for a theory developed specifically for human systems that covers social change and stability. Rogers proposes a theory of dynamic trajectories to adequately represent change and to understand how pre-existing system aspects can structure the trajectory of change. He states that “stasis and change are often viewed as a dichotomy; however, the potential for change may be embedded in many circumstances as a criticality potential, even if the change has not occurred. This implies that the probability space is a limiting factor in social disjunctures” (Rogers 2017: 1349). The probability space includes pre-existing conditions as sources of potential or limitation to continuity and change.

The theory of dynamic trajectories, among other concepts, proposes five change conditions—stasis, expansion, contraction, morphing, and displacement. Stasis, in particular, addresses social stability. Rogers (2017:1337) states that stasis occurs when “the trajectory continues under preexisting conditions. A certain amount of change is constant, although there are no abrupt changes under conditions of stasis.” Stasis is a dimension of action, actual behaviors of humans. Under this definition, stasis (or social stability) is dynamic and the processes that underlay it ought to be understood in their own right and sought out in the material patterns of the archaeological record.

Another contribution to note under this heading is that of chiefly cycling, elaborated by Anderson in the 1980s. Anderson did not discuss his ideas under the rubric of resilience theory but his concept of chiefly cycling is reminiscent. Anderson (1986) noted that Mississippian chiefdoms tend to cycle, in other words, expand, collapse, and then reconstitute. Concerning stability, Anderson (1986:193) states, "It can also be argued that the stability of chiefly societies, at least in part, is related to the effectiveness of the mechanisms by which the elite maintain their positions of authority." Cycling in an internal organizational process that acts to preserve chiefly structures over decades or even centuries. Anderson's explanation stands out because it emphasizes the impact of endogenous social processes on social stability at the global level. However, its scope is narrowly constructed to fit chiefdoms and to emphasize top-down processes.

The inclusion of the importance of individual action in the production of emergent social structures and the assumption that change is inherent to societies are important strengths of these theoretical perspectives. However, they focus expressly on social change with little attention paid to explaining when this is not the case.

Societies are inherently stable

Cultural Ecology is the main current in anthropological theory that assumes stability as a natural state toward which societies are striving. In Cultural Ecology, societies are ecosystems and adaptive processes are governed by self-regulation to achieve equilibrium or the steady-state. Culture functions as a thermostat, helping to achieve equilibrium (Bargatsky 1984). Rappaport, in particular, is known for expanding on the ideas of Cultural Ecology by introducing the concept of cybernetics, the automatic regulation of systems through feedbacks. In his *Pigs for the Ancestors*, Rappaport (1968) argues that the Tsembaga of New Guinea operate within a system and that ritual (the *rumbim* ceremonies) is the homeostat, maintaining the steady-state of the system. Social stability and environmental stability are linked inextricably together within a self-regulated, bounded ecological system.

Critics of Cultural Ecology and cybernetics note their problems with environmental determinism or the assumption that environmental factors are the main locus of change and that humans only react to that change. Social stability is conceived of rather narrowly as the natural or steady-state to which all societies are attempting to return to after a perturbation. The human ecological system is a closed system with known variables, where changes in one variable predict linear changes in another, and where a predictable steady-state exists (Bargatsky 1984).

Cultural Ecologists envisioned the human-nature relationship as a system and often used system analogies to understand society. Again, the systems perspective has been heavily criticized and has suffered somewhat by the same normative judgments that have plagued social stability studies. Social scientists are “reluctant to use systems as an ontological description of society” (Olsson et al. 2015:3). Social scientists point out that most social systems are not closed systems or functionally autonomous. Defining the boundaries of a social system is exceedingly difficult because actors often have relationships with other actors beyond the boundaries of the system defined by the researcher. Inspired by systems concepts, Clarke (1968) developed a theory about how continuity in societies can emerge from redundancy. For Clarke, redundancy meant redundant channels of information. A system depends on its ability to maintain active channels of communication. In the face of uncertainty and risk, redundancy maintains system continuity by combatting noise through the promotion of conformity and offering alternative channels of communication if another channel should happen to fail. The survival of a system depends on consistent communication. The fields of Computer Science and Ecology have addressed the relationship between stability and redundancy in network interactions more fully than has Archaeology. A portion of the literature related to the study of social stability focuses on the causes of societal collapse. One such example is Tainter's 2004 book *The Collapse of Complex Societies*. The author, while addressing processes of decline notes that social stability is a state that societies are striving to maintain. One of the ways people attempt to preserve stability is through intensification of resource production resulting in a concomitant increase in social differentiation. Tainter uses several case studies to demonstrate that this mitigation choice often fails when society engages in "overshoot" when increasing intensification produces declining marginal returns. Similar to other approaches described above, collapse studies often treat social stability as a state that societies progress-from or regress-to. Little explanation for social stability is provided.

Overall, these theories assume that the task of the archaeologist is to study mechanisms of change, the implication being that stability is the pre-existing steady state that does not require explanation. Moreover, stability is approached from the perspective of homeostatic mechanisms at the level of cultures; the individual is not considered. The presumption that social stability just exists until a change occurs is a *begging the question fallacy*. No independent argument exists to support the presumption of social stability.

For social change to exist, then some other state must exist and that must be social stability. Yet, no definition of stability is provided, no explanation for its existence, and no exploration of the processes that underlie it.

Other Social Science Approaches to Stability

A goal of this research is to contribute to the development of a general theory of social stability suited to application to the archaeological record. A general theory of social stability should be broad enough to explain its occurrence across different and often overlapping contexts—political, economic, environmental, and religious, among others. The challenges inherent in this endeavor are evident, and other social sciences outside of Anthropology have attempted to explain why some social groups persist longer than others do.

The field of Sociology has a more theoretically developed body of literature on the topic of social stability than does Archaeology. Any discussion must begin with Durkheim and his concept of social solidarity. Social solidarity comes in two forms—mechanical solidarity, a force that holds society together by reinforcing likeness between people and organic solidarity, a new kind of solidarity that arises out of the degradation of "collective consciousness" (or the progressive emphasis of individuality) and the rise of labor specialization, where each member has its specialized function in maintaining the system. The collective is, “The totality of beliefs and sentiments common to average citizens of the same society…” (Durkheim 2014:63). For Durkheim, the collective consciousness is a force that has a life of its own beyond the individual. Overall, Durkheim had a great interest in understanding social order, and his writings are the foundation of later social theory on stability.

Functionalism is another theme in the social sciences that has been criticized for downplaying the agency of individuals and its inability to account for change. Functionalism tries to understand how social structures function to maintain stability. This theoretical thread is important to the current work. Durkheim (2014), whose ideas inspired functionalism, made an important point when he distinguished between the stability of small-scale and large-scale industrial societies. He proposed that small-scale societies were held together by mechanical solidarity (strong family ties in an undifferentiated society) and large scale societies by organic solidarity (held together by an extensive division of labor and dependencies on specialists). In other words, more than one path to social stability exists and social structure can explain social stability. The contribution of Durkheim and later functionalists to some of the theories already described is evident. Society is a system and the goal of that system is to maintain social stability in the face of anarchy. The role of institutions, including cultural, in societies is to maintain social order and the role of the researcher is to determine how those institutions function to maintain stability. Possibly the most noteworthy objection to functionalism is the shaky assumption that society comes pre-ordained with a goal—to maintain stability—and that it has an existence outside of the individuals who comprise it. This is a problem that traditional functionalism is ill-equipped to address.

Functionalism is a consensus theory. Consensus theories focus on shared ideas and coordinated activities as the driver for social structure. It is worth noting that not all social theories assume that social stability exists as the natural state. Conflict theory emphasizes the study of how conflict and competition shape the social structure (Collins

1975). Conflict theory does not assume that social stability exists. It regards society as in a constant state of competition and that conflict drives social change.

Following Durkheim, Parsons (1940) and many others developed the concept of structural functionalism. Under this idea, the stability of society is dependent on society's ability to meet specific needs. Structures like economic, legal, and political institutions function to meet these needs. These structures constrain individuals and groups to act according to norms that maintain equilibrium. The focus of structural functionalism is the macro-structure, a focus that anthropologists have criticized for an inability to address agency and change.

If we move away from the assumption that society has an existential purpose, then we open up avenues of research such as the one proposed here. How people choose to organize results in particular socio-structural patterns and sometimes the patterns persist. What conditions lead to the persistence of social patterns and why do some patterns persist in the face of change? Assuming that stability is the natural state of society without defining a baseline is also dangerous. A society may fluctuate in the short-term but remain stable over the long-term. Furthermore, multiple states of stability with different characteristics may be possible. How do we know which one is the “natural state” toward which the institutions of society function to maintain? For these reasons, social stability must be defined and never assumed.

The works of Giddens and Baudrillard provide interesting critiques of functionalism and the conceptualization of social stability. Giddens emphasized the importance of considering both time and space for a proper understanding of social stability (Giddens 1981). Giddens strongly argues that the functionalist division between the synchronic and diachronic is misleading. The characteristic viewpoint that social stability is studied synchronically, while social change requires a diachronic perspective is erroneous. Under this perspective, time becomes associated with social change and not social stability. Social stability is associated with timelessness. Giddens argues instead that time is inextricably bound to social stability; the stability of a social system can be evaluated only by comparison to previous states. Social systems only have structural properties because of the reproduction of those properties through time.

For Giddens, social reproduction through the actions of individual agents accounts for social stability. Giddens emphasizes the recursive relationship between structure and agency. Individuals reproduce the institutions or structures that contextualize their actions, but they do so not as cultural dimwits but as knowledgeable actors. Social systems do not have needs; only individuals have needs. It is not logical to identify social stability as a need or property of a system. Instead, one should be asking about the conditions necessary to maintain social stability. Giddens advocates replacing the theory of functionalism with his theory of structuration. The theory of structuration posits that all social action consists of social practices located within time and space, organized by knowledgeable agents. Properties of social systems, such as social stability, are simultaneously the context and outcome of agent behavior.

One final note about Gidden's perspective concerns the duration of social institutions or the *longue durée*. Every social action through time contributes to the persistence of social institutions. For Giddens, there is no separation between history and sociology. In other words, there are no general laws that can describe a social system because the history of the social system, contingencies and all, produce the social system.

A social event may take different forms at different conjunctures in history, thus, the historical context through time and space is necessary to understand social phenomena. Several archaeologists (Varien and Potter 2008; Joyce and Lopiparo 2005; Dornan 2002; Dobres and Robb 2000) have advocated for and implemented Gidden's philosophy, a logical application since Giddens counsels that the study of long-term processes is necessary to understand social systems and social behavior.

Baudrillard suggests an interesting counterpoint to Giddens and most of the other viewpoints presented in this research. Baudrillard rejects the concept of the social entirely (Bogard 1990; Baudrillard 1983). The social is an artificial construct made up of traditional Western philosophical tenets such as social structure, social relation, social class, social institution, and even social theory. These terms themselves are the product of social processes, a copy of a copy. No one social hypothesis can claim to be the truth, because every conception depends on the individual's perspective on the social. Therefore, the meaning of something like social stability can never be fixed. We can only assess social stability using terms we define. Concepts like social stability do not exist outside of experience and are no more than simulations or delusions.

Baudrillard's theories and those of other post-modernists are important because they remind us to be careful about our assumptions. We cannot assume that social stability exists, but is, in fact, a product of the imposition of our definitions and traditions in Western philosophy. Knowing this does not mean that the study of social stability is worthless. It just has to be defined. Baudrillard's warning is that we always understand that any social concept is itself a social and historical product.

Other sociologists have addressed social stability by focusing on the bottom-up processes of relationship formation and resultant patterns of social structure. Simmel (1950), the developer of many of the main tenets of a quantitative theory of social structure, believed that social geometry influences social stability. Social geometry is the idea that specific social structures, or geometries, can be identified in all social settings and that each geometry has particular characteristics. For example, he argued that a group of two people (a dyad) is less stable than a group of three people (triad). A group of three people is more stable because conflicts between two of its members can be mediated by the third. The quantification of social structures inspired a new goal, that of producing a "social physics." Russell, an anthropologist, and Killworth (Russell and Killworth 1979) emphasized the need to achieve a quantifiable and reproducible way to describe and model relationships between people.

Emerson (1962) developed concepts around social balance and power-dependency relations. Emerson defined balancing processes that lead directly to processes of group formation, including the development of group norms, role structure, and status hierarchy. Emerson argues that different structures of power imbalance will affect group stability. The weakest member of a group of three is likely to defect unless network closure balances this antagonism. In other words, if A and B are friends and A and C are friends, A now has more power, and a power imbalance exists. To balance the structure, B and C must become friends and close the triangle. This triangle is strong and is a conduit for further reinforcement of group norms.

Hayek (1973) recognized that the basis for social order need not be attributed to outside forces, but is explainable by the actions of people and how these actions push along the evolutionary process. Importantly, he argues that social evolution is driven by shocks and mutations that change people's plans in unpredictable ways, thus the system is not necessarily deterministic. Hayek deemphasizes centralized decision making and says that communities are often formed organically through interaction. He states that central planning is less effective in maintaining social stability than just letting the system impose its logic.

Social Exchange Theory, as developed by Blau (1964), looks at the interaction of two individuals as they analyze the cost and benefits of a relationship. This theory is singularly focused on the notion of reciprocity, or equal exchange, and how trust that a transaction will be reciprocal increases stability. Blau recognized that the processes that govern exchange relationships at the dyad level shape the exercise of power and social stability and that these processes scale up to the level of social institutions.

Blau (1977) went further when he proposed his *Macrosociological Theory of Social Structure*, especially relevant to the research reported here. In Blau's theory, social structure is defined as the distribution of people among social positions in a multidimensional space. The approach allows the researcher to focus on social structure no matter what context or influence, be it technological, psychological, economic, or cultural. Blau does not deny the importance of these influences but asks what the critical structural processes that act independently of these influences.

Blau's definition of social structure permits the specification of analytic propositions about the likelihood of associations between people, just based on structural patterns. For Blau (1977:30), "The major structural condition that governs intergroup relations is the degree of connection parameters." Parameters are social positions, i.e., race, religion, wealth, power, group size, status inequality, etc. , that differentiate people. These parameters constrain rates of association between people, and social associations depend on opportunities for contact (Blau:1977).

Recognizing some of the short-comings of prior theories of social stability, Carley (1991), explicitly defines and tests a general “Theory of Group Stability.” Carley states (1991:331) that existing theories of group stability “usually suggest that favorable contexts are necessary for group stability, particularly when memberships change and new technologies and ideas emerge, and that highly differentiated contexts produce multiple groups.” Carley cites some of the prominent theorists and the particular contexts each addresses in reference to social stability: Aldrich (1979) and Hannan and Freeman (1977) on the environment; Blau (1967) and Simmel (1908) on institutions; Durkheim (1912) and Mead (1934) on ritual. Carley refers to these as “context-dependent” themed theories that are undertheorized in terms of the particular mechanisms that maintain social stability.

Instead, Carley offers a “constructural” perspective that is exceedingly general. In the author’s words, “According to this perspective, social change and stability result from changes in the distribution of knowledge as individuals interact and acquire and disseminate information” (Carley 1991:332). Groups form and persist because of differences in knowledge. The primary force for social stability is interaction and the exchange of information. A group is perfectly stable only when all members know all of the same information. In this scenario, the role of such phenomena as institutions, demography, religion, the environment, etc. is in the control of the exchange of information. A perfectly stable society would indicate the dissolution of all institutions because institutions control who knows what. In the face of change often in the form of new peoples and ideas, it is the initial social structure and the processes of information exchange that will control social stability.

Most of the theoretical work reviewed above as well as this current work, adopt a relational approach, referred to as *relationalism*. This approach is most closely associated with sociologists Charles Tilly and Pierpaolo Donati. Tilly (2002) espouses relational realism or "the doctrine that transactions, interactions, social ties, and conversations constitute the central stuff of social life." Donati (2011) takes this further by stating that “society 'is relation' and does not 'have relations' "and that relationships are the appropriate units of analysis for understanding the social structure. This particular perspective requires a shift in thinking, away from the viewpoints of *substantivalism* and *determinism*. Substantivalism sees individuals or “substances” as the locus of action; relationalism emphasizes practice and that action is always transactional (Bourdieu 1992). Determinism is the perspective that external social structures constrain members of a society and that social structure should be the unit of analysis. From a relationalist perspective, the smallest unit of analysis possible in the study of society is the relationship between a pair of actors.

The above ontological assumptions of relationalism transform epistemological considerations in the study of social stability. Social stability is studied in terms of the *dynamics* underlying network configurations, fields of forces, or social forms, rather than individual variables (Dépelteau and Powell 2013). Relationalism avoids debates about agency and social structure by considering social relation as the base unit underlying social structures and social forces (Donati 2011).

The Relevance of Social Networks

Interactions between socially organized species like humans can be represented as complex networked systems composed of interconnected and dynamic actors (Barabási 2002.) Archaeologists have proposed that the particular networked patterns of social exchange of past peoples are responsible for aspects of the formation of the archaeological record and that this record can be used to infer the social interactions responsible for its creation (Meskell and Preucel 2008; Wandsnider 1992; Wiessner 1983; Braun and Plog 1982; Renfrew and Shennan 1982). The shifting, patterning of styles and material inequalities and the relationships among them have served as archaeological proxies for the types of networked relationships existing between communities and the nature of socio-political complexity at the regional scale. Moreover, several archaeologists have proposed that the types and scales of social networks that a society exhibits have a profound influence on the evolution of social complexity (Bernabeu et al. 2017; Bernabeu et al. 2013; Coward 2013; Gamble 2007; Price and Feinman 1995; Renfrew et al. 1974). These complex interactions can be studied effectively in the form of a social network (Mills et al. 2013; Wasserman and Faust 1994).

A social network is just a quantitative, logical model for what archaeologists have often treated as the study of regional interaction with a crucial added advantage—the study of social networks allows the formalization of the processual links between the interactions of people or groups and the production of the emergent, material record (White 2012). In this project, relationships are represented by the flows of goods or information between sites. VBA architectural patterns suggest that settlements consisted of one or two tightly integrated household groups with primarily domestic functions and thus sites, rather than individual people, can serve as the locus of integrated action in this project (de Pedro Michó 1998). The opportunities for these interactions are affected not only by exogenous, environmental contexts but also endogenous, social mechanisms (tests for both of which will be described later in the Framing Hypotheses section and Methods Chapter) (Vaarst Anderson 2011; Feinman and Garraty 2010; Polanyi 2001; Uzzi 1997; Granovetter 1985). In particular, this research elucidates the role of endogenous mechanisms of social cohesion in maintaining social stability.

Following Durkheim and later sociological research, it has been demonstrated that multiple paths to social stability exist and the particular evolution of these paths may be responsible for a society's long-term resistance to change (Lewis and Weigert 1985). Subsequently, recognizing the mechanisms governing these paths is vital to understanding the evolution of social complexity.

This research uses formal, abstract modeling techniques from Network Science, the study of relational data, to understand the mechanisms of social stability. The use of network techniques has become increasingly common in archaeology by way of Social Network Analysis (SNA), typically in the form of network, descriptive statistics like clustering coefficients and degree distributions (Brughmans 2013). While these techniques are useful for characterizing resultant social structures, they are limited in their ability to test hypotheses about the driving factors that form these structures (Brandes et al. 2013). However, Network Science is theory-driven and involves a specific commitment to abstracting phenomena into a network where the study of connectedness across individual actors is fundamentally essential to understanding the system as a whole.

Research in Network Science shows that tendencies to form social ties at the scale of pairs of actors drive the mechanisms of group formation and maintenance. The smallest social relationship possible is the *dyad*—a pair of individuals. The relationship between two individuals, say A and B, is constrained by a style of social interaction, or tendency. A tendency frequently observed in humans is *reciprocity*, where mutual exchange exists. (Note that the term "reciprocity," while in many, useful ways analogous to similar concepts in anthropology, represents distinct behavior between network actors.) If enough time passes, this reinforced reciprocity results in a society characterized by trust, an essential mechanism of social cohesion (Friedkin 2004). If a third individual C enters into a relationship with A, the likelihood that this relationship will be based on reciprocity increases because of A's prior dependency with B. Also, the possibility that C will now form a relationship *triad* increases because of A and C's existing association. This process is sometimes written as "the friend of my friend is also my friend" (Robins et al. 2005). The tendency for triad formation is known as *transitivity*.

Additional tendencies common to human relationships to be analyzed for the VBA are *homophily*, the likelihood of a relationship forming based on some shared attribute, and *multiplexity*, the tendency to connect with the same actors across different interaction networks (Scott and Carrington 2011; Hanneman and Riddle 2005). A tendency toward homophily reinforces a dependency where future connections are dependent on socially balanced connections among existing relationships. A tendency toward multiplexity indicates the sustainability of partnerships. Pairs of actors who interact across multiple types of relationships increase mutual dependency and strengthen mutual trust (Wang et al. 2016). Figure 3.1 pictures some of the structures and processes commonly quantified in SNA.

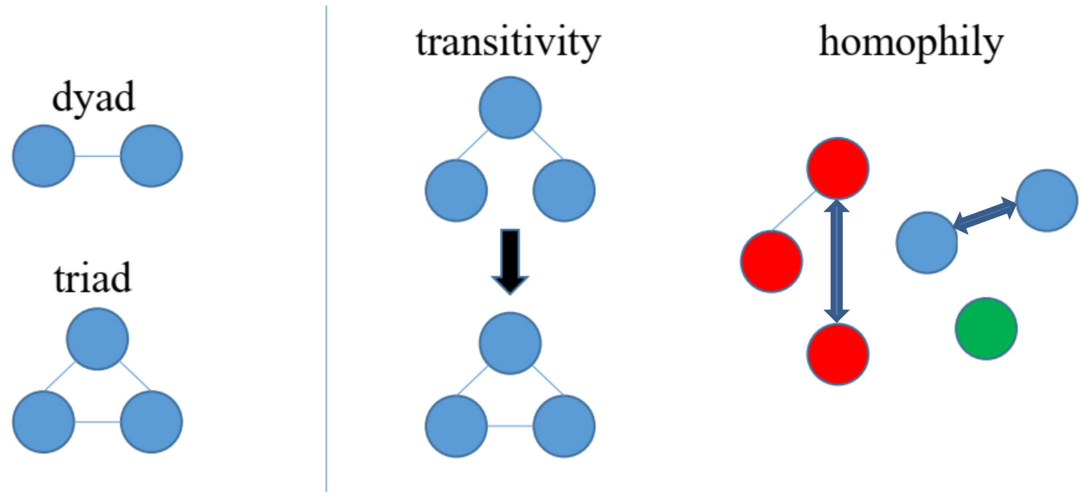


Figure 3.1. Network structures and properties commonly measured in social network analysis. Left: Basic units of analysis of the structural properties of social networks. A dyad is a pair of actors; a triad is a set of three actors. Right: Examples of common social network processes. Transitivity describes the common social tendency for a ‘friend of my friend to be my friend also’ and is the ratio of connected (transitive triads) and potentially transitive triads. Homophily describes the social tendency of ‘birds of a feather flock together.’ In the figure, red actors connect with each other, blue actors connect with other blue actors, while green remains unconnected.

These tendencies can be parametrized, modeled, and tested in combination or independently for their effects on social stability. Different combinations of these tendencies may be responsible for the levels of social stability observed in the VBA. In this project, I abstract these combinations into network models of social relations within six comparable spatial-temporal periods of the VBA to track rates of change in stability and compare these to explanations for the strength of social stability *over time and space*.

Network Science has developed a modeling tool, adept at testing hypotheses about social processes (Handcock et al. 2008). Exponential Random Graph Models (ERGMs) are statistical models for explaining the structure of social networks through hypothesis testing. An ERGM, like a regression model, estimates the size and effect of several independent variables proposed as key in explaining the dependent variable—the network structure. Because this method is not well-known to archaeologists, (see Brughmans et al. 2014 for an exception), the operational characteristics of ERGMs will be described in detail in Chapter 4: Methodology. These tools allow me to investigate the role of cumulative, bottom-up drivers of stability and change, and then relate them to empirical (archaeological), system-level factors more commonly proposed to account for the apparent lack of change in the VBA, such as the geographic distributions of households and communities, and opportunities for inter-societal contact or their lack. Drivers with acceptable goodness-of-fit are linked with the rates of social system change. This process is described further in Chapter 4.

There are clear, positive implications for the use of perspectives and methods of Network Science in archaeology where palimpsests of an incomplete, material record are represented. Individual actors are mostly invisible in the palimpsest archaeological record that comprises the debris of many individuals, often across many generations. Archaeological studies employing descriptive SNA have recognized the biases created by incomplete datasets, where information on the actors or ties between them is incomplete. Thus, these studies have tended to use datasets where relative "completeness" can be demonstrated, where a tie, for example, between sites A and B can be drawn explicitly (Mills et al. 2013.)

However, the abstract modeling of long-term processes does not require this type of explicitness. It does not seek to recreate the structure; it uses quantifiable characteristics of the structure to model possible forces behind the structure. It aims to discover the long-term, cumulative effects of the decisions of pairs of individuals to interact. Therefore, a palimpsest dataset like that in this project, if robust enough to capture overall trends, is ideal for use in Network Science as it has the time-depth to capture the repeated social actions and the development of macro-level processes responsible for social structure over time.

Quantifying Social Relationships

One can imagine that there are various aspects of the relationships between people that can be observed and compared through time—cognitive, cultural, and structural. For example, sharing the same language may be a factor in forming relationships. An actor's capacity to trust might be a factor. Sharing the same belief system and social values may increase the likelihood of a relationship. Inferring belief systems and language systems is often a tall-order in archaeology when we do not have the benefit of speaking with subjects in person. Many of the assemblages that archaeologists work with resemble that of the VBA's which is characterized by a scarcity of materials with ideological elements.

In contrast, measuring the structural dimensions of social relationships and their rates of change is practicable, especially after some of the latest advances in network analysis and theory. Structural dimensions include such quantifiable metrics as cohesion, clustering, the social distance between actors, the balance of power between actors and centralization, and the connectivity of social structures. All that is needed is to measure any of these is a reasonable approximation of the network of relationships between actors that make up the social system under study.

Sociologists have proposed that the structural dimensions mentioned above can constrain or promote social stability (Borgatti et al. 1998). The definitions for each dimension are provided below with a summary of how each dimension relates to social stability. An innovative contribution of this project is the development of quantitative characterization of social stability, what this research calls a Social Stability Index (SSI). Chapter 4: Methods contains the operational definitions for each dimension. Chapter 4 also explains the way this research uses these dimensions to develop the SSI in a way that measures social stability through time and space.

Vulnerability

Network vulnerability refers to a measure of the togetherness among actors within a network, or the ability of the network to withstand attacks. Network vulnerability includes the number of cut-points (or nodes that if removed would disconnect the network) and the division of a network into competing sub-networks.

Clustering

Social structures with clustering tend to be more stable. Why is this case? Imagine three actors, A, B, and C. If actor A trusts actor B, and actor B trusts actor C, it is more likely that actor A will trust actor C. Clustering reinforces bonding and trust in future exchanges and in turn, the stability of the social relationship between the three actors.

Distance

Social distance is defined as a count of how many steps on average, each actor takes to conduct an interchange with another actor. Again, imagine three actors A, B, and C. A talks to B and B talks to C, however, there is no relationship directly between A and C. The path between A and C is longer than between A and B. A social structure can be characterized by the average distance between actors.

Hanneman and Riddle (2005) state, “Where distances are great, it may take a long time for information to diffuse across a population…The variability across the actors in the distances that they have from other actors may be a basis for differentiation and even stratification. Those actors who are closer to more others may be able to exert more power than those who are more distant.” In other words, greater distances provide more opportunities for destabilization and change.

Centralization and power

What are the consequences to social stability if power is distributed unevenly? Conflict theory, which derives from Marx’s writings, explains the relationship between instability and power (Collins 1975). Imbalances in power cause constant competition for power, and from this perspective, constant conflict drives social change (Knapp 1994). Societies with imbalances of power are generally less stable, especially if a counterbalance is lacking (Emerson 1962). In the field of international relations, the ‘balance of power,’ or the equitable distribution of power through the counterbalancing of powerful nation-states, maintains global stability (Levy 2004).

Connectivity

Connectivity, in this research, describes the size of the social structure (number of actors), the number of relationships each actor possesses, and the number of possible relationships. Again, turning to Hanneman and Riddle (2005), “The number and kinds of ties that actors have are a basis for similarity or dissimilarity to other actors -- and hence to possible differentiation and stratification.” Connectivity affects stability by changing the number of opportunities that an actor has for interaction.

Structural cohesion

One network measure is a particularly useful way to quantify the structure of social stability—*structural cohesion*. Structural cohesion is “the minimum number of actors who, if removed from a group, would disconnect the group” (Moody and White 2003). It a measure of network vulnerability and therefore a good proxy for social stability. Groups often form connections with other groups, both heterarchically and hierarchically. Thus, a cohesive group can nest within other groups or groups can exist side-by-side with each other. Many cohesive sub-groups can be nested within the population as a whole. Actors interacting within dense, nested clusters of groups have different sets of resources and constraints than those who are not embedded in such networks. We can then argue that the structure of these nested relationships is an effective method to operationalize the structure of social stability. Chapter 4: Methods describes the algorithm used to quantify the structure of network cohesion.

The Evidence for Stability in the Valencian Bronze Age

As discussed in Chapter 2, Tarradell differentiated the VBA from the neighboring and materially dynamic Argaric (ca. 2300-1550 BCE) in the 1960s, by noting the VBA’s material uniformity (Martí Oliver and de Pedro Michó 1995). He listed several characteristics of the VBA that suggest cultural homogeneity through time and space: 1) sites are numerous and small; 2) sites are located on difficult to access hills and are fortified; 3) interments were of single individuals in nearby caves; 4) ceramics have little decoration (Gil-Mascarell and Aranegui 1981; Tarradell 1965). The location and number of sites in this analysis are shown in Figure 3.2.

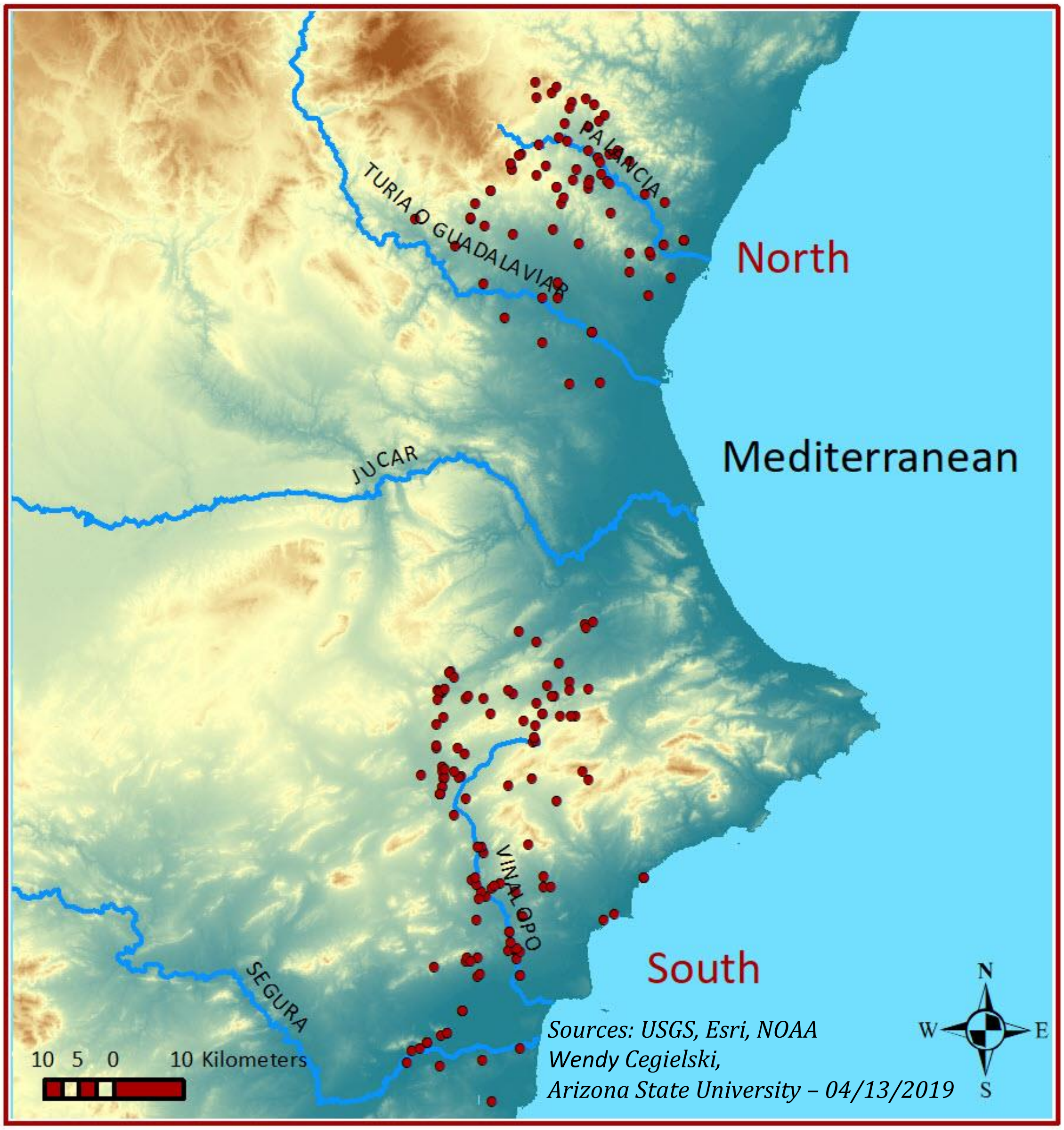


Figure 3.2. Close-up Digital Elevation Model of Valencian Bronze Age region with locations of sites utilized for this study. Northern and Southern Regions indicated.

Archaeologists now ascribe the cultural uniformity described by Tarradell to the Early and Middle VBA, a span that covers the 700 years between 2200-1500 BCE. The Late Bronze Age (1500-1100 BCE) is marked by a change in most of the archaeological features noted above and others (i.e., new ceramic styles, new technologies, increasing site elevations, the spread of bronze technology, techno-economic changes from agriculture to livestock). Several reviews in the 1990s of the archaeological evidence have questioned the level of "homogeneity" traditionally posited for the VBA. Gil-Mascarell (1995), Hernández Pérez (1985), de Pedro Michó (1998), Martí Oliver and de Pedro Michó (1995), and García Borja and Pérez Jordà (2012) all cite examples of variation in material culture, notably variation in site elevation from one meter to 350 meters above sea level, with low lying sites in the mountains, caves, and accessible, open-air plains. However, these authors do not agree on the extent of material variation or interpretative explanations for these changes. Many of these disagreements are rooted in the lack of large-scale, comparative studies that focus on the relationships between sites or go beyond snapshots of variability in material culture. One of the goals of this project is to measure the rate of social change in a comprehensive, comparative study of the Early to Middle VBA periods, and compare this to the rate of change in the Late and Final Bronze Age periods. Additionally, it investigates the social forces potentially driving these differences in social stability.

Even with consideration of the variation noted above by Iberian researchers, changes in the Early and Middle VBA periods appear modest and less vectored when compared to the developments within the Argaric, which coexisted with Bronze Age Valencia during the second millennium BCE. Social change in the Argaric is defined by a definite increase in several characteristics often related to increasing social complexity: 1) the development of site hierarchy; 2) more significant levels of political ranking in burials; 3) more highly organized agricultural production; 4) increasing warfare; 5) and the development of hilltop fortresses (Ramos Millán 2013; Scarre 2013; Gilman 1991).

The level of evidence for social change is so substantial that some have argued that the Argaric developed into a state, based on class-based wealth and division of labor (Gilman 2013; Lull 2000, 1983). While the material culture of the Argaric in this project is not analyzed in this project, it is still worthwhile to ask what might have caused the difference in rates of change in these two, geographically adjacent trajectories.

Explanations for changes in social complexity in the Eastern Iberian Bronze Age have derived mainly from evidence from the Argaric and applied to the VBA. Hence, the lack of change in social complexity in neighboring regions outside of the Argaric is attributable to the absence of triggers of change identified for the Argaric (Brodsky et al. 2013). However, some of the most common explanations proposed by Iberian archaeologists to explain social change are of limited value for understanding drivers of social stability. A commonly proposed trigger of change in the Argaric is the introduction of bronze smelting, the Argaric region having comparably more raw copper and tin sources than the Valencian region. Differential access to these resources gained by aggrandizing elites has been argued to explain the rapid development of social hierarchy in the Argaric culture (Lull 1983). Thus, the basic building blocks to cause changes to the means of production and promote social transformation were present in the Argaric region but not in the Valencian region (Gilman 1995, 1975). The appearance of bronze metallurgy is neither a sufficient nor necessary explanation for the ongoing maintenance of stability in the face of change. There is social change in societies without bronze and societies where bronze metallurgy is not associated with apparent changes in social complexity (Amzallag 2009). Additionally, other types of metallurgy (gold and copper) long preceded the advent of bronze metallurgy in the Valencian region. Thus, the introduction of metallurgy by itself seems suspect as a mechanism of stability or change.

The same can be said of climate as an explanation. Several researchers (Micó et al. 2010; Santiago et al. 2010) believe that the regional climate of Valencia was less variable than that of the neighboring Argaric, and proposed that variable climates provide more opportunities for aspiring elites to monopolize patchy, productive land. This absence of climate variability explains the VBA's comparative lack of social complexity. The underlying assumption of prior explanations is that the lack of change is due to stable weather, but can a pleasant climate be the cause of stability? Other Bronze Age cultures with less variation in climate than the Argaric region show greater increases in social complexity (e.g., Mycaneans, Hittites) (Kaniewski et al. 2013).

Traditional accounts of the VBA focus primarily on system-scale contextual factors like land accessibility and geographic proximity to (or isolation from) more socially complex societies like the Argaric or Phoenician trading colonies. Kristiansen and Earle (2010) discuss the potential for social change in terms of constraints on centralization in parts of Mediterranean Europe like the VBA. Semi-autonomous households can resist attempts at centralized control in these areas with dispersed productive resources (Scarre 2013; Carneiro, 1970). Gilman (1991) additionally has emphasized that the overall greater arability of the land in the Valencian region did not require intensification of agriculture as populations increased, eliminating the need for the central control of labor that could require increases in social complexity. However, this focus overlooks the diverse interactions among social actors that can drive the dynamics of human societies—promoting stability or change.

Perhaps the explanation for change in the Bronze Age Mediterranean Iberian Peninsula with the most extensive history of discussion is that of culture contact. For many decades before the 1980s, Iberian archaeologists widely attributed changes in social complexity to culture contact in the Bronze Age with the Phoenicians and Greeks (Chapman 2005). With advances in dating methods, this explanation has been partially dismantled–the dates of culture contact do not match one to one with changes in social complexity (Bernabeu Aubán and Martí Oliver, 1992; Bernabeu Aubán 1984; Llobregat, 1973). While intrusive elements primarily are found in the Late and Final Bronze periods from the Mediterranean and interior (Cogotas) and northern (Urnfield) Iberian cultures, it is not clear what effects if any, these influences had on the social trajectory of the region.

Framing Hypotheses

Considering the conceptual and theoretical frameworks noted above as well as prior research on the VBA, I generate testable expectations of drivers of the rates of change in social systems, accounting for both social and geographic factors.

Hypothesis 1 Social Processes

The stronger the reinforcement of group norms (transitivity), of similarity in relationship (homophily), and/or of overlapping affiliations (multiplexity), the more stable the social system (Rogan 2013; McPherson et al. 2001; Burt 2000; Cook et al., 1983; Verbrugge 1979).

Test implication: The higher the level of transitivity, homophily, and multiplexity in an observed archaeological network, the better the fit to a social system with a slow rate of change in network structure.

Hypothesis 2 Geographic Isolation

The more geographically isolated, the less likely the system will change. Isolated groups have less opportunity for diverse exchange opportunities (Alderman 2012).

Test Implication: Research on the VBA has suggested that geographic accessibility to more complex societies–the Argaric in the south and the seafaring Phoenicians–may influence rates of social change (Hernández Pérez 1997). Thus, with an increasing average distance from the south or the coast as measured from archaeological site locations, the better the fit to a social system with a slow rate of change.

Hypothesis 3 Neutral

The system appears to change randomly, due to particularistic, local factors. This hypothesis acts as a null model to evaluate the other hypotheses (Brantingham 2003; Connor and Simberloff 1986).

Test implication: Social networks do not appear to covary with any of the above factors.

The following chapter outlines the methods used in this research to address each of the above hypotheses as well as preparatory procedures including data collection, cleaning, and exploratory data analysis.

CHAPTER 4

METHODS

Research Design

For the theoretical approach employed here, social stability is not an inherent property of a social system; it is embedded over time through the accumulation of social dependencies between individuals who choose to form a relationship. The particular formations of these dependencies result in different levels of social cohesion, akin to "social glue" that promotes or thwarts social stability. Therefore, social stability is dependent on understanding the relationships between individuals and how these translate into emergent forces of social cohesion. It mandates that any study of social stability quantify it not only through time and space but formalize evolutionary links between behavior at the scale of pairs of individuals and global social structure. This project provides such a study combining methods developed in sociology, Network Science, and archaeology to understand the apparent social stability of the VBA in eastern Spain.

Research by Iberian archaeologists indicates material homogeneity, possibly representing a social system lasting with little change for nearly 700 years (2200-1500 BCE). After dividing the entire VBA region into two sub-regions and three time periods (henceforth referred to as the six chrono-regions) to compare stability over time and space, this research: 1) creates networks derived from empirical archaeological data, using Network Science techniques for each period; 2) measures the social stability and structural cohesion of each observed network using network statistics; 3) uses Exponential Random Graph Modeling, a formal network technique to statistically model populations of hypothetical networks that could be generated by different mechanisms of social cohesion in each period; 4) performs goodness-of-fit tests between modeled networks and the observed networks; and 5) associate measures of stability with the best-fitting set of explanatory models.

These tools allow the investigation of the role of cumulative, bottom-up drivers of stability and change that then are related to empirical (archaeological), system-level factors more commonly proposed to account for the apparent lack of change in the VBA, such as the geographic distributions of households and communities, and opportunities for inter-societal contact or their lack. Drivers with acceptable goodness-of-fit are linked with the rates of social system change.

Order of Operations

1) Data collection
2) Data munging and cleaning
3) Chronological attribution/Empirical Bayesian Estimation
4) Initial Data Analysis
    a) Summary statistics of the dataset
    b) Distributions
        i. Kernel density of assemblage richness
        ii. Sample size effects
5) Mapping
    a) Geographic coordinates
    b) Elevations
    c) Visibility analysis

6) Network Inference

   a) Creation of raw counts matrices

   b) Drop all artifact instances < 1 or 2

   c) Calculate the correlation matrix

   d) Calculate the four quartiles of correlation matrix values

   e) Threshold the correlation matrix; pairs of sites with correlation values in the second through fourth quartiles calculated in e) have a ‘relationship.’

   f) Create a binary adjacency matrix from thresholded values. “1” = relationship’; “0” = no relationship.

   g) Generate network

   h) Add node attributes to the network

7) Assess robusticity to missing data through network subsampling and replication

8) Network visualization and mapping

9) Network descriptive analysis

10) Multiplex analysis

11) Exponential Random Graph Modeling

Data Collection/Data Munging and Cleaning

Data collection began with the goal of identification of assemblages and artifacts appropriate for a robust, inclusive, and regional social network analysis. Therefore, conditions for elimination were few to include as many sites as possible. To be included in this analysis, a site must have been classified previously as Bronze Age, had to possess a geographical coordinate, and its assemblage needed to contain at least one artifact commonly ‘typed’ by Iberian researchers. The latter condition permits the use of data classifications already employed in publications. The artifact classes used in this study are: 1) ceramics and their decorations; 2) utilitarian metal objects; 3) adornments of shell, bone, stone, metal, and ivory; 4) bone tools; 5) utilitarian stone objects. This research also incorporates rare material items including amber, pasta vitrea, mother of pearl, lignite, and ochre.

VBA sites were identified using the Valencian provincial government's archaeological database *Conselleria de Educación, Investigación, Cultura y Deporte de Generalitat Valenciana*, published compendiums, as well as through word of mouth from Spanish researchers at *la Universidad de Valencia*, *el Museo de Prehistoria de Valencia*, *el MARQ Museo Arqueologico de Alicante*, and *la Universidad de Alicante* (see acknowledgements for the list of people involved in these endeavors.) The major published compendiums utilized are *La metalurgia prehistórica valenciana* by Simón García (1998), *Asta, Hueso Y Marfíl. Artefactos óseos de la Edad del Bronce en el Levante y Sureste de la Península Ibérica (c. 2500 – c. 1300 cal BCE)* by López Padilla (2011), *La Edad del Bronce en Alto Palancia: yacimientos y cuevas* by Palomar Macián (1995), *El Poblamiento durante el II Milenio a.C. en Villena (Alicante)* by Jover Maestre et al. (1995), and *La Lloma de Bextí (Paterna, Valencia): Un Poblado de la Edad del Bronce* by de Pedro Michó (1998).

Data from VBA sites were entered into a Microsoft Access database over the course of a year. In-field data collection on unpublished collections at *el Museo de Prehistoria de Valencia*, the MARQ, and *el Museo de Sagunto* was completed over six months. The rest of the data were retrieved from published material. Geographic locations in the form of Universal Transverse Mercator (UTM) coordinates were obtained from the provincial government's database, publications, and personal requests to Spanish researchers. Site sizes and radiocarbon dates were gathered from publications and Dr. Joan Bernabeu at the Universidad de Valencia. After data collection was complete, the data were exported and transformed into pivot tables within Microsoft Excel. All data were summarized using pivot tables in the form of raw counts.

The table in Appendix A contains the information collected for every site and artifact. The table is available digitally at *http://www.diggingdenver.net/*.

The designation of a site as Bronze Age can be complicated if no evidence for bronze is present. However, classification by Spanish researchers is reliable enough to act as a general heuristic. Thus, chronological designations in publications as well as from the provincial government's database were used to select Bronze Age sites. While over 800 Bronze Age sites initially were identified, this number was narrowed down to sites located within natural corridors identified in pilot research as routes of frequent contact. Iberian archaeologists, back to Tarradell, have noted material similarities along these natural corridors and thus have employed the corridors as analytical frameworks (Martínez Monleón 2014; Palomar Macián 2004; García Bebia 1994; Soriano Sánchez 1985; Tarradell 1965). Additionally, with some exceptions, most of the sites located outside of the natural corridors do not contain sufficient material for network analysis. Figure 2.12 indicates the natural river corridors—the Palancia, the Turia, the Júcar, the Vinalopó, and the Segura. A total of 212 sites were deemed appropriate for use in this research. The associated river valley for each of these sites was recorded for comparative regional analysis.

The chronological designation of VBA sites was refined further into the categories of Early Bronze (EB), Middle Bronze (MB), Late Bronze (LB), and Final Bronze (FB), or some combination of these. Iberian researchers often provide an estimated chronological attribution when recording a site based on material evidence. However, VBA sites are notoriously difficult to place in time. The EB and MB sites are difficult to separate using material evidence only. Therefore, additional techniques were employed to cross-check chronological attributions. These are described later in this chapter under the heading "Chronological Attribution."

For the most part, sites in this analysis are single sites. Where researchers report multiple, chronological contexts at the same site, each context receives a separate designation. Sites include both open-air sites and caves (usually but not always used as burial locales); however, all site types were analyzed together in this analysis for the following reasons: 1) the cave and open-air assemblages are similar; 2) the caves are associated with nearby, contemporaneous habitations; 3) the removal of caves sites would have eliminated much useful data; 4) the social networks in this analysis are inferred and are presented as general patterns. The patterns are not intended to prove actual links between caves and open-air sites.

Procedure for collection of ceramic data

The following process was used to classify all ceramic data. Decoration types for ceramics were recorded for any sherd or vessel with a discernible decoration type in this analysis. The decision to use ceramic decoration as a classifier is based on research that suggests that ceramic decoration can serve as a proxy for social interaction (Gosselain 2000; Hegmon 1998; Carr 1995). The repertoire of decorations on VBA ceramics is limited, however, and the terms that archaeologists use to describe ceramic decorations are largely consistent through time and across researchers. Yet, some standardization was necessary. The details of the ceramic decoration classification system are found in Appendix B.

In general, VBA peoples utilized four techniques for decorating ceramics—incisions, impressions, applique, and paint. Incisions and impressions are found on both the body of vessels as well as on vessel rims. Appliques and paint are located on the body of vessels. This research distinguishes between decorations found on the vessel rim and those on the vessel body.

Incisions range in complexity from simple linear features to more complex, representative designs. Figure 4.1 presents representative examples of incisions typically found on vessel rims. Figure 4.2 presents those typically found on vessel bodies.

(a)

(b)

(c)

(d)

Figure 4.1. Ceramic rim decorations—Incisions. (a) Diagonal wide incisions (diagonal wide incisions, oblique to edge); (b) Zig-zag incisions (short incisions on the rim in zig-zag pattern); (c) Vertical incisions under border (short vertical incisions just under rim); (d) short incisions (small incisions made with a tool).

(a) (b)

Figure 4.2. Ceramic body decorations—Incisions. (a) Fine incision (simple incisions); (b) Incisions with representative design (fine incisions with a concrete design).

Also, incision motifs exhibit chronological trends. Incisions are virtually absent in the Early VBA, appearing in more frequency and greater complexity by the end of the Middle VBA through to the Final VBA.

Impressions consist of simple designs made with a tool or with fingers or thumbs. Impressions range from linear to circular. Impression motifs also exhibit chronological trends. Unlike incisions, impressions do occur during the Early VBA, largely confined to vessel rims. Impressions appear in more frequency and greater complexity by the end of the Middle VBA through to the Final VBA. Figure 4.3 shows a range of typical examples of impressions on vessel rims. Figure 4.4 shows impressions on vessel bodies.

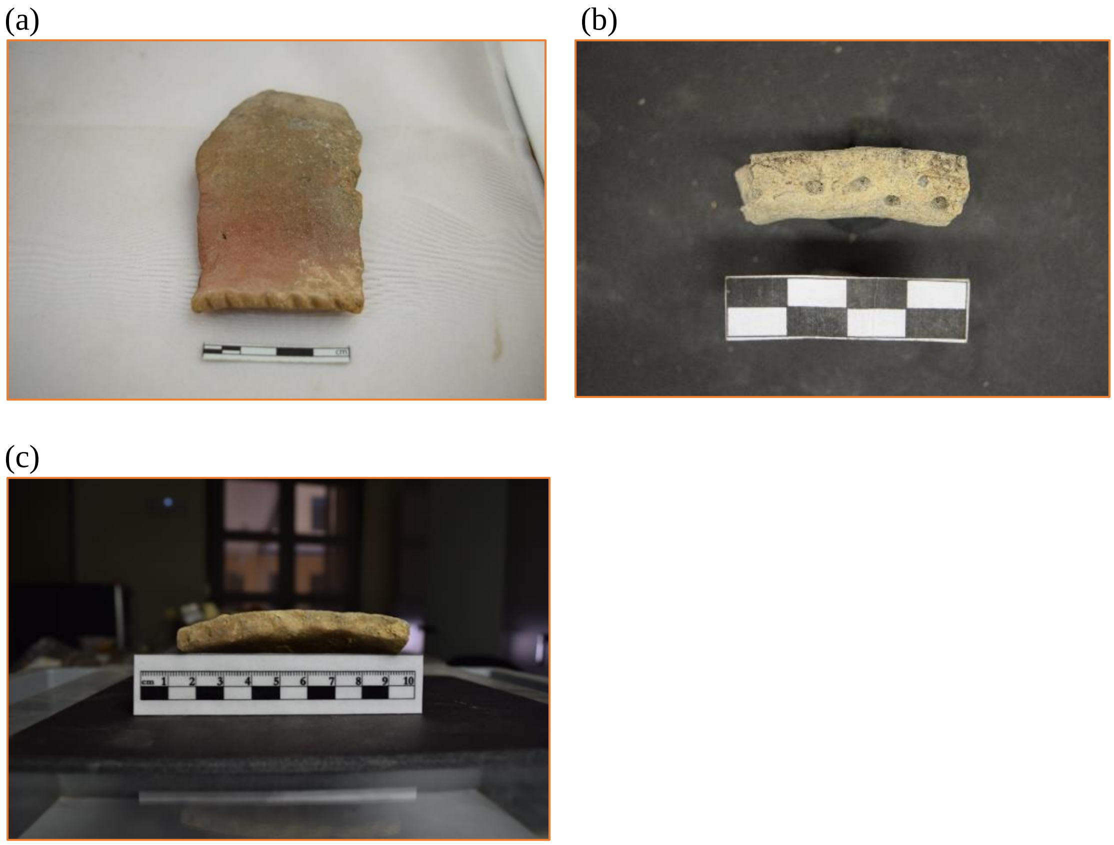


Figure 4.3. Ceramic rim decorations—Impressions. (a) Indentations (impressions that make an undulating effect; often includes a fingernail mark); (b) Punctates (tiny circular impressions); (c) Finger or thumb impressions (impressions made with fingers or thumbs).

(a) (b)

(c)

Figure 4.4. Ceramic body decorations—Impressions. (a) Simple tool impression (impressions made with a tool); (b) Punctates (tiny circular impressions). (c) Vessel with both impressions and incisions (Image from el Museo de Prehistoria (*La Lloma de Betxi (I) at http://www.museuprehistoriavalencia.es/web_mupreva/sala/?q=es&id=114*.)

Appliques typically come in two forms—*cordones* and *mamelones*. *Cordones* are long cables of clay applied to the body of the vessel either horizontally or vertically. *Cordones* were decorated with incisions or impressions or were undecorated. *Cordones* characterize the late Middle VBA and onward in time and are found in much greater frequency in the Northern VBA. Mamelones are small nodes found in multiples on the vessel body. This type of applique appears during the Late and Final VBAs. Figure 4.5 shows a range of typical examples of *cordones* and *mamelones*.

(a) (b) (c) (d)

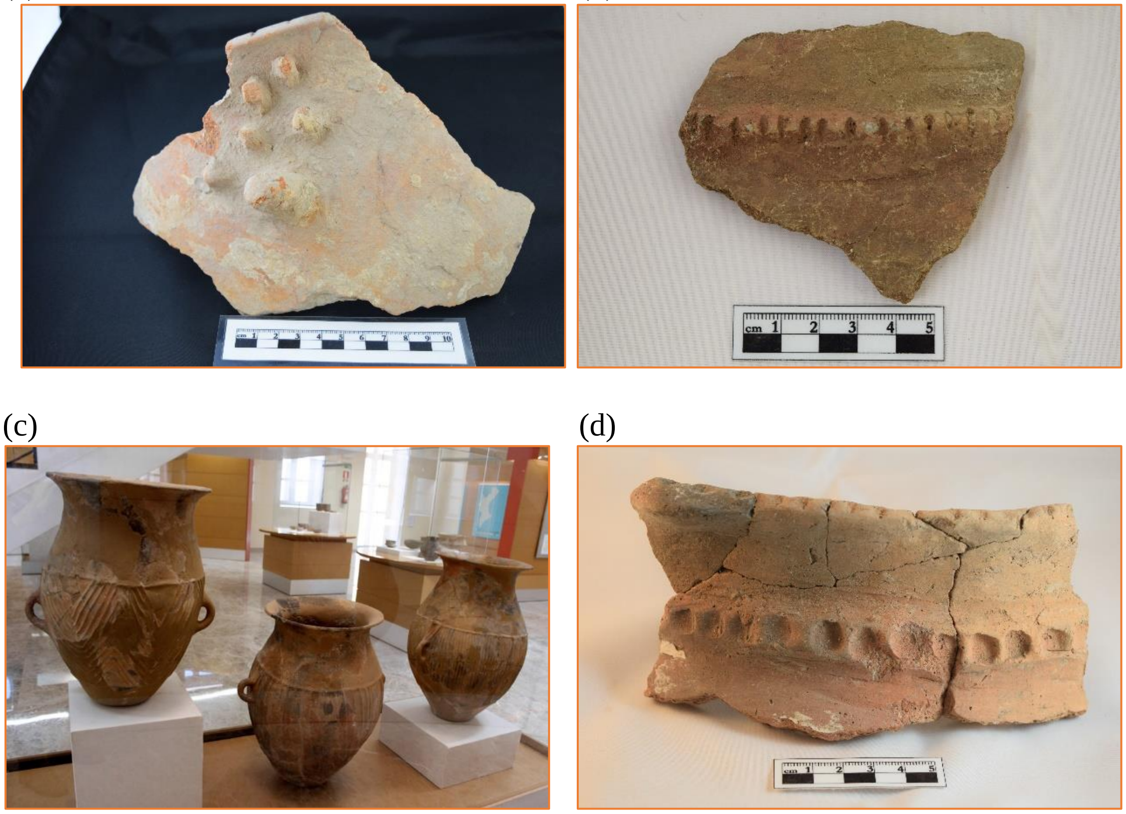


Figure 4.5. (a) Multiple mamelones (large nodes).; (b) Cords with indentations (cords with impressions that make an undulating effect; often includes a fingernail mark); (c) Cords no decoration (cords with no decorations) (Image from *el Museo de Prehistoria at http://www.museuprehistoriavalencia.es/web_mupreva/gallery/?q=es&t=digital&m=&id=[48097,51200,48087,48094,49475,48076,51196,49473,49476,49474,48096,14337,48084,49478,48092,51197,51198,48089,48091,48099,49477,14337,51195,51199]&gallery_title=Vitrina+64*); (d) Cords with finger or thumb impressions (cords with impressions made with fingers or thumbs).

Besides decorations, total counts of ceramic sherds were recorded (decorated and undecorated) for each site to be used to evaluate sampling bias.

Procedure for collection of metal data

The publication *La Metalurgia Prehistórica Valenciana* by Simón García (1998) contains the most comprehensive information currently available on VBA metals. Additional data on VBA metals recovered after 1998, was obtained from other publications. Material classes of VBA metals used here are: 1) tin bronze; 2) copper; 3) copper/bronze indeterminate; 4) lead (rare); 5) gold, and 6) silver.

Two types of bronze are typical for Mediterranean Bronze age sites—tin bronze and arsenical bronze, both of which are alloys. Tin bronze combines copper and tin, while arsenical bronze is an alloy of arsenic and copper. Both tin and arsenic add strength and casting versatility to bronze alloys. Archaeologists distinguish arsenical bronze and tin bronze through chemical analysis. Simón García provides chemical analysis results for hundreds of metal items. For this research, all chemically analyzed 'copper-bronze' objects that possess a tin composition greater than 3% were classified as bronze. The presence of tin bronze is chronologically sensitive, making this distinction useful. Any items that could not be classified as tin bronze are reported as copper/bronze indeterminate. Arsenic can occur with many copper ores naturally making it difficult to differentiate intentionally-produced arsenical bronze from copper with naturally-occurring arsenic. Therefore, those objects and any other object where the copper/bronze distinction is uncertain were classified as copper/bronze indeterminate. VBA peoples utilized copper and bronze in similar contexts. Therefore, analyzing them together is sensible.

VBA peoples used copper and/or bronze to produce a variety of items including daggers, axes, chisels, knives, halberds, points, punches, and adornments like beads, bracelets, and rings. Gold and silver were used for adornments like bracelets, rings, earrings, and beads. Bowls and jars made of gold or silver are found only among the items of the Tesoro de Villena.

Simón García's publication includes data on morphological types, physical dimensions, and chemical analysis, all of which were collected and transformed into spreadsheet format by Cole Von Roeder, an ASU undergraduate student. Objects recovered after 1998, the date of Simón García's publication, were evaluated according to Simón Garcia's template. The list in Appendix C translates Simón García's general morphological classifications. Figure 4.6 pictures a few examples of bronze/copper objects from the VBA.

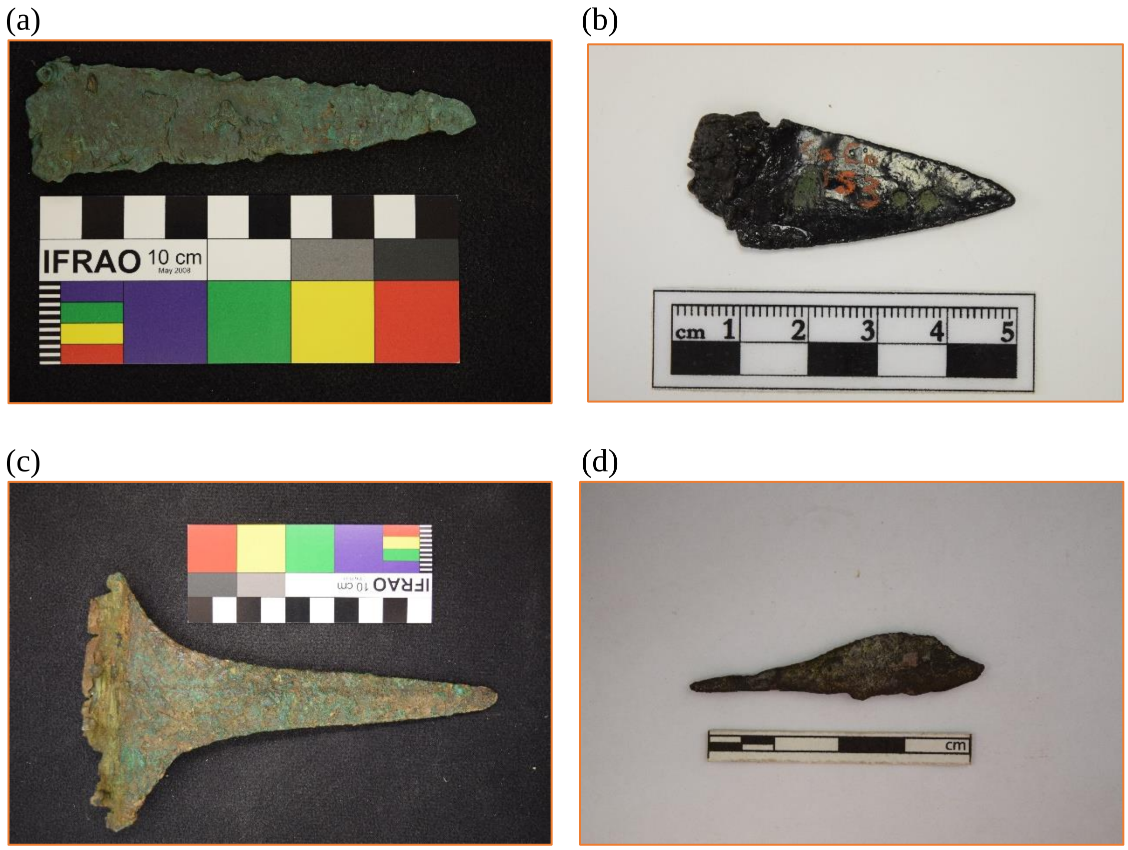


Figure 4.6. Bronze/copper objects. (a) *Cuchillo con remaches* (knife with rivets) ; (b) *Puñal con remaches* (dagger with rivets); (c) *Alabarda* (halberd); (d) *Punta de flecha* (point).

Procedure for collection of bone, antler, and ivory data

Artefactos Óseos de la Edad del Bronce en el Levante y Sureste de la Península Ibérica (c. 2500 – c. 1300 cal BCE) by López Padilla (2011) contains most data on bone, antler, and ivory items from the VBA. The author's dissertation classifies the primary worked bone and antler finds throughout the Valencian region by morphology and material type. Chapter IV of López Padilla's work discusses these classifications in narrative form, requiring a transformation into the Microsoft Access database. All materials not listed in this publication were typed according to López Padilla's classifications. Unworked bone and antler materials were not recorded. Appendix D summarizes these classifications. Figure 4.7 pictures some examples of bone, tooth, or ivory objects from the VBA.

VBA peoples across the region used bone for a variety of tools including punches, spatulas, chisels, scrapers, beads, pendants, buttons, saws, hair combs, needles or pins, and handles. Ivory was used principally for adornments like V-perforated buttons, but also bracelets, combs, pendants, and handles. Boar tusks were used for pendants.

Figure 4.7. Examples of bone, ivory and tooth artifacts. Bones: (a) *Espatula o alisador* (Spatula or smoother); (b) *Punzón* (punch); (c) *Cuenta* (bead). Ivory: (d) V-perforated button; (e) Bracelet. Tooth: (f) *Colmillo pendiente* (boar's tusk pendant).

Procedure for collection of all other artifact classes

Morphological class, material type, and counts were collected for all other artifacts. Appendix E lists the classes of items and Figure 4.8 pictures examples of shell artifacts and stone artifacts. VBA peoples used shells for adornments like necklaces, beads, and pendants but also buttons. Stone is found in the form of utilitarian tools like axes, adzes, plaques but also for adornments like beads, pendants, and bracelets.

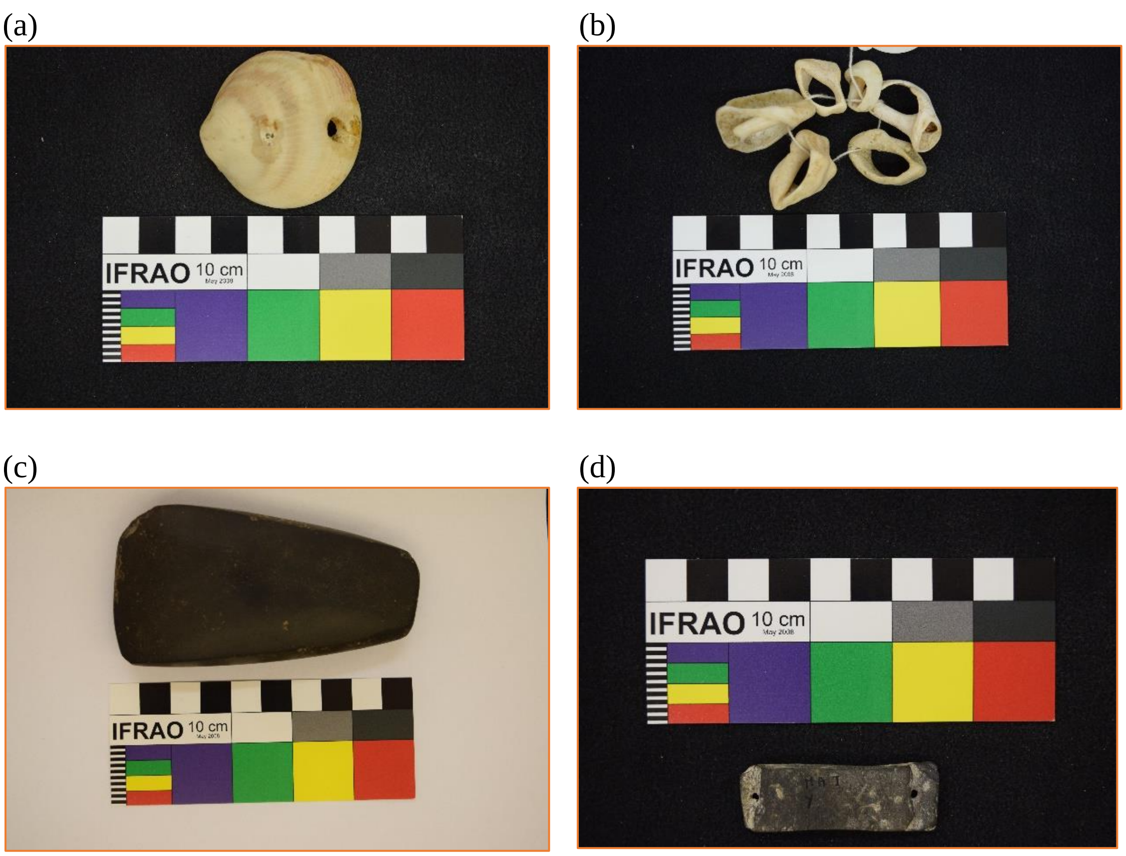


Figure 4.8. Examples of artifacts of other material types. (a, b) Shells with perforations; (c) Stone ax; (d) Stone archer's brace.

Mapping, elevation, visibility, and site size

To evaluate spatial relationships and obtain spatial variables for analysis, maps of site locations were created outside of the context of network analysis. Maps were produced in ArcMap/ArcGIS Desktop 10.7 from ESRI using European Datum 1950 (ED50). The maps show site locations layered with topographical and elevation data. ArcMap's online map repository *https://www.arcgis.com/home/webmap/viewer.html* provided topographical maps containing river and provincial shapefiles. Digital Elevation Maps (DEMs) for the Valencian region were downloaded from *Centro de Descargas* at *Centro Nacional de Informacion Geografica* (http://centrodedescargas.cnig.es/CentroDescargas). The suite of raster mosaic tools available in ArcMap/ArcGIS Desktop was used to process and stitch the maps together.

Maps layered with network diagrams were produced in RStudio utilizing a series of R packages. Appendix F contains the R code for map production with networks. The R code is available digitally also at *http://www.diggingdenver.net/*. For map production in R, topographical maps were downloaded from Google Maps, 2019. The use of Google Maps required the conversion of all UTM coordinates to latitude/longitude in decimal degrees.

Iberian archaeologists have noted that VBA sites tend to be located at medium elevations, trending toward higher elevations later in time. To evaluate these trends further, as well as to include site elevation as a variable in network modeling, the elevation for each site was extracted from the DEMs in ArcMap/ArcGIS Desktop using ArcMap's Spatial Analyst Tool. The order of operations in ArcMap is *ArcToolbox >Spatial Analyst Tools>Extraction>Extract Values to Points*.

Iberian archaeologists have observed that VBA sites are located on hilltops generally, but they have not agreed on an explanation for this. The most recent studies suggest that the locations are for strategic control of visible catchment areas. Whether or not strategic oversight of a catchment area relates to the structure of social networks through time and space in the VBA is an open question. Therefore, this research tested the hypothesis that the size of a viewshed is correlated meaningfully with a site's connectivity. Visibility for each site was extracted using the custom ArcMap toolbox called 'Calculate Visible Area' (Mackey 2012) available at *https://www.arcgis.com/home/item.html?id=912674d8f8db42abb3613a9befe8a3d4*. Visibility analysis can be used to determine visibility from particular observer locations. In this particular case, the "Calculate Visible Area' tool calculates the area visible within 1 km of each site location. Each site was assigned a "Visibility" value equal to the number of square meters visible to the site within 1 km, based on the site's location on the DEM. A higher value means that the observers at the site can see, and ostensibly control more geographic area. The surface offset is set to 1.5 to account for a human observer's eyes at a 1.5-meter high offset from the ground.

Finally, this research tested the hypothesis that site size correlates with patterns of social network connections. Logically, one could argue that with larger site sizes, one could see increases in the number of connections that a site possesses. Additionally, Iberian archaeologists propose that site size increases through time due to the processes of population aggregation. To test both hypotheses, site size in meters squared was recorded for all sites for which this value is published.

Data exclusion

Sites excluded from this analysis lacked the materials needed for network analysis. As already stated, 800 sites qualify as Bronze Age, 212 of which had the necessary materials and fell within the boundaries of the research area defined earlier. Every effort was made to count all relevant, artifact instances in every collection. The only exception is the collection for the site of Tabayá. This collection is immense and mostly unpublished. Thus samples of the ceramics are capped at 150 examples per archaeological context. Tabayá's ceramic collections are organized by archaeological context (area of the site where the artifact originated) and level. A random sample of 150 decorated ceramics was drawn from every archaeological context housed at the museum.

Additional site exclusions were made based on known geographic patterns of exchange. This analysis does contain sites associated with the Júcar River corridor, but for the most part, Júcar River sites are scarce and contain little to no information about their material assemblages. For efficiency and time's sake, these sites were eliminated. Other sites excluded include sites outside of the region bounded by the modern cities of Almansa, Villena, Canals, Bocairent, and Onil. A few significant sites exist outside of this area, like Mola D'Agres and its ivory workshop. Including these sites in future research may enhance this analysis. However, the bounded region just noted is a natural and logical grouping as it contains several important east-west and north-south travel corridors that have been used by people for centuries. Therefore, while a difficult decision, focusing on this bounded region and sites to the south along the Segura River is a reasonable method to limit this analysis.

The ‘boundary specification’ question is a commonly faced problem for social network analysts. Networks do not have natural boundaries and need not be well connected or even connected at all to be a network. Smith (2014:615) notes that networks are often conceptualized from a *nominalist* perspective. A researcher taking a nominalist perspective imposes network boundaries based on analytical reasoning and driven by a research question. The nominalist perspective also argues that no true network exists outside of that which is conceptualized by the researcher. It is the researcher who defines the network by choosing a set of nodes and types of ties according to the goals of the particular research project.

This research is based on the nominalist view that a social network is a model driven by a specific research question, in this case, what causes some societies to resist change? The decision to bound the VBA networks by river valley association is based on a known relationship between river valley location and the intensity of social interaction. Alternatively, one could have bounded the VBA networks based on any number of other commonly-used approaches, e.g. reputational (settlements with the most connections or the most ‘valuable’ artifacts) or positional (the differing roles that settlements might occupy within the network) (Smith 2014). Moreover, this research acknowledges the fact that different bounding choices can lead to different analytical outcomes. However, the geographic bounding approach utilized here is qualitatively backed by prior archaeological research. Moreover, assumptions undergirding this approach are acknowledged openly as part of the treatment of VBA social networks not as social realities but as researcher-designed models.

Chronological Attribution

Archaeologists have been able to estimate coarse chronological attributions for VBA sites using radiocarbon dates, ceramics forms and decorations, metal object types, and trends in bone tool types. Only 24 sites in all of the VBA have radiocarbon dates, although there are multiple dates at some sites. Archaeologists have estimated the chronology of all other sites based on types of artifacts present. To briefly review, this research utilized a chronological classification system consisting of four periods: Early Bronze, Middle Bronze, Late Bronze, and Final Bronze with ranges of approximately 300 to 400 years each. Table 4.1 presents the chronological classification system for the VBA.

Table 4.1. Valencian Bronze Age chronology

Early	Middle	Late	Final
2200-1700 BCE	1700-1500 BCE	1500-1100 BCE	1100-750 BCE

One can immediately see two different opportunities to refine this chronology: 1) further subdivide the periods into smaller ranges; 2) increase the confidence level in the estimates for sites that do not have radiocarbon dates. The first opportunity is a challenge due to the small number of radiocarbon dates, the small number of excavations, and the homogeneity of the ceramics. An archaeologist, maybe even this one, can successfully meet this challenge in the future. However, it is not necessary for the type of analysis proposed in this project. The abstract network modeling of long-term processes employed in this project does not require this type of explicitness. This type of modeling seeks to discover the long-term, cumulative effects of the decisions of pairs of individuals to interact. Therefore, a coarse chronological attribution is robust enough to capture overall trends and the development of macro-level processes responsible for social structure over time.

Empirical Bayesian Estimation Dating

The second opportunity is worthwhile to this analysis and attainable with tested methods already in use in archaeology. The approach taken here is a three-step verification process:

1) Collect chronological estimates of all sites from publications or personal contact with the excavator, curator, or researcher.
2) Perform Empirical Bayesian Estimation Dating (Fernández-López and Barton 2015; Ortman 2007)
3) Identify inconsistencies between 1) and 2), cross-reference published information and additional available data, and make a final chronological designation.

Empirical Bayesian Estimation Dating is simple in concept and easily reproducible. It estimates the probability of occupation at a site based on its artifact assemblage, by utilizing prior knowledge of temporally sensitive assemblage data from securely dated sites (Fernández-López and Barton 2015). Barton and Fernández-López (2015:559) employed this technique with lithic surface assemblages because it presented a suitable way to develop a chronology for surface scatters “composed of artifacts that can accumulate over multiple occupational episodes.” Considering that this project’s dataset consists of varying contexts and collections methods, both systematic and not-so-systematic, the choice of this method is appropriate.

Different types of Bayesian inferences exist. Fernández-López and Barton make a compelling case for Empirical-based Bayesian (EBB) approaches as successful in treating large datasets with high variability. EBB calculates a prior probability density function from the dated assemblages and calculates a posterior probability for the age of undated assemblages. To calculate prior probability, a "calibration" dataset is needed that contains sites with radiocarbon-dated assemblages that cover all four time periods. In this case, 72 radiocarbon dates available from the 24 site assemblages as a calibration dataset were used to estimate the age of the rest of the sites without absolute dates. Furthermore, the calibration dataset must contain attribute data known to be chronologically sensitive. It is clear from prior research that particular ceramic decoration techniques found on the body of vessels are more common in later periods. Therefore, ceramic decoration data is used for calibration.

For each assemblage, the frequency of each ceramic decoration type relative to the total of all decoration types is calculated. Then, the mean is calculated of the relative frequency for each decoration type for each of the periods for which that decoration type was present. Posterior probabilities were calculated based on the counts of each ceramic type for each assemblage. The Bayes Theorem used in this research to estimate the probability that a ceramic decoration type dates to a chronological period is derived from Ortman et al. (2007) and Fernández-López and Barton (2015) (IV-Eq1):

$$P(m_i|type_j) = \frac{P(m_i) * \sum_{j=1}^{n} P(type_j|m_i)}{\sum_{l=1}^{k} P(m_l) * \sum_{j=1}^{n} P(type_j|m_l)}$$

IV-Eq1

where i =1 to k are the chronological periods, j = 1 to n are the chronologically sensitive ceramic decoration classes, $P(type_j \mid m_i)$ is the conditional probability for $type_j$ and chronological period m_i, and $P(m_i)$ is the prior probability ceramic decoration class $type_j$ being represented in a chronological period m_i.

The posterior probability that an assemblage dates to each chronological period is given by (IV-Eq2):

$$P(m_i|d) = \frac{P(m_i)}{\sum_{l=1}^{k} P(m_l)}$$

where

$$P(m_i) = \left\langle n_j * P\left(m_l \middle| type_j\right)\right\rangle_j \qquad \text{IV-Eq2}$$

and $P(m_i)$ indicates the probability of documenting a chronological period m_i according to the average of the number of artifacts n_j times the probability of period m_i being represented according to the presence of artifacts $type_j$. Thus, each assemblage obtains one probability for each period.

The prospects for refining the chronology the VBA sites seemed dim at the outset. VBA chronology is infamously tricky. However, the results were impressive. EBB identified chronological misattributions as well as confirmed sites with multiple contexts. Additionally, the estimates by archaeologists matched the Bayes results nicely, so much so that the Bayes results could be trusted to refine the archaeologists' estimations further. Comparisons of the archaeological estimates with the Bayes results as well as notes on where the Bayes posterior probabilities were useful in identifying errors and refining site chronologies are presented in Chapter 5: Results.

Initial Data Analysis

Initial Data Analysis (IDA) is the process of assessing the quality of one's data for analysis. IDA is an essential first step in data analysis, and this research uses IDA to evaluate data distributions and the effects of sample size (Adér 2008). First, however, descriptions of the basic summary statistics of the dataset reported for this research are presented.

Summary statistics of the dataset

The data collected are in the form of discrete counts and thus appropriate measures of location and spread for discrete count data are required. These are site-level and artifact type marginal sums, medians, modes, ranges, and ratios.

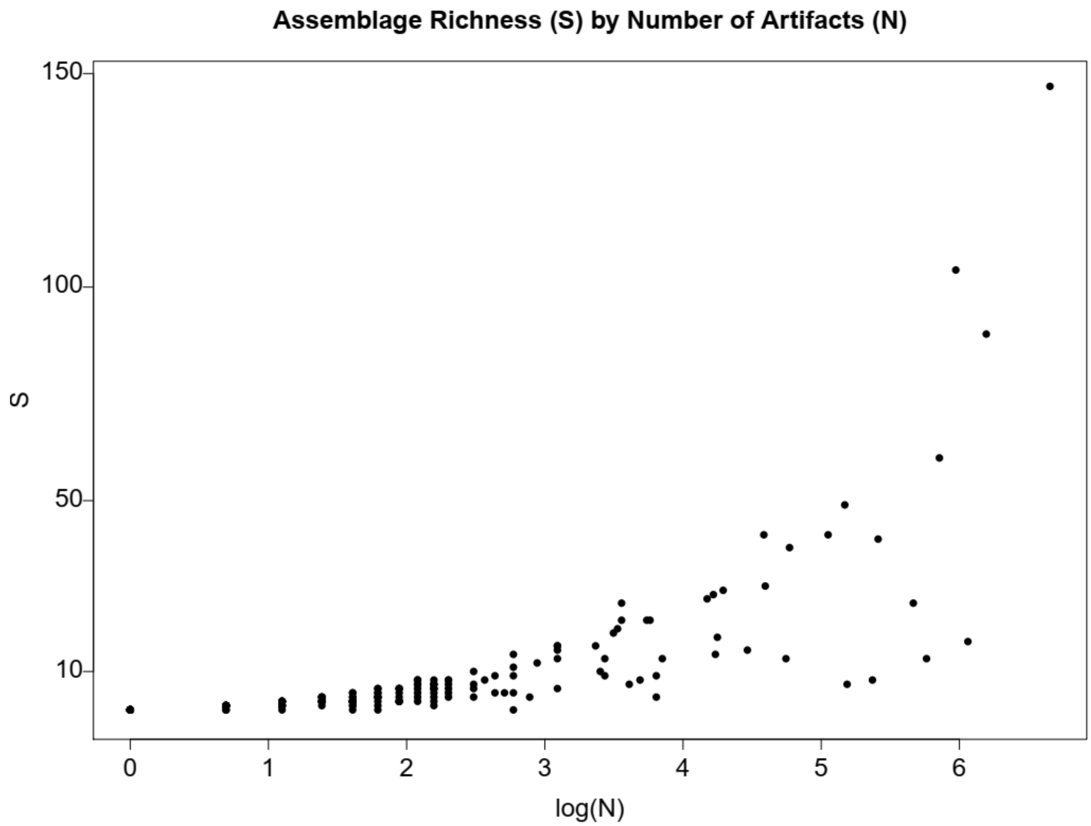
Distributions

The procedure described below was used to assess the normality of the distribution of counts for artifact types over the entire data set. This is followed by an evaluation of artifact richness versus sample size. This procedure assesses the need to account for collection biases before network analysis.

Richness is defined as the number of artifact classes in an archaeological assemblage (Carlson 2017). Using the R software package 'vegan,' a vector was produced of richness values for the 212 sites in this analysis. These values were plotted using a kernel density function, a procedure that plots a smooth curve estimating the probability density function of a continuous variable without assuming normality. The plot indicates whether the data distribution is normal or skewed, a prerequisite for choosing appropriate statistical methods.

A standard IDA procedure in archaeology is to assess whether any sample size effects should be accounted for in further analyses (Kintigh 1984). Richness often correlates with assemblage size and assemblage size itself is often a product of collection bias. Since this dataset derives from a wide range of sampling contexts—excavations, prospections, old and new datasets—an assessment for sample size dependency was deemed necessary. The method employed here is to plot richness against the logged number of artifacts for each site assemblage and look for correlation.

The bottom of Figure 4.9 presents the results for the kernel density analysis based on artifact richness. The distribution is not normal, skews toward zero, and indicates that low richness characterizes most assemblages. The top of Figure 4.9 indicates that the correlation between artifact richness and sample size may be a problem for small sample sizes below 7. A regression analysis between artifact richness and sample size is significant at the 0.5 p-value level, however, the adjusted R-squared value of 0.489 is low. The trend indicates that the richness provides information about sample size but does not fully explain the variation around the regression line, especially for larger assemblages. Therefore, the sample size effect may not be as problematic for larger assemblages.



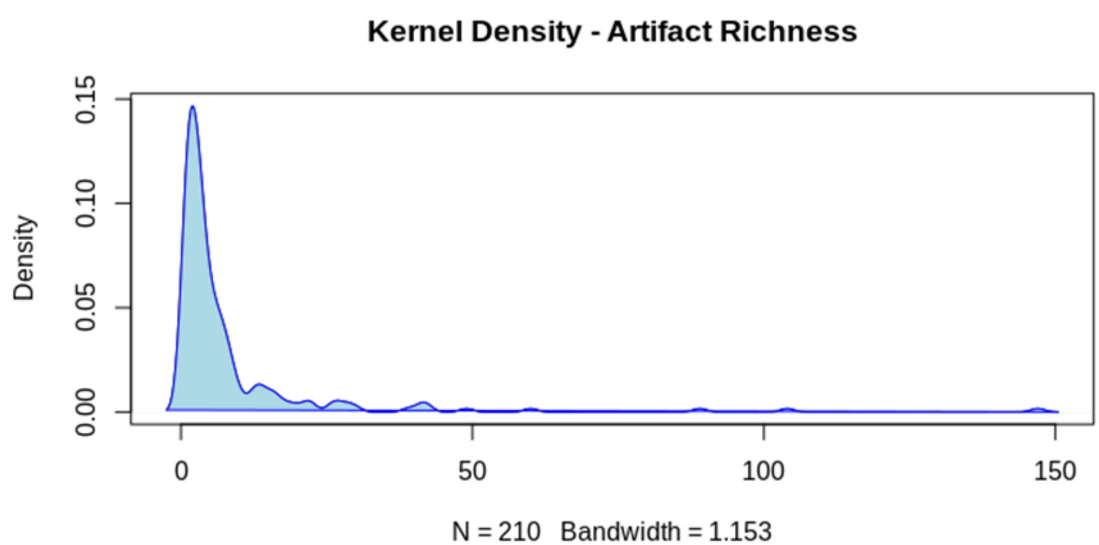


Figure 4.9. Assemblage richness plotted against the number of artifacts in the assemblage (top); Kernel density analysis results based on artifact richness (bottom).

Network Inference, Thresholds, and Minimum Number of Artifacts

Network inference is the process of defining edges between nodes based on node characteristics when the certainty of direct connections is either not knowable or in question. Through a process of statistical inference, node characteristics can be used as proxies to predict ties between nodes (Kolazcyk and Csárdi 2013).

This research employs 'association network inference,' a process that defines a minimal level of association between the characteristics of two nodes for a tie to exist. In practice, this involves creating a correlation matrix of similarities between nodes based on nodal attributes. In this case, node characteristics are the raw counts of artifact variables associated with each site. The following discussion describes the four, ordered steps conducted to create each VBA network followed by an illustrative example.

First, a matrix was developed with VBA sites as columns and raw counts of artifact types as rows (Step 1). The six chrono-region networks were derived by including all artifact types. Second, each matrix was thinned by a minimum number of artifacts threshold (a process described in detail below) to eliminate 0 and 1 counts (Step 2). Thresholding by a minimum number of artifacts before network inference is a common practice. In this context, a minimum number of artifacts means that enough of a type of an artifact type must be represented to assist in network inference. Two methods are followed in this analysis. For network inference based on all artifact classes, an artifact must be represented in at least two sites for that artifact class's inclusion in the network inference. This choice acts as a "thinning" mechanism. Networks inferred from the entire set of artifacts classes contain thousands of links, therefore to increase clarity and to emphasize only those artifacts classes with more than an isolated instance, the datasets are minimally thinned.

For subsets of networks based only on one material type or artifact class, the minimum number of artifacts is reduced to one. Thresholding by a minimum number of artifacts is only meant as a thinning technique and is not necessary on smaller datasets. Every effort is made when possible to preserve information from all of the data before network inference since additional thresholding occurs during the process of network inference.

Third, a correlation analysis is conducted on each matrix (Step 3) followed by the final step of binarization of the values in each matrix (Step 4). The dataset of raw counts does not follow a normal distribution. Thus it was necessary to choose a type of correlation that can handle non-parametric, skewed data distributions. 'Spearman's Rho' is a non-parametric test used to measure the strength of association between two variables, where the value 'r' ranges from 1 for perfect correlation and -1 for no correlation.

Fourth, the correlation matrix is thresholded to indicate meaningful relationships by first, reclassifying those correlation values equal to or less than 0 as '0' indicating no relationship. Second, the four quartiles of the correlation values of this reclassified correlation matrix are calculated. Third, if the correlation value between sites is contained within the second through fourth quartiles, a tie is inferred. (The first quartile contains pairs of sites with the weakest correlations.) Meaningful relationships are reclassified as '1' indicating a relationship.

The first quartile threshold is used for all networks produced in this analysis, except for copper and bronze and *cordones* networks where no threshold is implemented. Copper and bronze and *cordones* are rarer occurrences, and as such, the presence or absence (1 or 0) of either is a meaningful indicator of a social relationship. Therefore, any correlation between two sites greater than 0 is a relationship.

Imagine five VBA sites named A, B, C, D, and E. The artifact assemblages of these five sites as raw counts are arranged in the form of a matrix shown in Table 4.2. The row sums are calculated for each row. Any artifact type with a row sum equal to or greater than 2 is retained. In the example in Table 4.2, Copper Type 1 is dropped from the analysis. The next step is to conduct a Spearman's rho correlation and to evaluate the correlation matrix for meaningful relationships as in Table 4.3. All correlation values in the first quartile or equal to or less than 0 are converted to 0 (no relationship) as seen in Table 4.4. All correlation values in the second through fourth quartiles are converted to 1 (indicating a relationship).

Table 4.2. Raw counts of artifacts from the imaginary sites of A, B, C, D, and E.

	Site A	**Site B**	**Site C**	**Site D**	**Site E**
Ceramic decoration 1	5	4	0	0	0
Ceramic decoration 2	4	4	0	0	0
Shell type 1	3	3	0	0	0
Bronze Type 1	0	0	3	0	0
Bronze Type 2	0	0	3	0	0
Copper Type 1	0	0	0	0	1

Table 4.3. Correlation matrix of the imaginary sites of A, B, C, D, and E.

		Site A	Site B	Site C	Site D	Site E
Site A		1.00	0.97	0.044	-	-
Site B		0.97	1.00	-0.91	-	-
Site C		-0.89	-0.91	1.00	-	-
Site D		-	-	-	1.00	-
Site E		-	-	-	-	1.00

Table 4.4. Binarized correlation matrix of the imaginary sites of A, B, C, D, and E.

	Site A	Site B	Site C	Site D	Site E
Site A	*	1	0	0	0
Site B		*	0	0	0
Site C			*	0	0
Site D				*	0
Site E					*

Assessing Network Robusticity to Missing Data

Most archaeological network studies must deal with the issue of incomplete datasets, whether it be from missing sites or missing artifact data. The VBA is no exception. Any networks produced from this analysis are samples of a “complete network” that will not be realizable. Thus, it is helpful to have a way to determine the extent to which missing data may influence network outcomes. The following procedure for analyzing the robusticity of network measures to missing data is adapted from an online tutorial by Peeples (2017), “Network Science and Statistical Techniques for Dealing with Uncertainties in Archaeological Datasets”, who developed the technique based on work by Costenbader and Valente (2003) (see also Borgatti and Everett 2006).

The idea is to take an observed, incomplete network and determine the robusticity of different metrics of that network to sub-sampling. This procedure estimates the degree to which a sub-sample approximates the network from which it was drawn. As Peeples

(2017) states, “If a particular metric is robust to sub-sampling in the data we have, we may have greater faith that a particular measure approximates the value in the complete network.” The approach is to sub-sample a network’s nodes at intervals of 10% (producing multiple replicates for each sampling fraction with each replicate produced from an increasing percentage of nodes removed) and then calculate network degree and centralization for every replicate of each fraction. The next step is to calculate rank-order correlations (Spearman’s ρ) between the metrics for both the observed network and every sub-sample to evaluate how robust network metrics are to missing data.

All networks produced for the VBA were evaluated in this way for robusticity to missing data.

Visualization of Network Data

The R software statistical package and the graphical interface RStudio are well-developed tools for network graph visualization. Two R statistical packages for network visualization were employed in this analysis—‘igraph*’* and ‘statnet*’*. All code utilized in this section is published in Appendix F and digitally at *http://www.diggingdenver.net/*. The procedure followed in this research is as follows. After network inference, the matrix of meaningful relationships is binarized in the form of an adjacency matrix. A “0” indicates no relationship; “1” indicates a relationship. This adjacency matrix is undirected in the sense that we do not know the directionality of the relationships. For example, we know that a relationship between site A and site B exists, but we do not know the direction of the relationship. Is the relationship vectored from A to B or B to A or both?

The adjacency matrix is a representation of the relationships between sites. It does not include other site attributes that we should like to add to the overall network analysis.

Site attributes are assigned to each node in the form of "vertex attributes." Iteratively assigned to each node is a series of vertex attributes from a list associated with each site. At this point, a complete network has been created and is ready to be rendered visually.

All graphs in this research are rendered using the Fruchterman-Reingold Layout Algorithm. This algorithm is a spring-embedder method of network graph drawing where the positions of pairs of vertices are defined by the distance (correlation) between them. This process is done iteratively until all vertices are placed based on the convergence of a vector of net forces (Kolczyk and Csárdi 2014). The Fruchterman-Reingold Layout is used commonly in network visualization because it helps to illuminate the relative closeness of social relationships.

Color-coding is another common visualization technique that can assist in understanding network graphs. In this research, nodes are color-coded according to their river valley location.

Giant Components

A 'giant component' is the largest, connected component in a network. In other words, the connected component with the largest proportion of the nodes that make up the network. Often it is helpful to visualize and perform calculations on the giant component only. Additionally, some types of statistics can only be calculated on fully connected components. Giant components are used for most of the network analyses in this research.

Dimensions of Social Stability

Specific network structures can be related to various social dynamics. For example, triangle counts represent the well-known social dynamic of a friend of my friend is also my friend. Degree is a node's number of connections. Network structure is often investigated descriptively, as opposed to inferentially. For this analysis, several descriptive measures were selected to address Hypothesis 1 Social Processes:

The stronger the reinforcement of group norms (transitivity), of similarity in relationship (homophily), and/or of overlapping affiliations (multiplexity), the more stable the social system (Burt, 2000; Cook et al., 1983; McPherson et al., 2001; Rogan, 2013; Verbrugge, 1979).

Appendix F contains all R code for these calculations. The descriptive measures are organized below according to what this research refers to as Dimensions of Social Stability (DSS). For detailed mathematical formulas and descriptions of each measure, refer to *A User's Guide to Network Analysis in R* by Luke (2015) and *Statistical Analysis of Network Data with R* by Kolaczyk and Csárdi (2014).

Connectivity:

Network size

Network size is defined as the total number of nodes in the network. Network size is a fundamental network property that constrains opportunities for interaction.

Average degree

Average degree is the mean degree of nodes in a network. Degree is a node's number of connections. Average degree is an indicator of the overall connectivity of the network.

Distance:

Diameter

The diameter of a network is the longest, shortest path in a network and quantifies how many steps it will take to "travel" the network. To clarify, imagine three nodes, A, B, and C. A path between two nodes may be direct, i.e., node A is connected directly to node B, or indirect, where A can only connect to B though both A's and B's connection with node C. In the latter scenario the network path between A and B is longer. The longest of these paths in a network is the diameter.

Average path length

The average path length is the mean graph-distance between all pairs of nodes. Graph-distance is the length of the shortest path between two nodes. Average path length indicates how many steps on average, each node takes to conduct an interchange with another node.

Average closeness

Average closeness is the mean closeness centrality of all nodes. Closeness centrality measures the mean distance from a node to all other nodes. The more central the node, the closer it is to all other nodes.

Clustering:

Density

Density is defined as the ratio of the actual number of links to the number of possible links in a network with *n* nodes. The density of a network can control how quickly information spreads on a network.

Global transitivity (Clustering Coefficient)

Global transitivity is the number of closed triangles divided by the total number of triangles (both open and closed). Global transitivity is a social clustering measure.

Centralization and Power:

Global Eigenvector Centralization Index

The Global Eigenvector Centralization Index is a measure of graph centralization using weights on the first eigenvector. Eigenvector centrality captures the idea that the more central the nodes to which you are connected, the more central you are. For a given graph $G{:}{=}(N,E)$ with $|N|$ nodes let $A = (a_{i,j})$ be the adjacency matrix, $a_{i,j} = 1$ if node *i* is linked to node *j* and $a_{i,j} = 0$ otherwise. The relative centrality score of node *i* can be defined as (IV-Eq3):

$$x_i = \frac{1}{\lambda} \Sigma_{j \epsilon M(i)} x_j = \frac{1}{\lambda} \Sigma_{j \epsilon G} a_{i,j} x_j$$

IV-Eq3

where $M(i)$ is a set of the neighbors of i and λ is a constant. This can be rewritten in vector notation as the eigenvector equation $Ax = \lambda x$. In other words, the centrality of each vertex is proportional to the sum of the centralities of its neighbors.

The Global Eigenvector Centralization Index is the ratio of summed eigenvector centrality scores in a network and the maximum summed eigenvector centrality scores over all possible networks. The Global Eigenvector Centralization Index summarizes centralization over the entire network and can indicate if a power imbalance exists.

Vulnerability:

Cut-point

A cut-point is a node in a network such that when removed breaks the network into subsets or, in other words, increases the number of components in a network graph. An increase or decrease in the number of cutpoints through time can serve as a proxy measure of a network's stability. Identification of cut-points can help determine where and how much a network is vulnerable to an attack. The removal of a cut-point node would be detrimental to the connectivity of the social network.

Modularity (fast-greedy optimization)

Modularity is a measure of the strength of the division of a network into clusters or modules. Networks with high modularity have dense connections between nodes within modules but sparse connections between nodes of different modules. Modularity calculations define cohesive groups and coupling between groups. Fast-greedy optimization is an agglomerative hierarchical clustering algorithm that searches the network for all possible modules.

Cumulative Degree Distributions

Cumulative Degree Distribution (CDD) is a graphic representation of the distribution of node degrees over the whole network. It can indicate if a power imbalance exists and is useful for investigating rich-get-richer tendencies, or the unbalanced accumulation of wealth among the wealthiest actors (Bernabeu et al. 2013; Barabasi 2009). Rich-get-richer tendencies also referred to as preferential attachment, exhibit heavy-tailed degree distributions, where most nodes have few connections and a few nodes have a high number of connections. This research produced CDDs for each of the six chrono-regions to investigate power imbalances.

Measuring Social Stability

Social stability is quantified in two ways, first using a network measure called structural cohesion and second, through the development of a Social Stability Index (SSI) from several of the network measures above described.

Structural cohesion

Social cohesion, the force that glues society together, can be operationalized succinctly in a way conducive to quantification as a network property. Sociologists Moody and White (2003) discuss the theoretical ambiguity in use in the literature, when social cohesion is conceived both relationally and ideationally. The ideational component refers to an individual's identification with the group, while the relational component refers to observed connections of individuals within the group. Ideational social cohesion is related to one's perceived identification with a group, a common consciousness. Relational social cohesion centers on the structure of relationships in the group. It is the latter aspect that Moody and White call “structural cohesion,” a concept useful for investigation of cohesion and stability in networks.

Structural cohesion is “the minimum number of actors who, if removed from a group, would disconnect the group” into different groups (Moody and White 2003:109). A group is not cohesive unless individuals are interacting with each other. Imagine the beginnings of group formation for a set of actors. Actors form relationships through time based on some shared identification with other actors. At some point in group evolution, we can imagine a point when each individual in a group is reachable by every other individual in the group by exactly one path. This is minimal structural cohesion. Some individuals within the group may make connections to multiple group members strengthening the “glue” that holds the group together. This process can happen when most group members follow one or more leaders or when the relationships are spread among the group members more evenly.

Moody and White (2003) argue the case that the more evenly distributed the relationships, the more strongly cohesive the group. Logically, if an individual is dependent on only one other individual, then the loss of that individual destroys the relationship. However, if an individual is connected to at least two individuals, one of the relationships still exists if the other is broken. The strongest groups are called ‘cliques,’ where every member is directly connected to every other member.

Groups usually do not operate in isolation. They often form connections with other groups, both heterarchically and hierarchically. Thus, a cohesive group can nest within other groups or groups can exist side-by-side with each other. Many cohesive sub-groups can be nested within the population as a whole. The concept of nestedness reflects

Granovetter's (1985) concept of social “embeddedness” or the idea that the range of options available for human action is embedded within a structure of pre-existing social ties. Actors interacting within dense, nested clusters of groups have different sets of resources and constraints than those who are not embedded in such networks.

Moody and White (2003) developed an algorithm for modeling and graphing structural cohesion through a process called “cohesive blocking.” A network can be divided or “blocked” into many sub-graphs of cohesive components. A ‘component’ of a network “consists of all nodes that can be connected to each other by at least one path” (Moody and White 2003:108). Components are classified in terms of how many independent paths exist between pairs that never cross the same set of nodes. For example, in Figure 4.10, *k* represents the number of independent paths that exist between pairs that never cross the same set of nodes. This network has 11 ‘k-components’, k=1, k=2, k=3, k=4, k=5, k=6, k=7, two k=8 components, k=9, and k=10. The largest component is Block 1 where k=1, with the other k-components embedded within it. A k-connected graph has a ‘cut-set’ with exactly *k* members. A cut-set consists of the set of edges that have one endpoint in each partition or block. In other words, an edge from a cut-set crosscuts the partition between two subgraphs. The k=10 component is the most highly connected and is nested within other larger components (Moody and White 2003).

Block	Cohesion
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	8
10	9
11	10

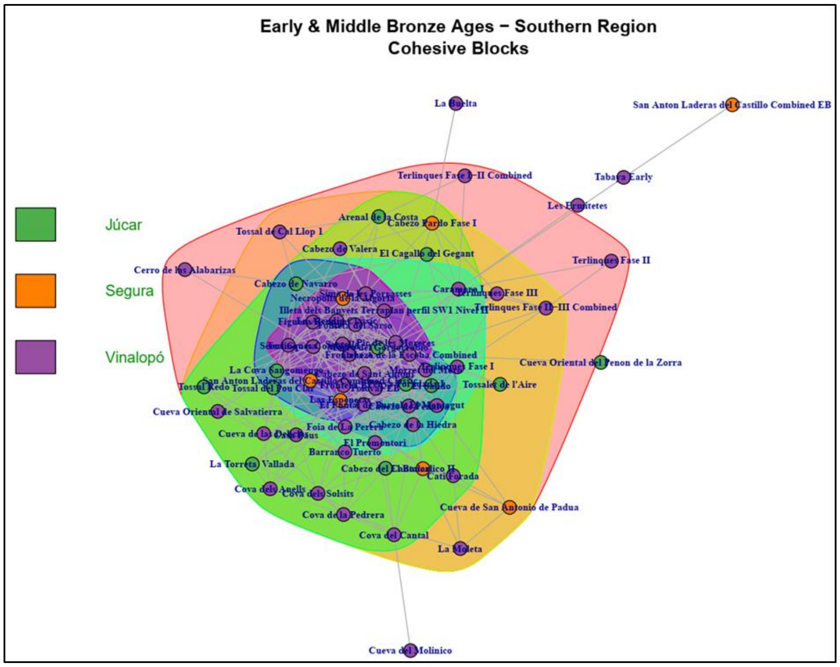


Figure 4.10. A visualization of the structural cohesion of the Early and Middle Bronze Ages in the Southern VBA. The table on the left displays the value k (cohesion) for each block; the image on the right displays the nested cohesive blocks. The colors of the blocks on the left match the colors in the table on the right. Nodes are color-coded by river valley location.

The algorithm for identifying cohesive blocks is conceived of as follows, taken directly from Moody and White:

> *One first identifies the k-connectivity of an input graph, then removes the k cut-set(s) that hold(s) the network together. One then repeats this procedure on the resulting subgraphs, until no further cutting can be done. As such, any k+l connected set embedded within the network will be identified. Moreover, each iteration of the procedure takes us deeper into the network, as weakly connected nodes are removed first, leaving stronger and stronger connected sets, uncovering the nested structure of cohesion in a network. [Moody and White 2003:109]*

We can look at how these cohesive blocks or sub-graphs are arranged using a hierarchy tree and conclude a network's type of structural cohesion. In this analysis, hierarchical trees were created and compared for each of the six chrono-regions. These trees act as proxies for the underlying social structure of each chrono-region. Analyzing how the underlying social structures change or do not change through time allows estimation of the rate of change for the Northern and Southern Regions of the VBA. Thus, the level of social stability for each region can be assessed quantitively.

Social Stability Index (SSI)

To capture multiple aspects of social structure related to changes in social stability, the five dimensions of DSS described earlier in this chapter (Connectivity, Distance, Clustering, Power and Centralization, and Vulnerability) are calculated from related sub-categories. Then, the SSI for each of the six chrono-regions is developed from the five dimensions.

Each dimension is made up of subcategories. For example, the Clustering Dimension is calculated by combining the network measures of density and global transitivity. The first step in this process is to normalize the values of the subcategories so that they range between 0 to 1. The minimum and maximum possible values are set for each subcategory. The maximum value is the maximum value of the subcategory vector for the region. For example, for the Southern VBA, the vector for the dimension “diameter” contains three values {6, 5, 5}. The maximum value is set to the maximum value in this vector, which is equal to 6. The minimum is theoretical. A network cannot have a minimum diameter of less than 2. Thus the minimum value for diameter is set equal to 2.

The social stability Dimensions are calculated using the minimums shown in Table 4.5.

Table 4.5. Minimum values of Subcategories

Subcategory	Minimum Value
Network size: largest component	2
Average degree: largest component	1
Diameter	1
Average path length	1
Cut-points	0
Modularity	0

These values are used to calculate the normalized value for each subcategory under each dimension using the formula:

Subcategory Value $V = \frac{actual\ value - minimum\ value}{maximum\ value - minimum\ value}$

Next, the Subcategory Value *V* under each Dimension is aggregated into a Dimension Index *D* by calculating the average of the subcategory values.

The technique underlying the SSI is based upon that used by the United Nations for the Human Development Index (HDI), a summary measure of key dimensions of human development (http://hdr.undp.org/en/content/human-development-index-hdi, accessed May 2019). The HDI is the geometric mean of normalized indices for each dimension. This method is adapted for the five dimensions of social structure.

The Dimension Indices *D* are aggregated into the SSI for each chrono-region *t* by calculating the geometric mean of the Dimension Indices:

$SSI(t) = (D_{Connectivity} * D_{Distance} * D_{Clustering} * D_{Power\ and\ Centralization} * D_{Vulnerability})^{1/5}$

Finally, the percent changes in SSI between the Early/Middle to Middle/Late periods as well as the Middle/Late to Late/Final periods for the Northern and the Southern VBAs are calculated.

Multiplex Analysis

When people interact, they do so in complicated ways, across multiple types of exchange relationships. Consider a network of relationships analyzed from the point of view of the exchange of ceramics. Do patterns of exchange relationships based on ceramics match those based on the exchange of bronze, or stone, or shell? Are the mechanisms that govern network structure the same for each? Social network analysis can handle these types of questions through the study of multiplex networks.

A multiplex network is a complex of layered networks where each layer represents a unique type of interaction between a shared set of nodes (Baggio et al. 2016). During analysis, the layers are combined into a "supra" matrix of relationships enabling the enumeration of overlapping affiliations that exist between pairs of nodes. For example, if A and B share a relationship in the ceramic network layer, do they also share a relationship in the shell network layer?

Theoretically and logically, sharing more overlapping affiliations should increase the stability of the bond between a pair of nodes. This relationship solidifies through the process of embedding within multiple types of network relationships. If we see that many overlapping affiliations characterize a multiplex network, then we might see a concomitant rise in social stability and robusticity to crisis.

In this analysis, a multiplex network was produced for each of the six chrono-regions consisting of five layers, each based on a material class with sufficient data to produce networks for all six chrono-regions. While the multiplex analysis could have been based on other socially meaningful categories (i.e. utilitarian versus adornment or exotics versus local), the decision to use material class is based on the expectation that different materials may travel in different networks. The material classes are: 1) ceramic; 2) bone; and 3) copper and bronze. Material class is a simple heuristic and is an essential consideration when deciding to form an exchange relationship. Gold and silver, as well as other minor material classes, were eliminated from analysis because they lacked sufficient numbers to produce networks in all six chrono-regions.

For each chrono-region, the number of sites with overlapping affiliations is tallied by producing a multiplex network in the R package 'mplex'. (The code for this process is reproduced in Appendix G) The number of sites and the number of connections differ between the six chrono-regions. These variables were recorded to control for any possible influence each might have on the count of overlapping affiliations. Furthermore, a normalized Overlap Index consisting of the number of overlapping connections divided by the number of connections is calculated for each chrono-region.

Finally, a measure of multiplex network clustering called the Global Overlay Clustering Coefficient is generated. The non-trivial task to measure the clustering of a multiplex network is accomplished through tensor mathematics. Without going into detail, tensor mathematics is the analysis of tensors or geometric objects that are mapped multi-linearly using vectors. The formula and a detailed explanation for this calculation can be found in De Domenico et al. (2013). The Global Clustering Overlay Coefficient is an indication of how tightly clustered relationships are across multiple layers of relationships with the idea that strong clustering contributes to social stability.

Exponential Random Graph Modeling

Network Science has developed a modeling tool (in the R statistical package), adept at testing hypotheses about social processes (Handcock et al., 2008). Exponential

Random Graph Models (ERGMs) are statistical models for explaining the structure of social networks through hypothesis testing. An ERGM can be seen as a regression model that estimates the size and effect of several independent variables that might explain the dependent variable—the network structure. This tool is not well-known to archaeologists (see Brughmans et al. 2014 for an exception.) Therefore, the operational characteristics of ERGMs are described in the following paragraphs. These tools allow the investigation of both the role of cumulative, bottom-up drivers of stability and change, as well as their relationship to empirical (archaeological), system-level factors more commonly proposed to account for the apparent lack of change in the VBA, such as the geographic distributions of households and communities, and opportunities for inter-societal contact or their lack. Drivers with acceptable goodness-of-fit are then linked with the rates of social system change.

ERGMs range in the complexity of their underlying assumptions about relational dependency, or the influence that actors' attributes and/or relationships have on tie formation. Before addressing more complex statistical ERGMs, it is helpful to understand the baseline form of a network—the simple random graph. A simple random graph is a network chosen from a probability distribution of all networks with *n* nodes, with each tie in the network having the same probability (Harris 2014). Ties occur at random and are independent of each other. A comparison of observed networks to simple random graphs of the same size and density of connections illustrates how observed graphs deviate from random.

The simplest ERGM is the simple random graph model, in which ties occur at random and independently of each other. The simple random graph model, or the Erdős-

Renyí model, specifies a collection $G_{Nv,Ne}$ of all graphs $G = (V, E)$ with $|V| = N_v$ and $|E| = N_e$, and assigns probability $\mathbb{P}(G) = \binom{N}{N_e}^{-1}$ to each $G \in G_{Nv,Ne,}$ where $N = \binom{Nv}{2}$ is the total number of distinct node pairs. In the formulas above, *V* stands for vertex or node and *E* stands for edge or tie. Less formally, let *G(v,p)* be a random graph with *v* vertices and *p* specifying the probability for each edge to appear in the network graph (Luke 2014). It is the null model because, in the real world of social relationships, ties between actors typically have some dependency relationship. For example, if site A and B are trade partners and sites A and C are trade partners, then a relationship between B and C might be dependent on the relationship that site A has with both B and C. In the null model, relationships form at random with a certain probability. The ability to test observed networks against a null model is a powerful tool. If an observed network does not fit a null distribution, then we can conclude that relationships do not form at random and there are other underlying causes to explore.

For each of the six chrono-regions, the ERGM null model is used to test Hypothesis 3, the neutral hypothesis.

Hypothesis 3 Neutral**:**

The system appears to change randomly, due to particularistic, local factors. This acts as a null model to evaluate the other hypotheses (Brantingham, 2003; Connor & Simberloff, 1986).

More complex ERGMs allow us to estimate the probability that certain common, social interaction processes, like transitivity and homophily, can explain the structure of an observed network. In 1986, Frank and Strauss developed dyadic dependence models, a set of statistical models drawn from the exponential family of distributions that incorporate assumptions of interdependence among actors (hence the name Exponential Random Graph Modeling) (Harris 2014). The exponential family of distributions is a set of distributions, where the distribution varies with a finite parameter vector. This family includes a broad set of commonly useful distributions, including the normal distribution.

Dyadic dependence models incorporate dependence among network members. An example of dyadic dependence is an archeological example might be that an exchange relationship between Sites A and B is dependent on a relationship between Sites B and C because the two dyads or pairs of sites have Site B in common. The incorporation of dependence is Frank and Strauss' key innovation and what gives ERGM the ability to more accurately model social relationships. To account for dyadic dependence statistically, Frank and Strauss introduced Markov dependence, the assumption that links sharing a node have a dependency relationship and links not sharing a node are conditionally independent. Frank and Strauss' Markov random graph model can incorporate hypothesis testing of common network micro-structures that might explain an observed network.

Advances in the Frank and Strauss Markov model have been made to adopt a more general conditional dependence among ties (Wasserman and Pattison 1996). These newer models are called p* models and assume that, given all other network ties, "the chance of any two ties both existing is different from the combined chance of each existing" (Harris 2014). ERGMs as p* models allow for an impressive trick. They allow for the prediction of a tie, conditional on other ties in the network, rather than the prediction of the structure of the network as a whole. This conditional dependency is what makes ERGM different than traditional logistic regression.

Just like ERGM, traditional logistic regression is predictive in that it explains the relationship between one dependent binary variable and one or more other variables. In logistic regression, however, the other variables are independent. For example, a medical researcher might use logistic regression to investigate whether things like age and weight can predict the chance of a heart attack. Age and weight are independent variables. In a traditional logistic regression, the regression coefficient describes the strength and positive/negative relationship between the independent and dependent variables. The coefficient is multiplied by the value of the independent variable, whereas in an ERGM, the coefficient is multiplied by the 'change statistic.' The change statistic is the change in a network statistic of interest when a tie is added between a pair of nodes. In network notation, a pair of nodes is referred to as node *i* and node *j*. Thus probabilities produced by ERGMs are always framed as the probability of a tie between *i* and *j*, conditional on the rest of the network.

Another advantage conferred by p* ERGMs is that they can incorporate *both* network dependencies *and* attributes of network members. In an archaeological case, for example, one can include attributes such as site size, site wealth, geographic location, chronological age, artifact characteristics, or any other characteristic associated with the question of interest. These attributes often influence patterns of network connections, and p* models can account for this. The ERGMs within this research account for both network dependencies like transitivity and homophily as well as local attributes including geographic location and site size. In this way, the influence and interaction of network processes and member attributes can be teased apart. Taken directly from Robins et al. (2006), the general form of an ERGM that includes model parameters is (IV-Eq4):

$$\Pr(\mathbf{Y} = \mathbf{y}) = \left(\frac{1}{\kappa}\right) \exp\left\{\sum_{A} \eta_A g_A(\mathbf{y})\right\}$$ IV-Eq4

where the summation is over all configurations A; η_A is the parameter corresponding to the configuration A; $g_A(\mathrm{y}) = \prod_{yij \in A} y_{ij}$ is the network statistic corresponding to configuration A; $g_A(\mathrm{y}) = 1$ if the configuration is observed in the network y, and is 0 otherwise, K is a normalizing quantity for the probability distribution. Robins et al. (2006:179) explain, "The probability of observing any particular graph y in this distribution is given by the equation, and this probability is dependent both on the statistics $g_A(\mathrm{y})$ in the network y and on the various non-zero parameters η_A for all configurations A in the model." Configurations represent testable hypotheses.

ERGMs are vulnerable to a problem called degeneracy, a phenomenon that occurs during the process of simulation when the model produces networks that are either nearly empty or complete. Degeneracy occurs when "most of the probability mass" is "concentrated on a very small subset of the parameter space" (Karwa et al. 2016) For example, observed social networks commonly exhibit skewed degree distributions. A frequently observed cause of skewed degree distributions is the intense clustering of triads with shared edges seen in many social networks. While a degenerate ERGM may successfully produce a result, in all likelihood, it is not a good model of the observed data (Harris 2014). Snijders et al. (2006) proposed the use of three non-linear terms—geometrically weighted degrees, geometrically weighted edgewise partners, and geometrically weighted dyadwise shared partners—to help attenuate problems with degeneracy. Hunter and Handcock (2006) modified the three terms, which are described in the following paragraphs and are utilized in this research.

Geometrically Weighted Degrees

Geometrically weighted degrees, or the GWD statistic, is commonly used to understand if an actor's number of social connections is a factor in network construction. It accounts for the differing proportions of high and low degree nodes in a social network. Social networks often exhibit a declining degree distribution where a few nodes have high degrees in comparison to the rest of the network members. The statistic multiplies the frequency of each value of degree by a decay parameter (Harris 2014).

Geometrically Weighted Edgewise Partners

Geometrically weighted edgewise partners, or GWESP, is used to determine how much transitivity contributes to relationship formation. It accounts for the increased transitivity and shared edges associated with clustering common to many social networks. In this calculation, dyads must be connected by a tie and share a partner, also referred to as edgewise shared partners. The statistic multiplies the frequency of each value of edgewise shared partners by a decay parameter.

Geometrically Weighted Dyadwise Partners

Geometrically weighted dyadwise partners, or GWDSP, accounts for the number of dyads with shared partners, without having an actual tie between the dyad, also referred to as dyadwise shared partners. A strong effect from GWDSP would mean that having a connection to a node is not a prerequisite to sharing a “friendship” with a third node. GWDSP is the base effect of GWESP. The statistic multiplies the frequency of each value of dyadwise shared partners by a decay parameter.

Modeling the VBA with ERGMs

Modelers typically work through several steps when modeling with ERGMs. The following commonly-used steps were taken to produce the ERGMs for each of the six-chrono-regions of the VBA. The description of these steps is adapted from Robins et al. (2007), Harris (2014), and Shaeffer (David Schaeffer, personal correspondence 2013). Generally, modelers begin with the null model with a single term representing the number of connections in a network. This term is called the edges term and is a representation of the density of the network. The idea behind starting with the null model is to test whether or not the network structure is due to random processes and to account for noise. ERGMs are not deterministic models. By including the edge term at this step and in all other more complicated iterations, an ERGM can account for stochastic processes that might explain network patterns.

In terms of basic notation, a random graph *Y* consisting of a set of *n* nodes and *m* dyads $\{Y_{ij} : i = 1, \dots, n, ; j = 1, \dots, n\}$ where $Y_{ij} = 1$ if the nodes *ij* are connected and $Y_{ij} = 0$ otherwise. An observed network is notated as y_{ij}.

At this point, the researcher decides what additional variables to add to the null model. It is good practice to begin with a main effects model. Below is an example of a main effects model for the VBA that includes several different attributes of interest to relationship formation in the form of node covariates and node attributes:

main effects model = ergm(network ~ edges + nodecovariate('UTM.X') + nodecovariate('UTM.Y') + nodecovariate('Elevation') + nodecovariate('Visibility') + nodecovariate('Site.Size.m2') +nodefactor('River.Valley'))

In the example, the term *network* is the observed network, *edges* is the edges term serving as the null model, and *nodecovariate* (used for continuous variables) and *nodefactor* (used for categorical variables), are nodal attribute variables that may help to explain observed network patterns. In the example above, site elevation, site visibility, and site size are examples of variables that might increase the likelihood of sites to form a relationship. *Nodecovariates* and *nodefactors* in a main effects model can serve a similar role to control variables in a regression.

Adding a homophily term to an ERGM estimates the likelihood of ‘like connecting with like.’ After running main effects models for all six chrono-regions, homophily and differential homophily were evaluated for all nodal attributes. Differential homophily evaluates the influence of magnitudes of difference in attributes between nodes on the likelihood of connection. A relevant archaeological example might be the hypothesis that small sites tend to connect with large sites because large sites have more resources. Below is an example from the VBA analysis of a homophily/differential homophily model. Variables preceded by *nodematch* are homophily variables. Variables preceded by *absdiff* are differential homophily variables. Variables preceded by *nodecovariate* are control variables. In the example below, *nodematch('River.Valley', diff = T)* is used to test the hypothesis that membership within the same river valley or natural corridor increases the chance of connection. The variable *absdiff('Site.Size.m2')* is included to test whether small sites tend to connect with large sites as defined by area in meters squared.

homophily model <- ergm(network ~ edges + nodematch('River.Valley', diff = T) absdiff('Site.Size.m2') + nodecovariate('Elevation') + nodecovariate'Visibility') + nodecovariate('Site.Size.m2'))

The running of any simple ERGM model results in parameter estimates for each variable through a Maximum Likelihood Estimate (MLE). MLE estimates parameters with the most probability of producing the observed network by finding the values for parameters for a given statistic that makes the likelihood distribution a maximum. For a detailed discussion of MLE, refer to Harris and Stöcker (1998). 'Statnet' provides results that indicate whether or not the estimate is significant. In this research, only variables that are significant below a value of 0.5 were retained for further analysis.

After evaluating which variables are significant, the next step is to test models with the dependency terms of GWD, GWESP, and GWDSP. As already discussed, ERGMs often have trouble with degeneracy and whenever complex assumptions are modeled, degeneracy must be addressed. 'Statnet' produces degeneracy diagnostics that allow the researcher to evaluate which combination of decay parameters produces the best results. The decay parameter can be estimated, but more commonly in practice, it is pre-defined for each ERGM based on an iterative process where combinations of decay parameters are simulated and sifted through for best results. Degeneracy diagnostics were used to choose the parameter combination that best matched the observed patterns in the network for each of the six chrono-regions.

MLE is not used for estimation with models containing dependence terms due to complex calculations. Instead, standard practice is to use Markov Chain Monte Carlo (MCMC) techniques in the general form of a Markov dependency equation, dependent on modeled configurations of parameters and counts of these configurations in the observed network to generate distributions of networks (Brughmans et al. 2014; Snijders et al. 2010). This approach loops through the process of generating distributions of networks under different parameters, assessing the likelihood that a particular distribution generated the observed network, and based on this assessment, restarting the loop with samples from the generated distributions until convergence is reached. Convergence is the end state when the model reaches a stable distribution.

MCMC diagnostics provide additional insight into whether or not the model converged adequately or suffered from degeneracy. Graphic diagnostics produced in 'statnet' show the MCMC time series for each model statistic. If the model has converged, the statistic should hover around the mean of 0 in the graph. Figure 4.11 is an example from the VBA of a model that has properly converged. All ERGMs in this analysis were evaluated using 'statnet's graphic diagnostics and models and parameters with adequate convergence were retained.

The MCMC process is computationally heavy, and processing times increase substantially as terms are added or the number of simulations increased. For this reason, it is advisable to use high-performance computing techniques in the form of parallel processing. MCMC calculations were performed using RStudio Server and 16 computer cores.

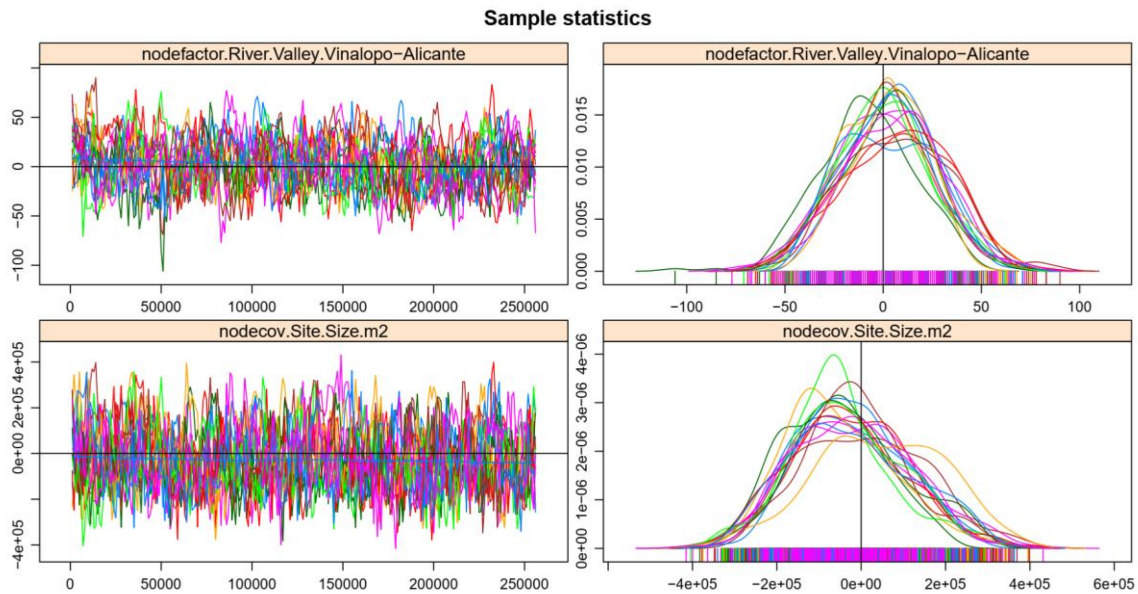


Figure 4.11. Example MCMC diagnostics for an ERGM produced in R statnet. The diagnostics show how much the model is converging around an estimate. The sample statistics on the left show that MCMC is varying randomly at each step around the observed values. The sample statistics of simulated values on the right show a nice bell-shaped distribution around 0. If the model has converged, the statistic should hover around the mean of 0 in the graph.

ERGM results are typically rendered in table output and include both the parameter estimate and the significance of the results. Table 4.6 is a summarized example of ERGM results.

Table 4.6. Example ERGM estimates and significance

	Estimate	**Significance**
edges	-8.108e+00	***
GWD	3.769e+00	***
nodecovariate.UTM.X	-1.780e-07	*
Significance key (p-value): 0 = ***; 0.001 = **; 0.01 = *		

To illustrate how to interpret these results, we can drill down on one example—*nodecovariate.UTM.X*. This covariate assesses whether east to west geographic location affects tie likelihood. Putting this in the context of the VBA, does having a site location closer to the Mediterranean (further east) affect the likelihood of forming relationships with other sites? First, notice that the estimate is negative. The negative sign means that the further away a site is from the Mediterranean, the more likely it is to form connections with other sites. A positive estimate would have meant the opposite. Is this result significant? The significance level is indicated in the column *Significance*. These are based on p-values. The significance codes below the table of results indicate that this result is significant at the 0.01 level. This result would be recorded as significant and the results interpreted accordingly. The procedure is the same for all estimates in this research.

The overall idea of this entire process is to simulate several models with different variables and use model estimates to assess which variables have significant value in explaining the observed network. For each of the six chrono-regions of the VBA, significant results from the null, main effects, homophily, and dependence models were combined and modeled together to produce a full model. The full model contains variables with significant effects on the observed network patterns. Yet, how do we know if the full model, with all variables combined including complex dependencies between variables, is a good fit to the observed data?

Goodness-of-fit for ERGMs is evaluated in two ways. The first way uses either the Akaike Information Criterion (AIC) or the Bayesian Information Criterion (BIC). These are variations of deviance measures. Deviance is the log-likelihood multiplied by -2 and is considered a measure of lack of fit. The smaller AIC or BIC is, the better the fit. The idea is to iteratively run models with different variables and parameter values until the lowest achievable AIC or BIC value is obtained relative to the results of the conducted simulations. The second way uses graphical comparisons of observed and simulated statistics for network degree, GWESP, GWDSP, and triangle census (number of triangles of actors) (Figure 4.12). The graphs show confidence intervals to evaluate whether or not observed and simulated networks come from the same distributions.

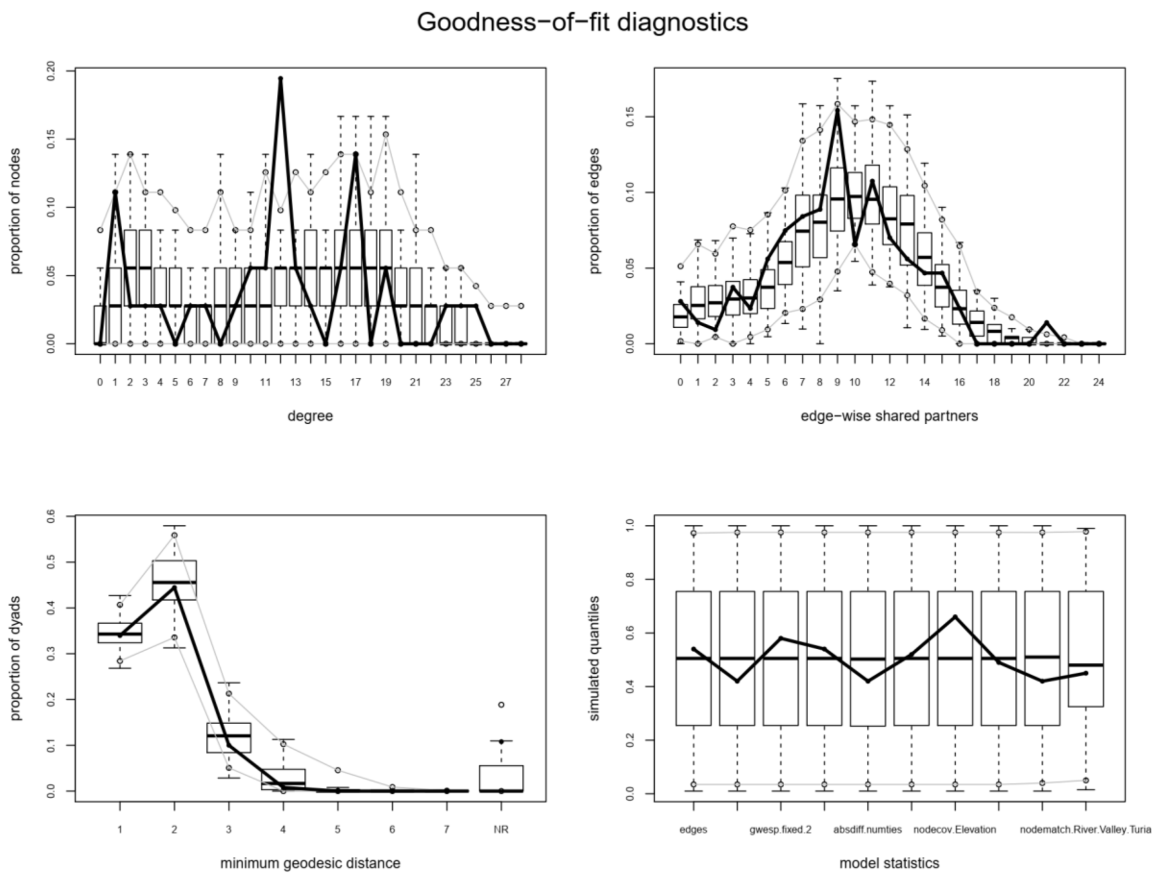


Figure 4.12. An example of Goodness-of-fit diagnostics calculated for a VBA network. The solid black line is the observed network data for each network statistic shown in each graph. The two light gray lines in each graph are confidence intervals surrounding the simulation results depicted as boxplots. Confidence intervals that more closely match the observed results indicate a better model fit.

Both AIC and the Goodness-of-fit graphics were used to assess model fit for all six chrono-regions. This type of modeling is an iterative process involving hundreds of model runs and parameter adjustments. Each chrono-region necessitated 20-50 comparative simulation runs where parameters were adjusted to achieve the best AIC and goodness-of-fit. Finally, because this is a modeling technique using multiple simulations to produce estimations, certain specifications should be consistent across simulations. Appendix H lists these specifications and the values used for every ERGM model in this analysis that required MCMC.

For the VBA, ERGMs were used to assess both Hypothesis 1: Social Processes:

The stronger the reinforcement of group norms (transitivity), of similarity in relationship (homophily), and/or of overlapping affiliations (multiplexity), the more stable the social system (Burt, 2000; Cook et al., 1983; McPherson et al., 2001; Rogan, 2013; Verbrugge, 1979).

and Hypothesis 2: Geographic Isolation:

The more geographically isolated, the less likely the system will change. Isolated groups have less opportunity for diverse exchange opportunities (Alderman, 2012).

The next chapter discusses the results obtained through the methods described above as they relate the framing hypotheses.

CHAPTER 5

RESULTS

The goal of this project is to understand how and why some social systems resist change using archaeological material proxies from the VBA and social network analysis. To reach this goal, several steps were taken to better understand and refine the data before the formal network analysis. The results presented here in the first several sections justify the chronological attributions made for each VBA site through Empirical Bayesian Estimation as described in Chapter 4: Methods. The section following discusses how summary statistics of the entire dataset contribute to our overall understanding of the VBA and especially to the proceeding network analysis. The final two sections present the results of the robusticity tests and the formal network analysis. The results from the network analysis are organized in terms of how they answer each of this project's hypotheses.

Chronological Attributions

Assessment of Empirical Bayesian Estimation

The Empirical Bayesian Estimation provided four probability estimates, one for each period that a site might have been occupied. Table 5.1 presents an example set of results for the site of Cami de Catral along with interpretations. The original archaeologically-based estimation for the occupation of Cami de Catral is the Final Bronze Age (FB). The most likely period of occupation with a probability of 0.7372 as indicated by the Empirical Bayesian analysis is FB (highlighted in green in Table 5.1). Therefore, in this analysis, Cami de Catral was categorized as FB. The Empirical

Bayesian Estimates for each VBA site are found in Appendix I, along with the original archaeological estimates and notes about how the decision to chronologically classify each site was made.

Table 5.1. Empirical Bayesian Estimation example results

Site Name	Empirical Bayes Estimation				Bayes Estimation	Archaeologically Estimated Chronological Attribution	Notes
	Early Bronze (EB)	Middle Bronze (MB)	Late Bronze (LB)	Final Bronze (FB)			
Cami de Catral	0.0107	0.0304	.2217	.7372	FB	FB	Match

As stated in Chapter 4: Methods, this research utilized ceramic assemblages, assigned to a VBA time period using available radiocarbon dates and/or archaeological context, as priors. The radiocarbon dates used to assign the ceramic assemblages to a period are found in Appendix J. For the VBA, radiocarbon dates are reported in the published and unpublished literature with different levels of resolution. When sources only report one date range, that date range was used in this analysis to assign assemblages to a VBA period. When standard deviations are reported for a date, the date with one standard deviation was used. If the date ranges have been refined further in a publication by a researcher, then the researcher(s)' conclusion was used. Sites with the added moniker of "Combined" have been aggregated using all dates from the site.

Overall, the Empirical Bayesian Estimation Analysis provided reasonable estimates for the majority of VBA sites relative to estimates provided by Iberian archaeologists. Only 3.76% of the sites in this analysis were clear misattributions by the Empirical Bayes Analysis. The majority of errors occurred because of a limited number of sites that contain HCT materials. HCT materials include decorated ceramics that resemble decorations from later periods. These HCT decorations were classified under the same decoration categories as later periods resulting in the misattribution of HCT assemblages to the Late or Final VBAs. In these cases, other archaeological evidence, i.e. published research with compelling and corroborating material evidence for occupation during a particular period, controlled the choice of chronological attribution.

Site list, chronological attribution, and regional classifications

A total of 53 VBA sites or archaeological contexts were used as priors in this research to provide chronological estimations for 159 archaeological sites or contexts. Figure 5.1 displays locations and site names for all sites in the Northern VBA analyzed in this research. Figure 5.2 shows sites and locations for all sites analyzed in this research within the Southern VBA. Appendix J lists sites included in this analysis, their classification as Northern or Southern VBA, site name abbreviations used in certain network graphs, final chronological attribution based on the results of the Empirical Bayesian Estimation described above, and the River Valley location for each site.

Some sites were occupied across multiple time periods. When site occupation spans over multiple periods and information is available that separates successive phases explicitly (i.e., radiocarbon dates), the site was divided into each of its chronological classes for network analysis. For example, the site of Pic dels Corbs is divided into five separate chronological phases for analysis. However, for many sites, this type of resolution is not available. For sites where the Empirical Bayes Estimation analysis suggests the possibility of multiple or overlapping occupation periods, the sites are assigned to multiple periods. For example, the site of Abrigo II de las Peñas is assigned to both the Middle and Late Bronze Ages (MB_LB). (Note that Spanish accent marks are not used in any charts and tables that became part of the quantitative analyses. The accent marks confuse software programs.)

VBA sites do not have a typical occupation span. Iberian archaeologists estimate that small sites endured approximately 200 or 300 years while large sites for approximately 700-750 years. These lengthy occupation spans permit the possibility that many sites should be attributed to multiple periods. In addition, the Bayesian chronological estimates, as well as the archaeological estimates, are probabilities that a site was occupied during a particular period, not absolutes. Many sites had equal or close to equal probabilities of occupation in more than one time period. Moreover, distinguishing between Early Bronze and Middle Bronze Age sites is extremely difficult. For these reasons, the six chrono-regions have some overlap in chronological classifications—Early-Middle, Middle-Late, Late-Final. Thus, some sites may appear in more than one chronological period.

This arrangement is not problematic for the type of social network analysis conducted here. Sites are connected based on correlation, or similarity between artifact assemblages. A site assemblage with both Middle and Late Bronze Age artifacts but dominated by typical Middle Bronze Age artifacts will show a strong connection to other Middle Bronze Age dominated sites and a weak or no connection to the Late Bronze Age sites. Late Bronze Age sites classified as Middle to Late Bronze Age will tend to be linked with other Late Bronze Age sites. The adjacent chronological classifications better reflect the reality on the ground, that many of these sites had a peak occupation during one time period but were occupied across traditional VBA chronological periods for hundreds of years, evolving materially through time.

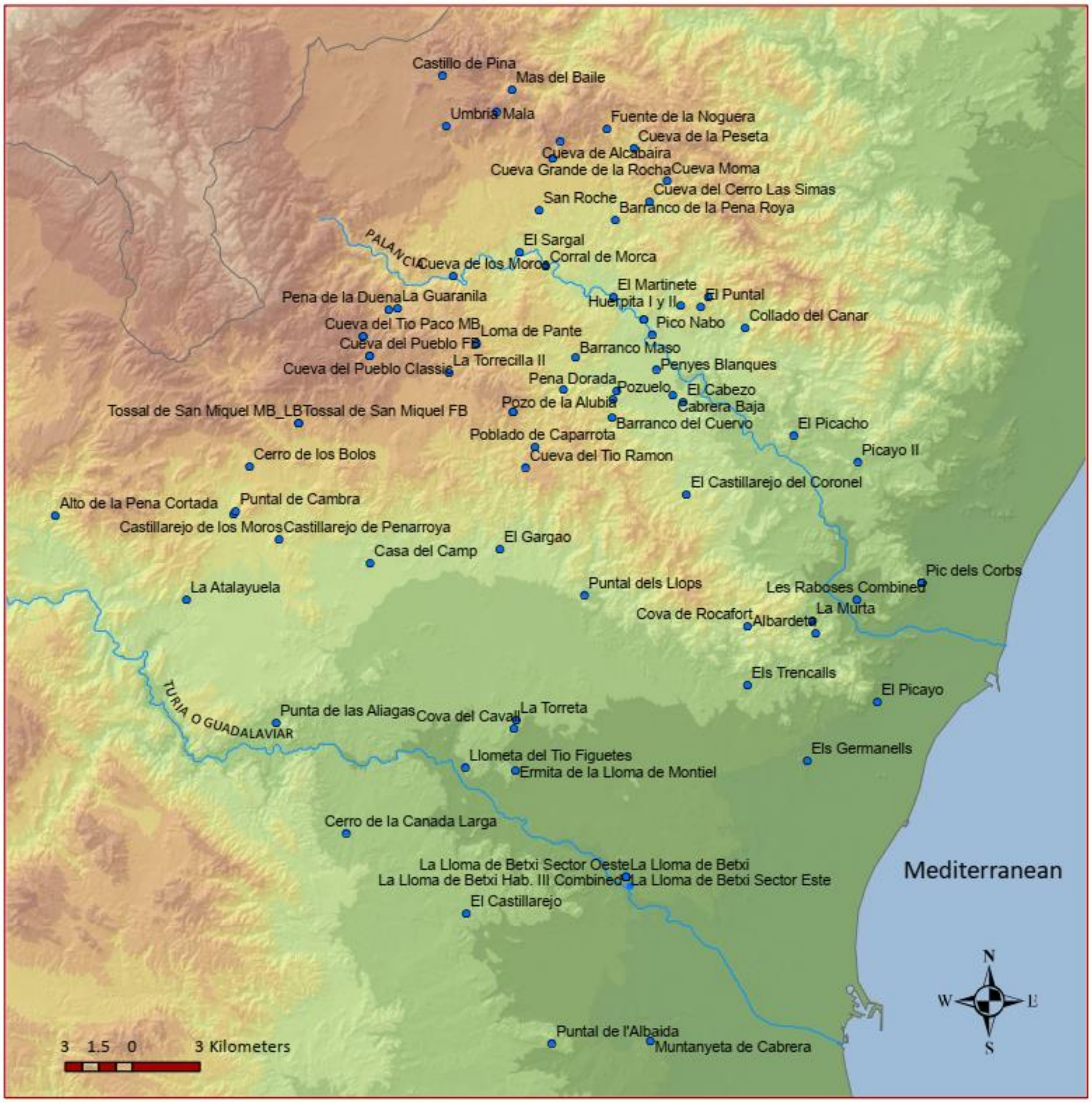


Figure 5.1. Locations of Northern Region sites in this analysis from all time periods.

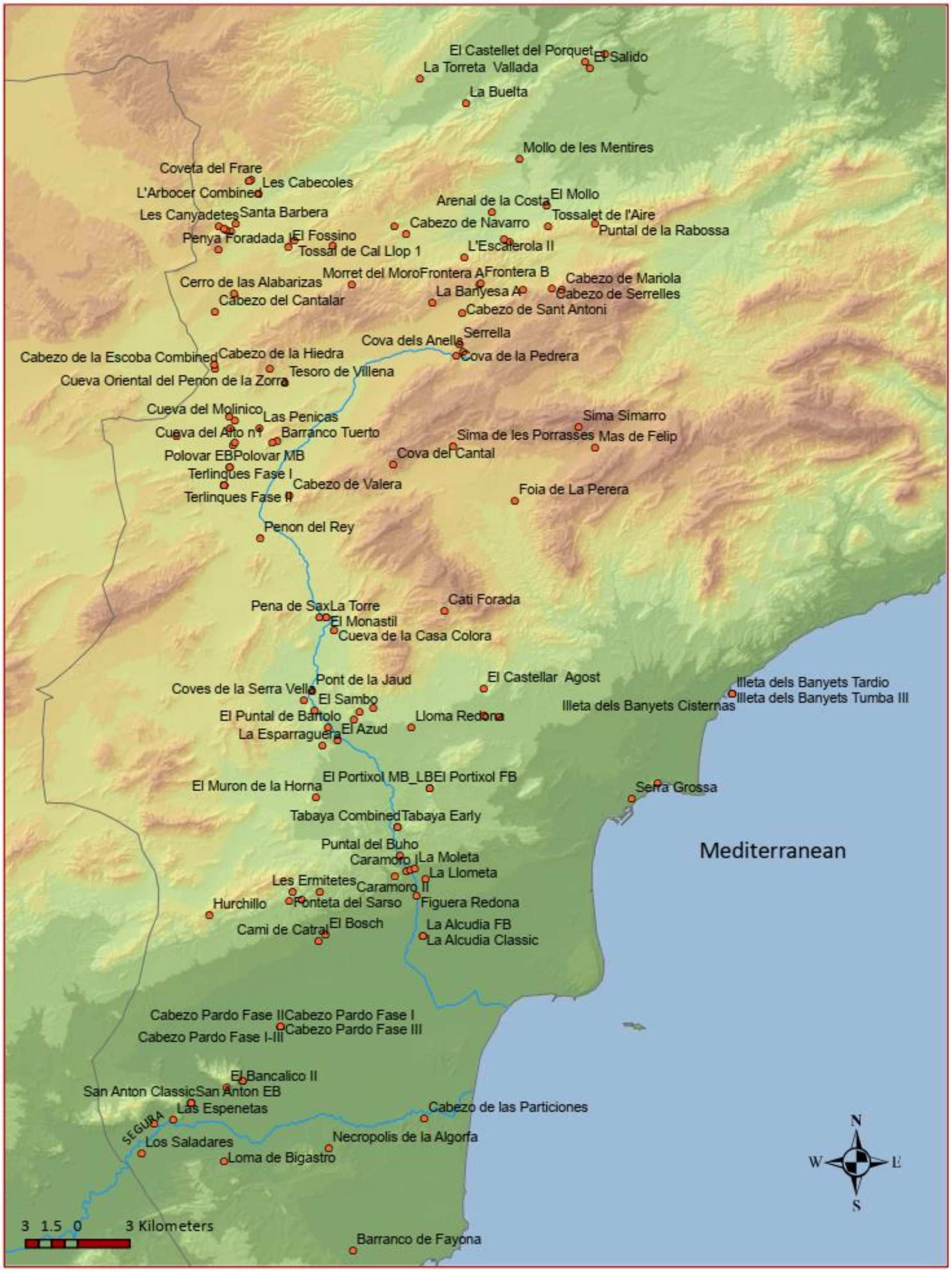


Figure 5.2. Locations of Southern Region sites in this analysis from all time periods.

Summary Statistics

The following table and figures present the summary statistics for the assemblages and artifact classes used in the network analyses. The dataset, in its entirety, is found in Appendix A.

Figure 5.3 presents the amounts of each material type in all collections combined. The top three material class categories are ceramic, stone, and shell. The total number of undecorated ceramics is 51,662. Decorated ceramics constitute 30% of all artifacts used for network analysis. (Only four out of every 100 ceramics are decorated.) Plainware is significantly more common than decorated ware in the VBA, although the network analysis does not utilize undecorated ceramics.

The dominance of undecorated ceramics in VBA assemblages is not an unexpected result. VBA settlements were small-scale and production was conducted on a similarly small-scale. Iberian archaeologists have noted both the lack of bronze production for most of the VBA and the lack of decorated ceramics.

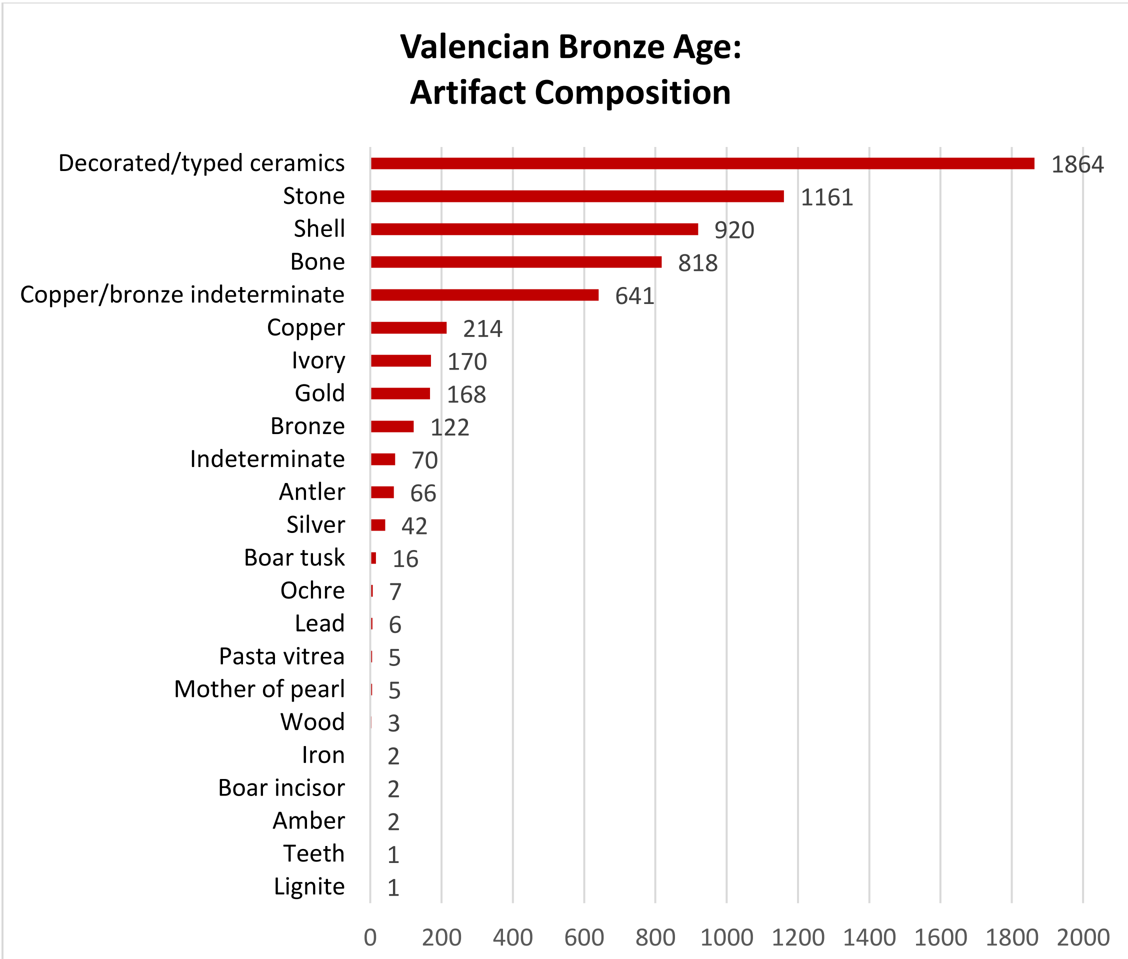


Figure 5.3. The number of instances of each material class contained in all VBA artifact assemblages. Total artifacts in analysis = 6,369.

Figure 5.4 compares the amounts of each material type in the Northern and Southern Region assemblages. Iberian archaeologists note lower levels of bronze and ivory production/consumption in the Southern Region. Figure 5.4 confirms these conclusions. Overall, the Southern Region has a more varied assemblage composition, including a much higher presence of copper, bronze, gold, and ivory. Gold and silver are practically non-existent in the Northern Region. As a result, decorated ceramics dominate the Northern Region assemblages. Decorated ceramics are uncommon finds in the Southern Region until the Late to Final Bronze Ages.

Tin bronze and ivory do not have local sources. This along with the fact that the Southern Region's assemblage is more varied suggests that Southern VBA peoples were participating in different and more diverse exchange relationships than were peoples in the North. While a plausible conclusion, it is debatable in light of the fact that the Northern Region's ceramic assemblages contain a more diverse array of ceramic decorations than those of the South. The processes that created these material patterns are not well understood but the overall consensus by Iberian archaeologists is that the Southern Region's material culture is partially a result of participation in the Argaric sphere while the Northern Region developed out of prior Bell Beaker cultures. Without the further formal analysis of social processes presented later in this chapter, it is difficult to draw conclusions about the evolution of the structure of social relationships through time and space in the VBA as affected by opportunities for material exchange.

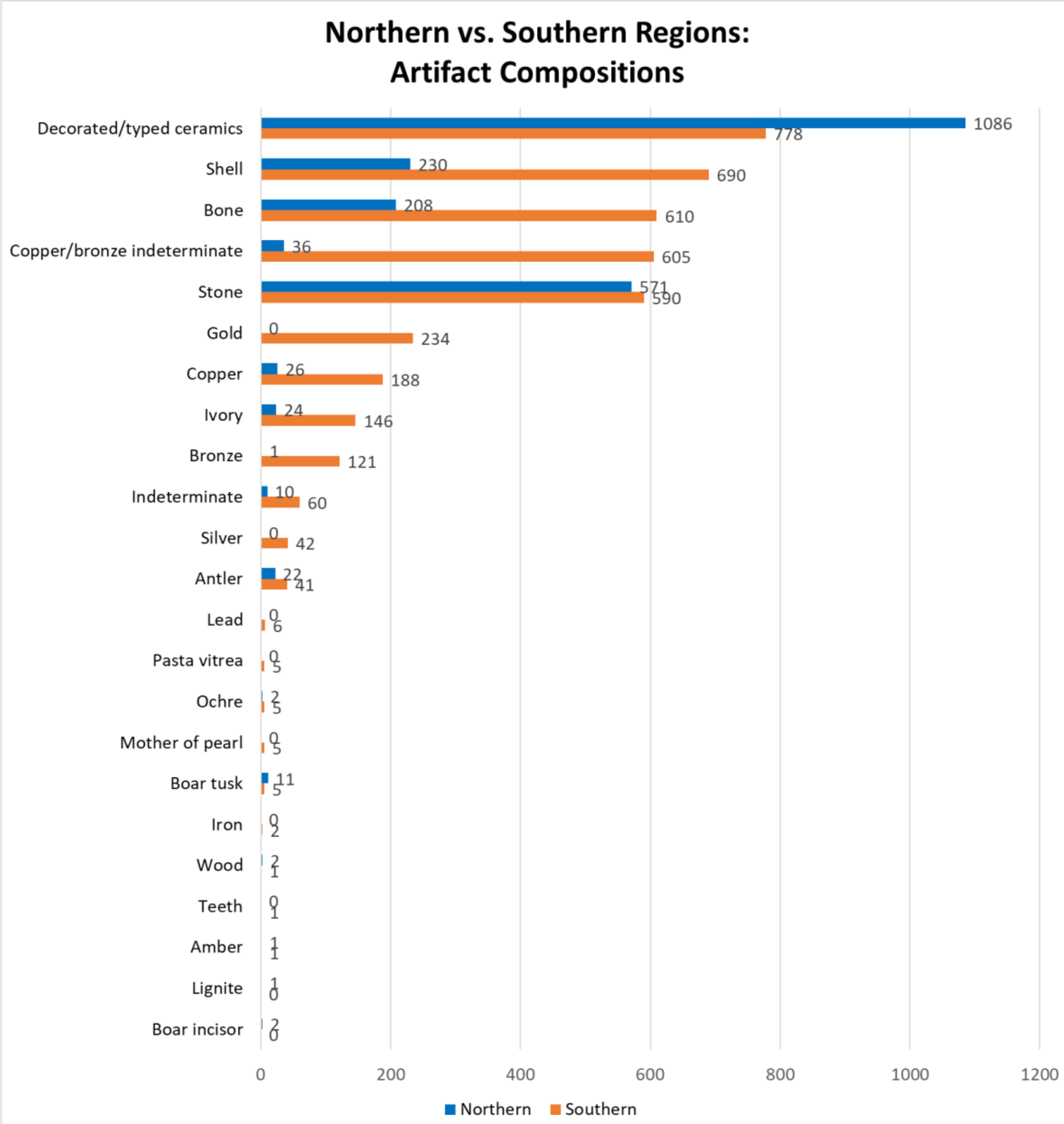


Figure 5.4. The number of instances of each material class contained in Northern versus Southern VBA artifact assemblages.

Table 5.2 summarizes the site elevations, visibility values, and artifacts counts across all assemblages for all VBA sites, sites in the Northern Region, and sites in the Southern Region. The median site elevation across all VBA sites is 466 meters, a median that corresponds with the conclusion that sites are located on medium elevations. The range of site sizes is large, but the median site size for all VBA sites is only 820 meters squared. VBA sites are generally small and we can see that here. The range in site elevations, visibility, and site size in the South is higher than in the North. However, the median site elevation and median site size are higher in the North than in the South.

Table 5.2. Summary statistics

Summary Statistic: All Sites	Site Elevation m	Visibility m2	Site Size m2 (N = 114)	Artifacts Counts Across Sites
Range	0-1196	2041-14472	15-34000	1-777
Median	466	7050	820	5
Summary Statistic: Northern Region	Site Elevation m	Visibility m2	Site Size m2 (N = 34)	Artifacts Counts Across Sites
Range	39-1196	2412-11874	15-25000	1-429
Median	480	7236	840	5
Summary Statistic: Southern Region	Site Elevation m	Visibility m2	Site Size m2 (N = 80)	Artifacts Counts Across Sites
Range	0-1189	2041-14472	55-34000	1-777
Median	417	7050	775	6

Total artifacts analyzed: North = 2,233; South = 4,136

A comparison of the summary statistics between the North and South through time confirms the existence of regionally specific patterning. Figures 5.5, 5.6, and 5.7 summarize and compare site elevations, visibility values, and site sizes for sites within the Northern and Southern VBAs through time. These values are summarized through violin plots that combine box plots and rotated density plots placed on each side of the centerline of the violin to represent the data distribution shape. The width of the violin is proportional to the site count for each chrono-region. The white bar is the interquartile range and the black horizontal line dividing the white bar is the median. Wider portions of the violin represent a higher probability that a site will take on the given value.

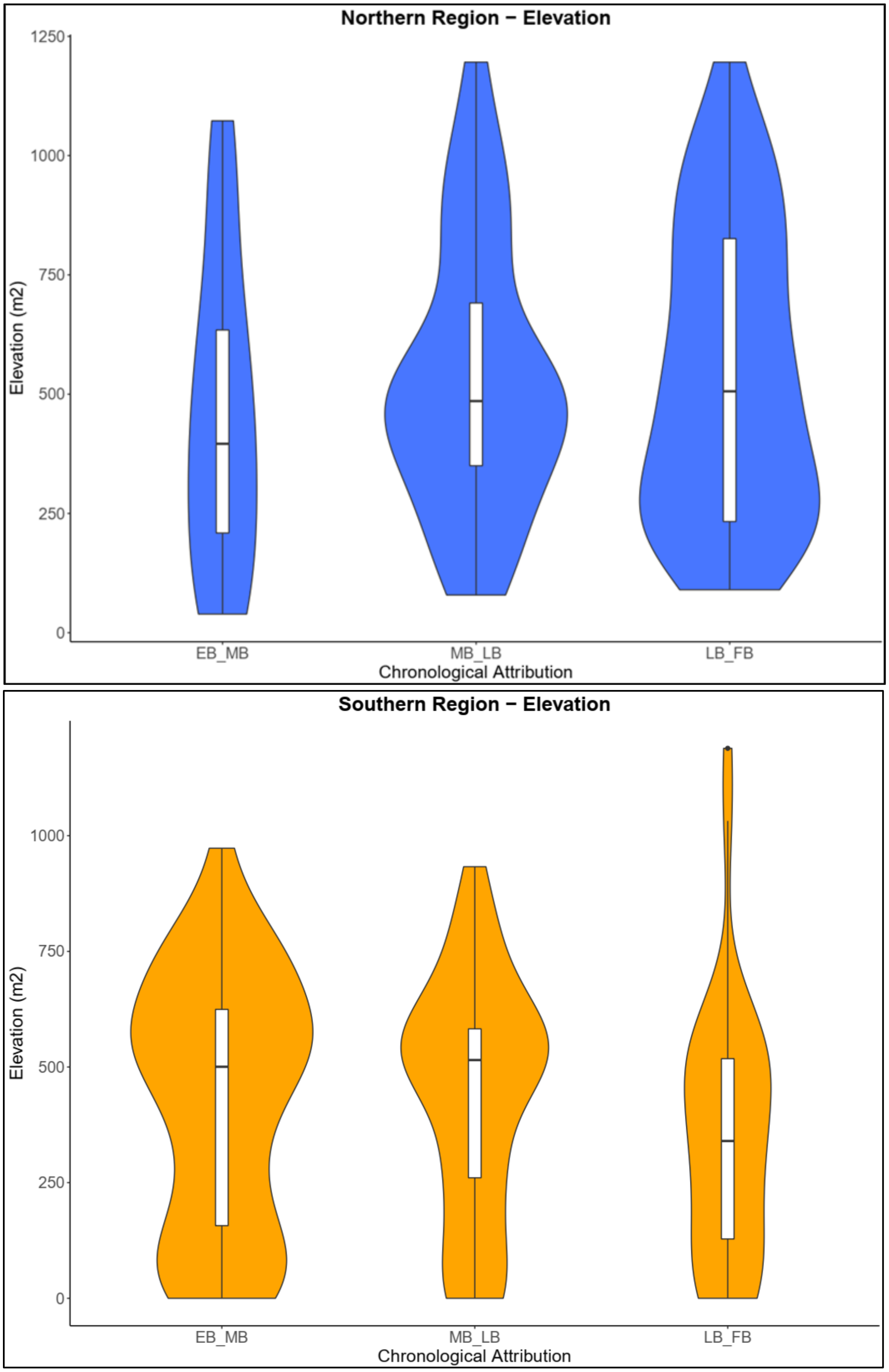


Figure 5.5. Elevation trends through time and space for the Northern and Southern VBAs.

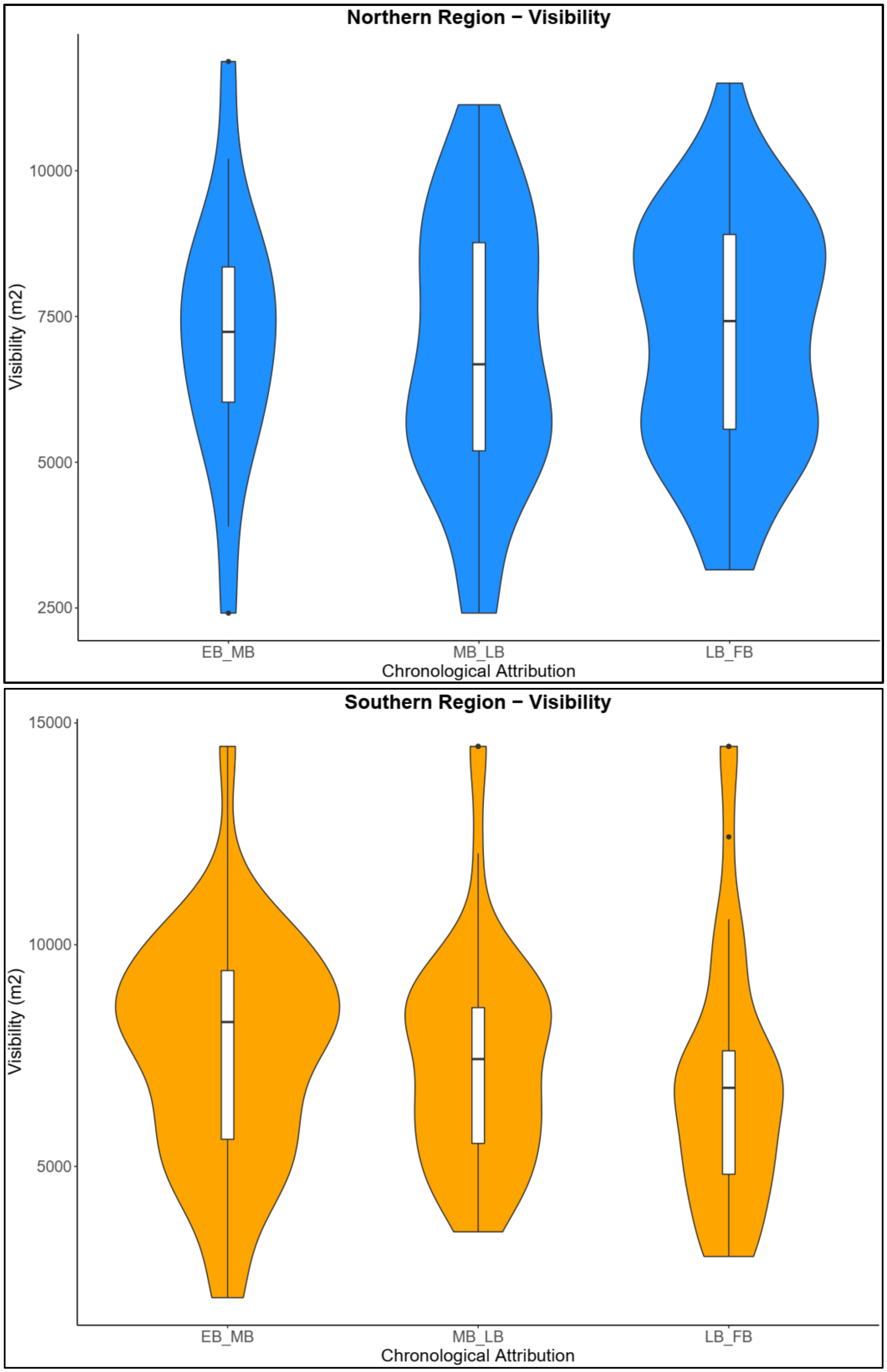


Figure 5.6. Visibility trends through time and space for the Northern and Southern VBAs. (Visibility is the number of visible square meters from a site's location.)

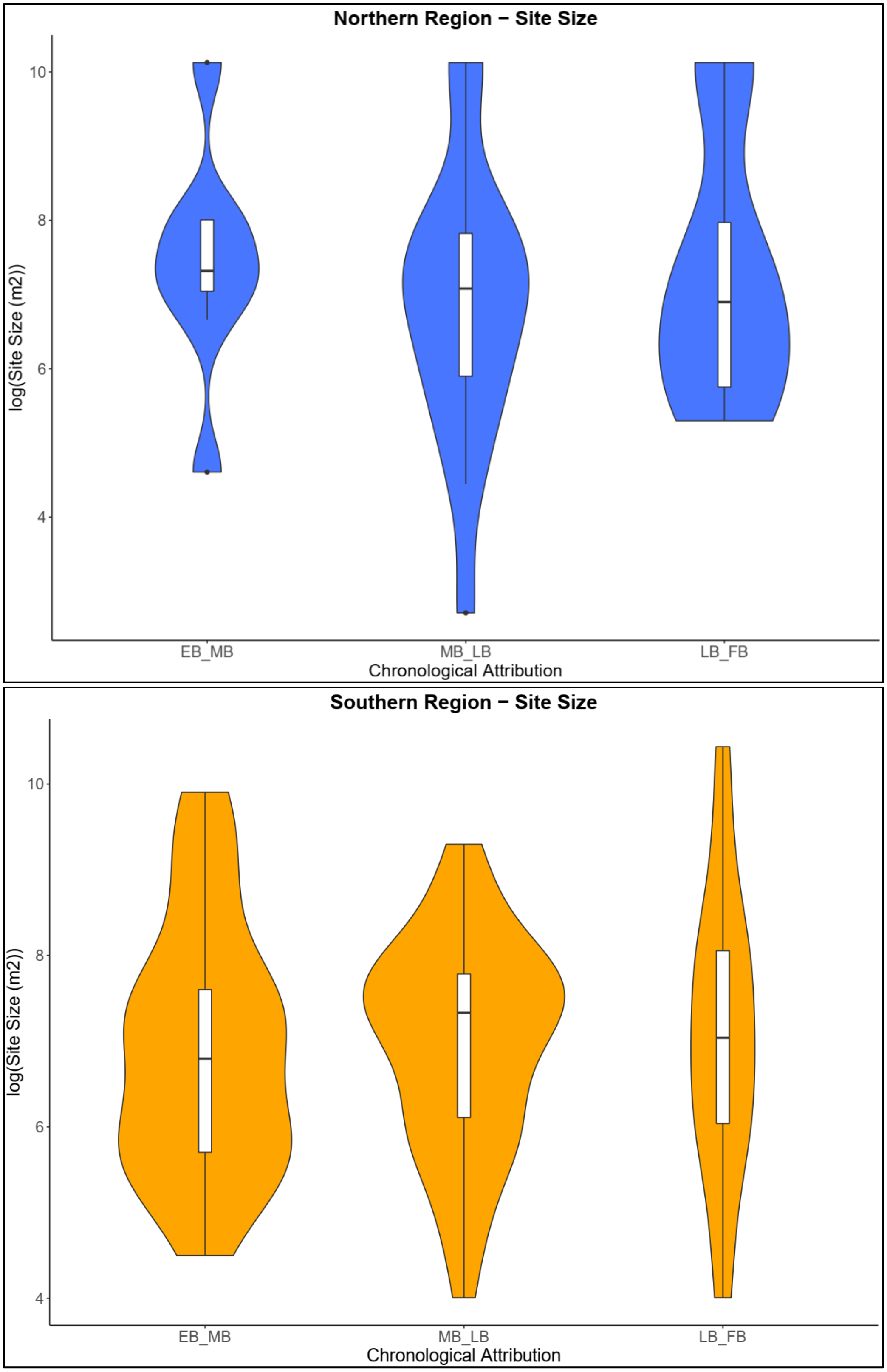


Figure 5.7. Site size trends through time and space for the Northern and Southern VBAs. (Y-axis has a logarithmic scale.)

The median and range of elevations increase through time in the Northern VBA. The opposite occurs in the Southern VBA. However, the Southern VBA has one high outlier in the Late and Final Bronze Ages. Most Iberian archaeologists contend that VBA sites tend to be located at higher elevations through time. These results indicate that this subject appraisal is not accurate. The tendency to locate at higher elevations later in time occurs in the North but not in the South. More will be said on this in the next chapter, however, the results of this analysis suggest that shifts in elevation are due to region-specific, population reactions and reorganization caused by Late Bronze Age exogenous pressures.

Visibility is the number of visible square meters from a site's location. The Northern and Southern regions display opposing trends in visibility through time. Visibility decreases in the South while increasing in the North. Median site size increases slightly in the Southern VBA through time while the median site size decreases through time in the North. This evidence indicates that the population aggregation suggested by Iberian archaeologists to have occurred during the later periods of the VBA occurred more so in the South.

VBA Networks

Network visualizations provide a first comparative glimpse of social patterning through time and space in the VBA. Figures 5.8 through 5.13 present network visualizations for each of the six chrono-regions. Also, note that these graphs indicate the River Valley location for each site. These visualizations are discussed in more detail in Chapter 6: Discussion. However, general observations are presented here.

The network graphs for the Northern VBA (Figures 5.8, 5.9, and 5.10) reveal several interesting patterns. First, the number and connectivity of sites increased through time, most notably between the Early to Middle and Middle to Late Bronze Ages. Thus, the social networks describing the Northern VBA are not static through time. Second, if we compare trends at the scale of river valleys, the number of sites and connectivity increased more so within the Palancia River Valley than within the Turia River Valley. The Palancia River Valley is bounded geographically by two mountain ranges and is more physically isolated.

The increase in the number of sites within the Palancia River Valley could suggest an influx of people through time and/or substantial settlement pattern reorganization within the most northern part of the VBA funneled through the mountain ranges of the *Sistema Iberica Turolense*. The mountain ranges along the Palancia may have been a physical conduit for outside influences like the Cogotas I cultures from the *Meseta Central* and migrations from Central Europe. The rise in network connectivity through time within the Palancia River corridor indicates an increase in social cohesion through time within an established, sub-regional social structure.

Furthermore, the focus of interaction shifts away from the Turia River Valley (sites in red) toward the Palancia River Valley sites (sites in blue) during the Middle to Late Bronze Ages, then back again to the Turia River Valley during the Late to Final Bronze Ages as evidenced by which sites are more centrally located within each network graph. Patterns of interactions within each of the River Valleys in the Northern VBA appear to be distinct from each other. In other words, Palancia River Valley sites tend to interact more with other Palancia River Valley sites and Turia River Valley sites interact more with other Turia River Valley sites and in a different trajectory. These patterns suggest the influence of geography on network connectivity patterns in the Northern VBA.

The social network patterns presented for the Southern VBA tell a different story (Figures 5.11, 5.12, and 5.13). The differences between the Early to Middle Bronze Ages and Middle to Late Bronze Ages are challenging to detect using visual analysis of these graphs only. However, the Late to Final Bronze Age network graph shows a drastic change. The number and connectivity of sites decreased substantially. The Argaric collapsed by the Late Bronze Age and this occurrence is a potential explanation for the socio-structural changes seen here.

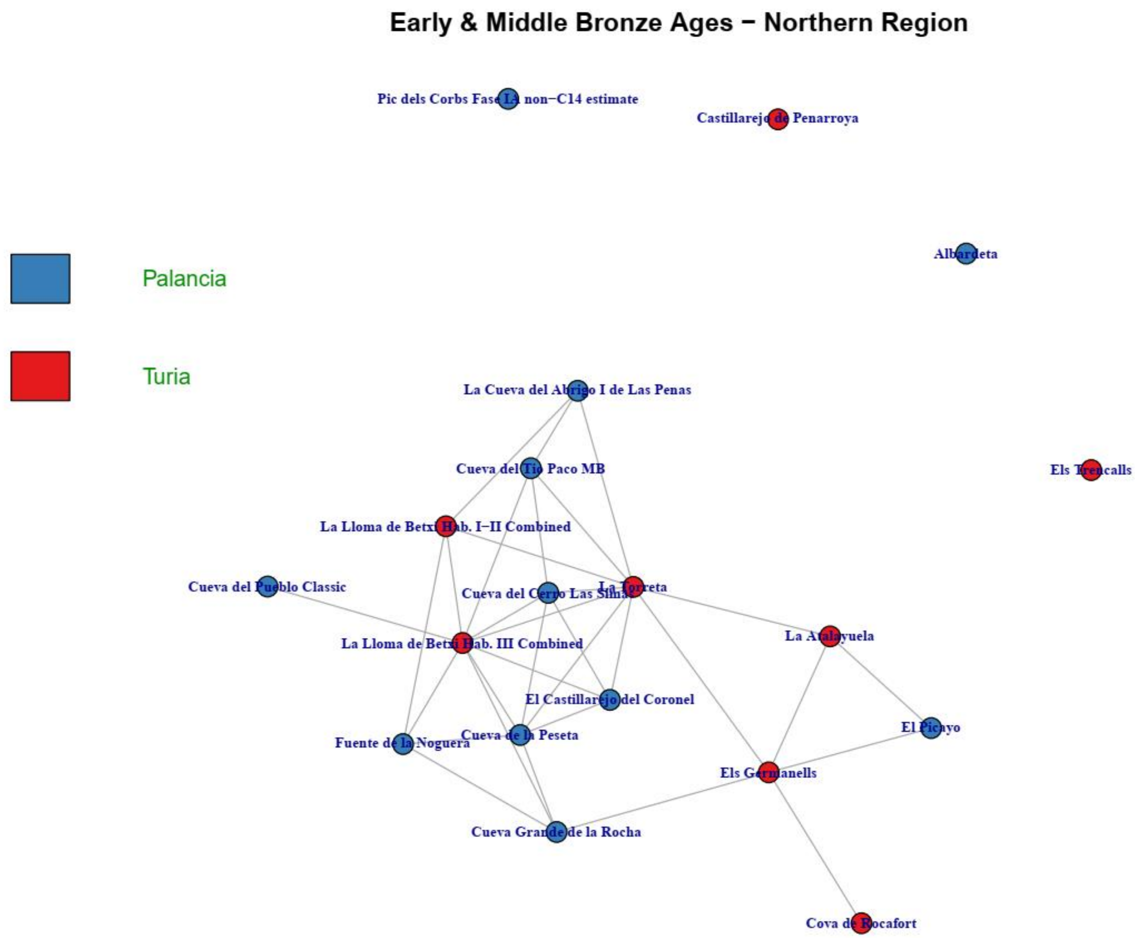


Figure 5.8. Early and Middle, Northern Valencian Bronze Ages network with river valley membership indicated for each site. Note that sites are arranged by the Fruchterman-Reingold layout algorithm commonly used in network visualization and not by geographic location. The Fruchterman-Reingold layout algorithm plots closely related nodes nearer to each other. Two sites have a relationship if their correlation value falls within the upper three quartiles of the correlation matrix for the network.

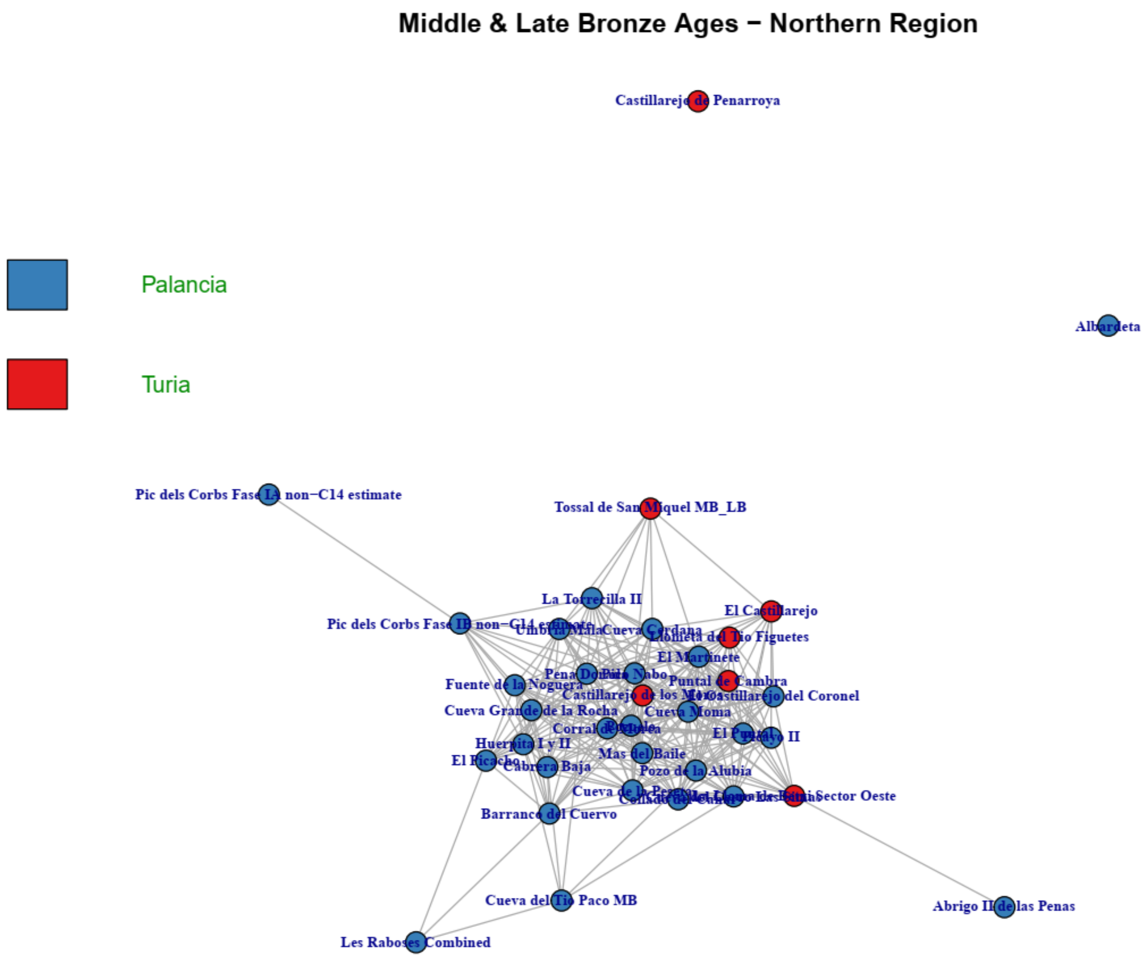


Figure 5.9. Middle and Late, Northern Valencian Bronze Ages network with river valley membership indicated for each site. Note that sites are arranged by the Fruchterman-Reingold layout algorithm commonly used in network visualization and not by geographic location. The Fruchterman-Reingold layout algorithm plots closely related nodes nearer to each other. Two sites have a relationship if their correlation value falls within the upper three quartiles of the correlation matrix for the network.

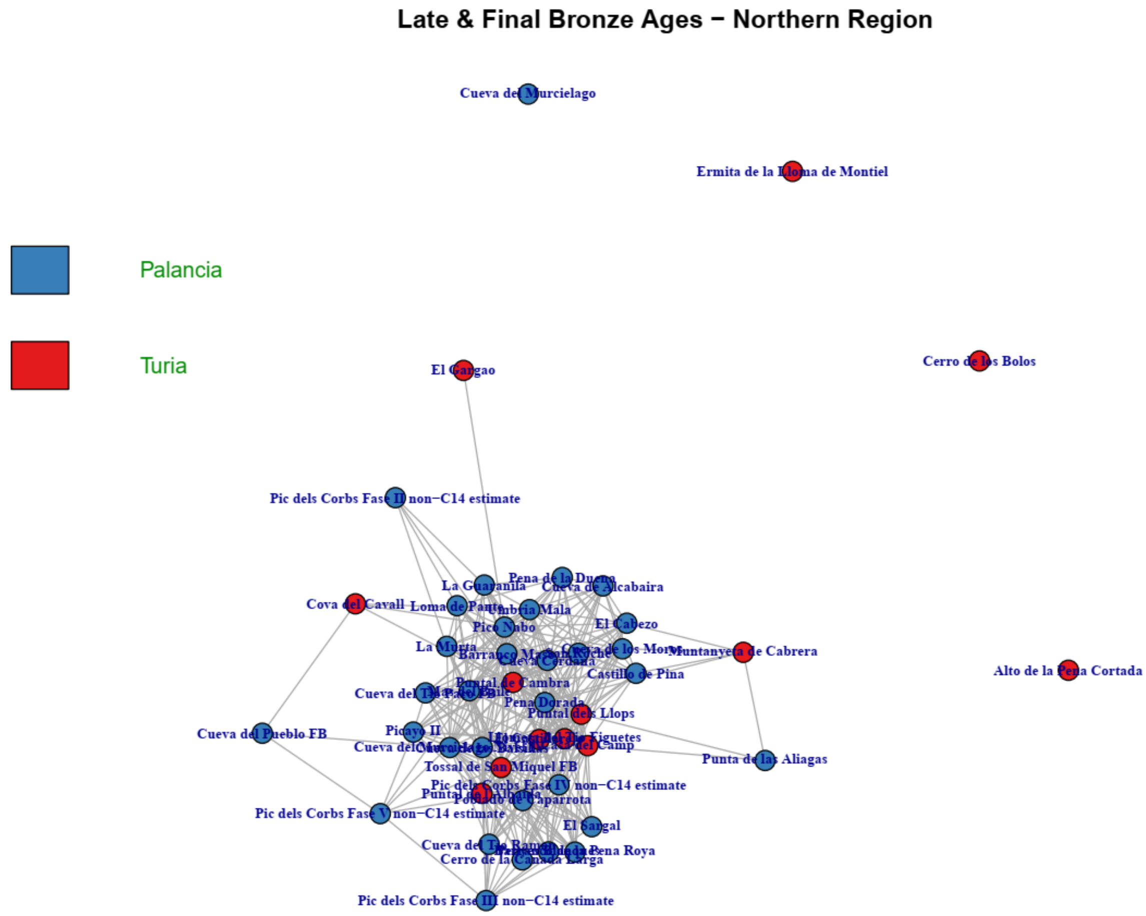


Figure 5.10. Late and Final, Northern Valencian Bronze Ages network with river valley membership indicated for each site. Note that sites are arranged by the Fruchterman-Reingold layout algorithm commonly used in network visualization and not by geographic location. The Fruchterman-Reingold layout algorithm plots closely related nodes nearer to each other. Two sites have a relationship if their correlation value falls within the upper three quartiles of the correlation matrix for the network.

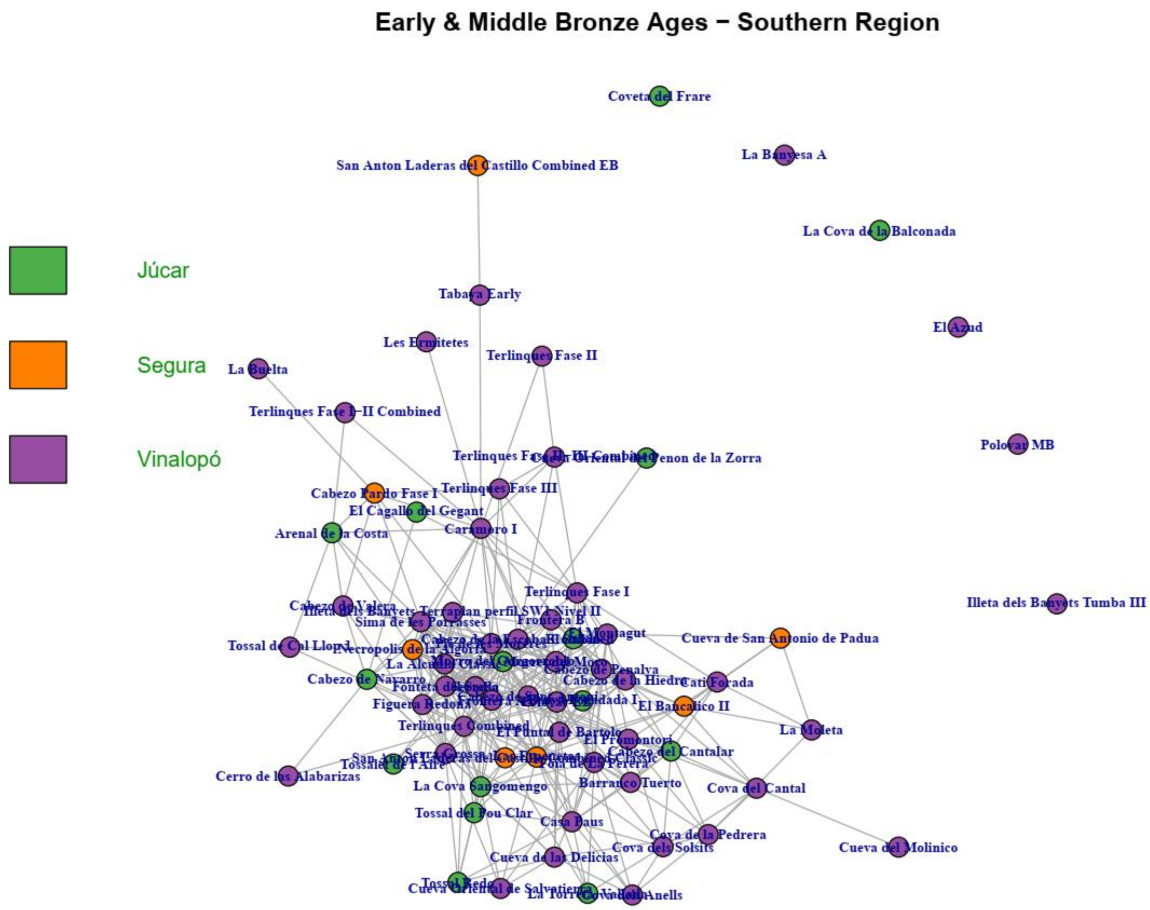


Figure 5.11. Early and Middle, Southern Valencian Bronze Ages network with river valley membership indicated for each site. Note that sites are arranged by the Fruchterman- Reingold layout algorithm commonly used in network visualization and not by geographic location. The Fruchterman-Reingold layout algorithm plots closely related nodes nearer to each other. Two sites have a relationship if their correlation value falls within the upper three quartiles of the correlation matrix for the network.

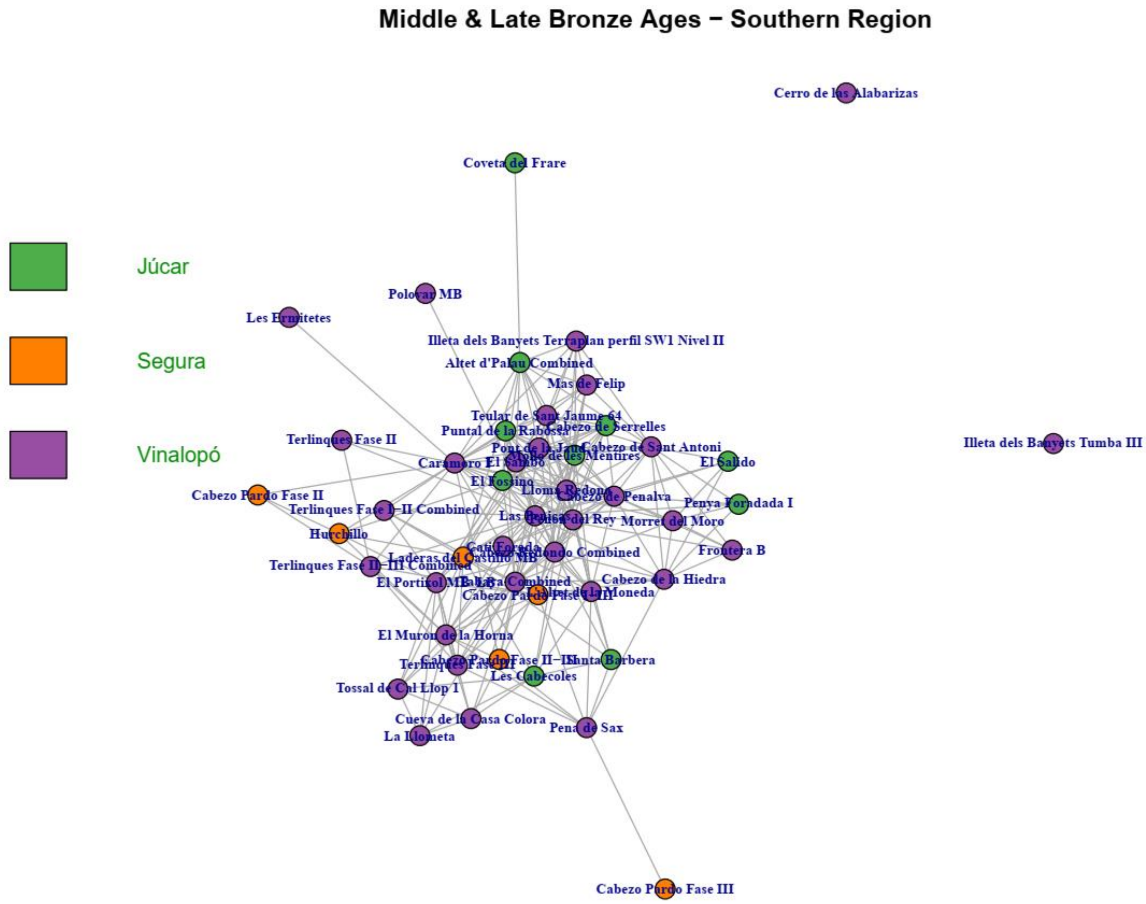


Figure 5.12. Middle and Late, Southern Valencian Bronze Ages network with river valley membership indicated for each site. Note that sites are arranged by the Fruchterman-Reingold layout algorithm commonly used in network visualization and not by geographic location. The Fruchterman-Reingold layout algorithm plots closely related nodes nearer to each other. Two sites have a relationship if their correlation value falls within the upper three quartiles of the correlation matrix for the network.

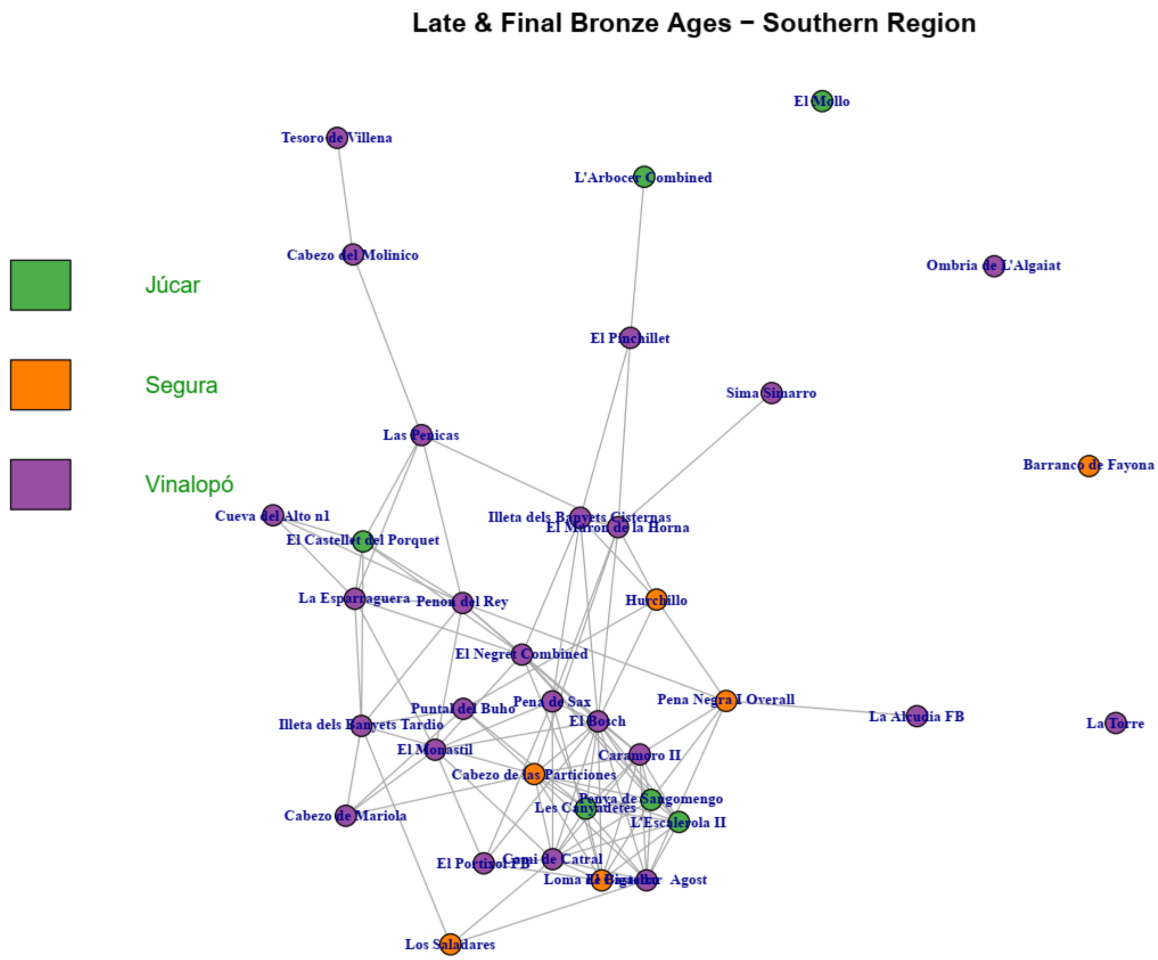


Figure 5.13. Late and Final, Southern Valencian Bronze Ages network with river valley membership indicated for each site. Note that sites are arranged by the Fruchterman-Reingold layout algorithm commonly used in network visualization and not by geographic location. The Fruchterman-Reingold layout algorithm plots closely related nodes nearer to each other. Two sites have a relationship if their correlation value falls within the upper three quartiles of the correlation matrix for the network.

Results of Robusticity Tests

Overall, the results of the robusticity tests for all six chrono-regions (Figures 5.14 through 5.19) show that VBA networks produced in this analysis are robust to missing nodes. Up to 60% of the nodes in the Northern Region can be removed before the correlation between the network measures of each simulation begins to vary substantially. Up to 50% of the nodes in the Southern Region can be removed before the variation of

Spearman's rho values analyzed for sampled networks within each sampling fraction increases considerably.

Northern Region

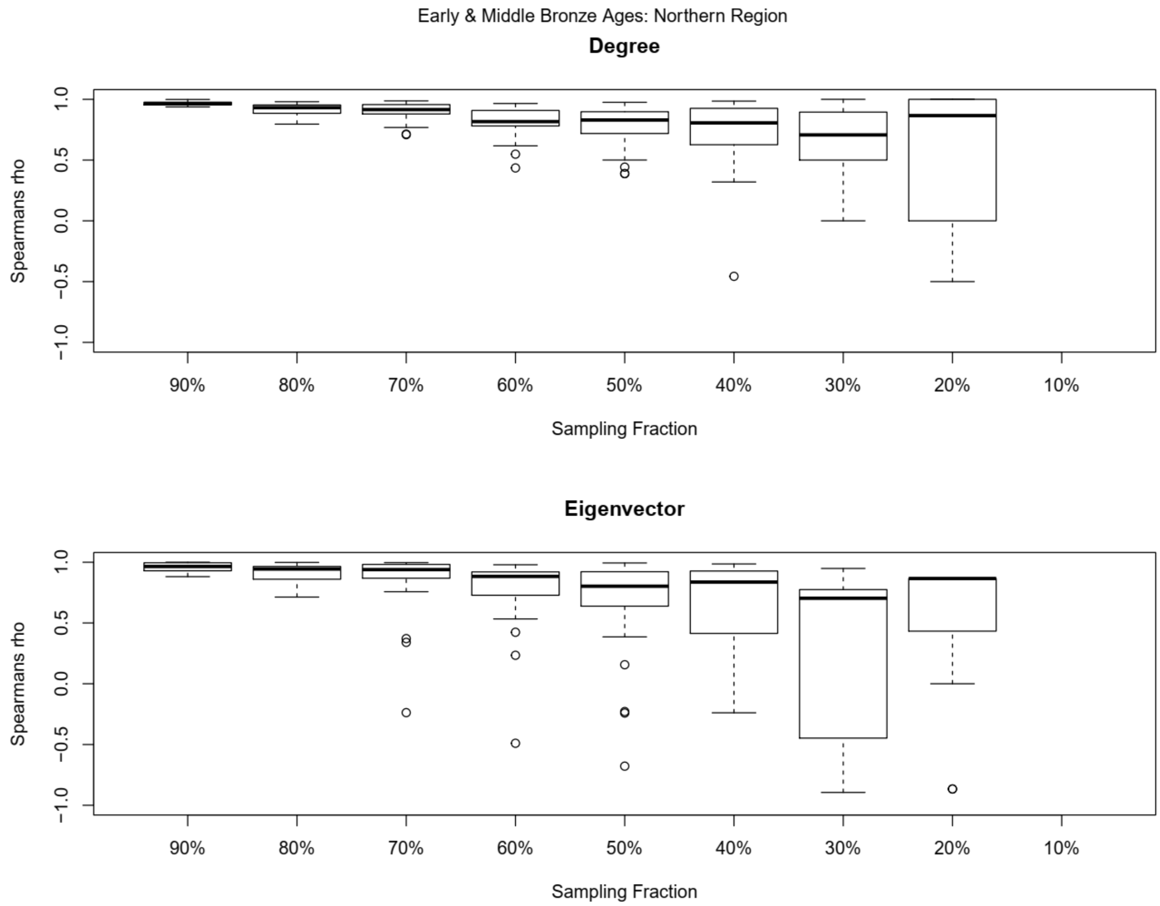


Figure 5.14. Robusticity results for the Early and Middle, Northern Valencian Bronze Ages. Shows two different network metrics: network degree (top); eigenvector centrality (bottom).

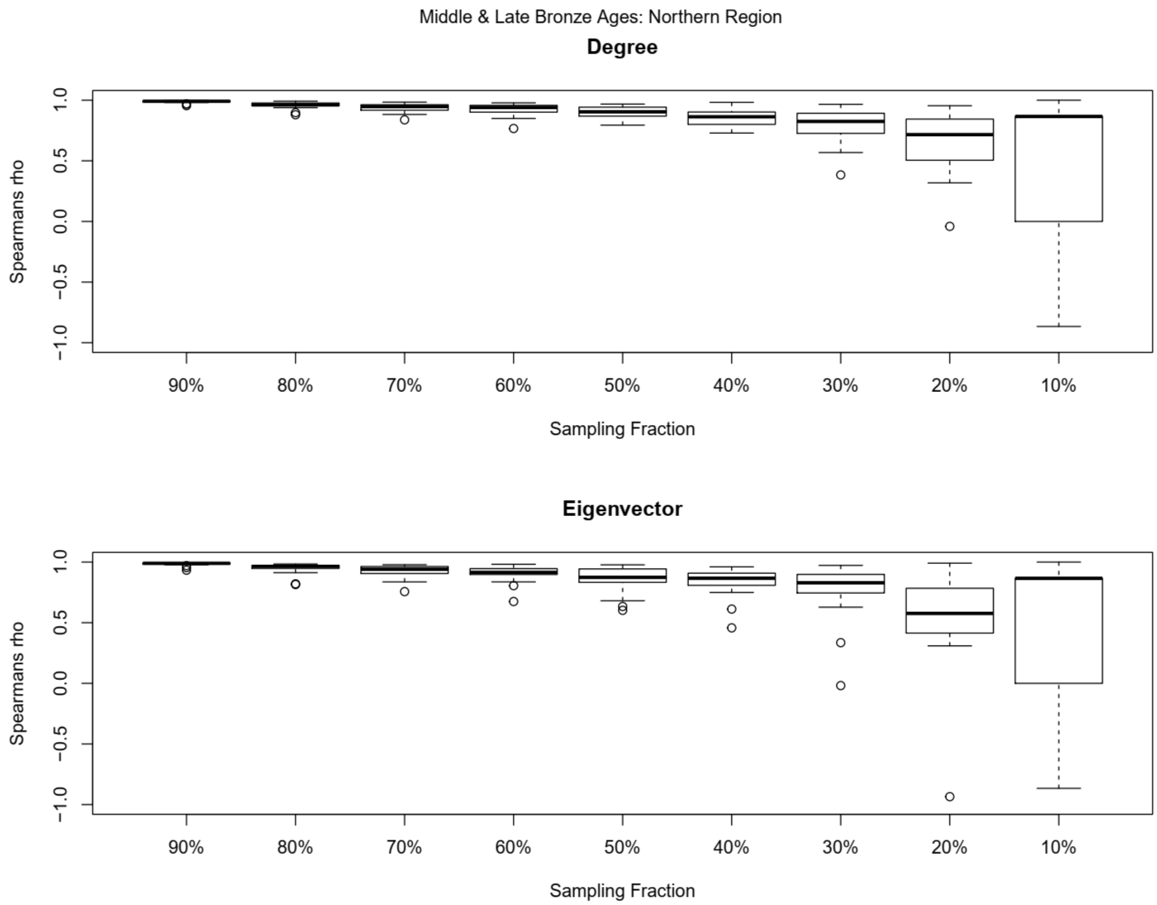


Figure 5.15. Robusticity results for the Middle and Late, Northern Valencian Bronze Ages. Shows two different network metrics: network degree (top); eigenvector centrality (bottom).

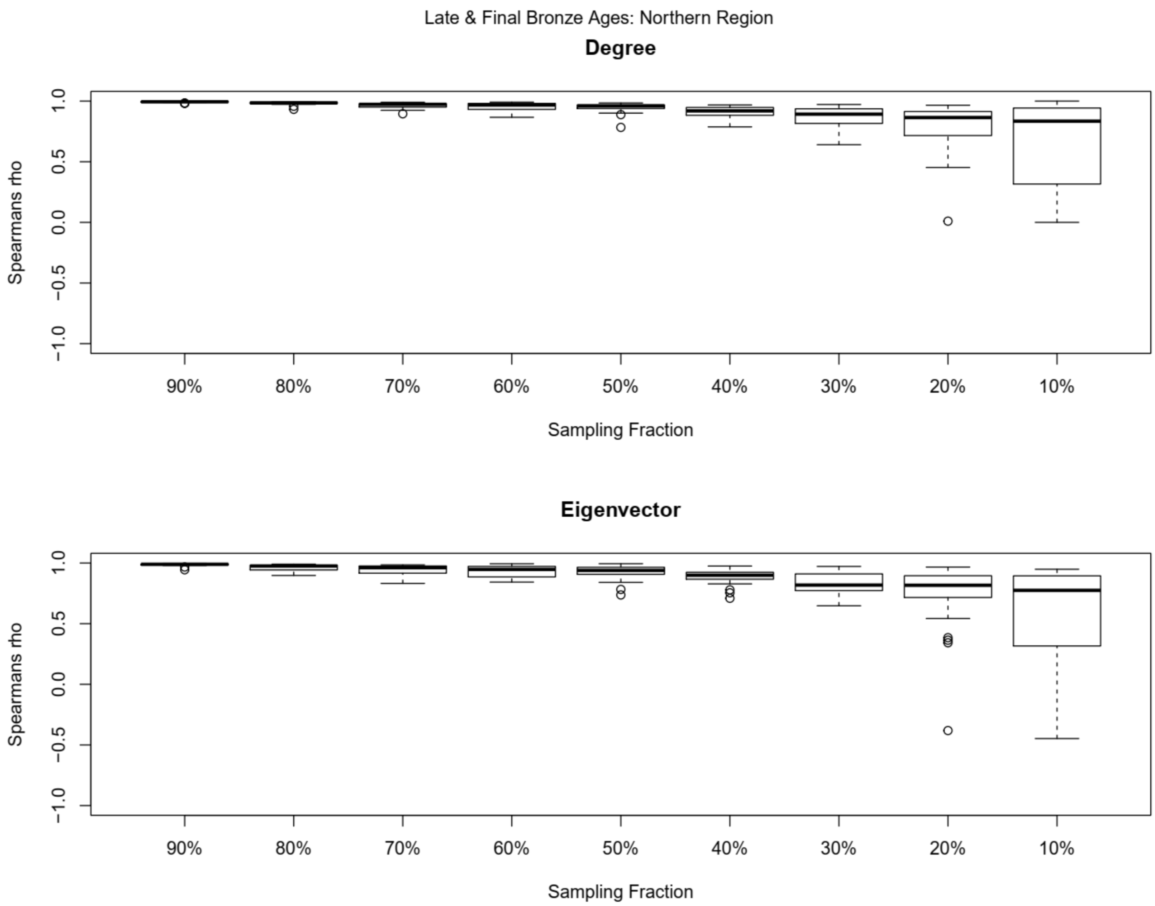


Figure 5.16. Robusticity results for the Late and Final, Northern Valencian Bronze Ages. Shows two different network metrics: network degree (top); eigenvector centrality (bottom).

Southern Region

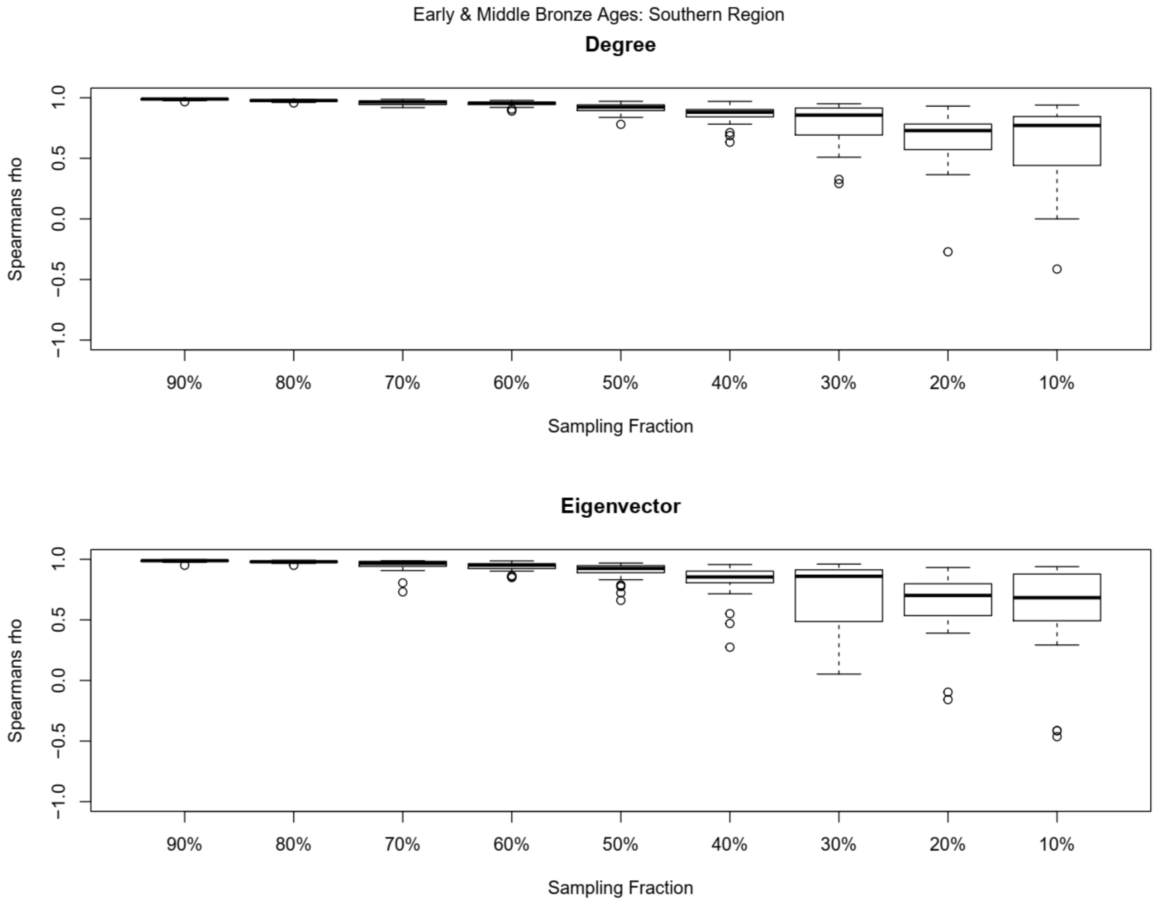


Figure 5.17. Robusticity results for the Early and Middle, Southern Valencian Bronze Ages. Shows two different network metrics: network degree (top); eigenvector centrality (bottom).

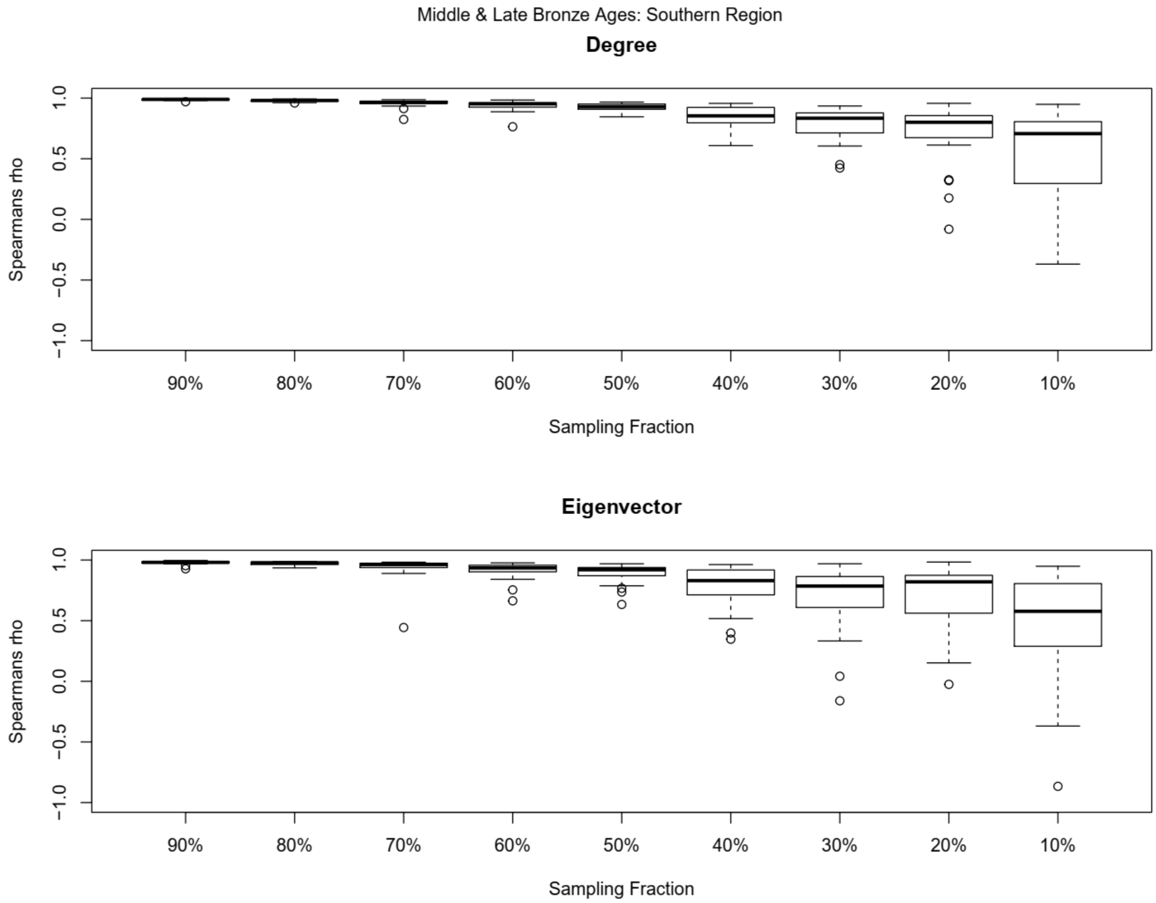


Figure 5.18. Robusticity results for the Middle and Late, Southern Valencian Bronze Ages. Shows two different network metrics: network degree (top); eigenvector centrality (bottom).

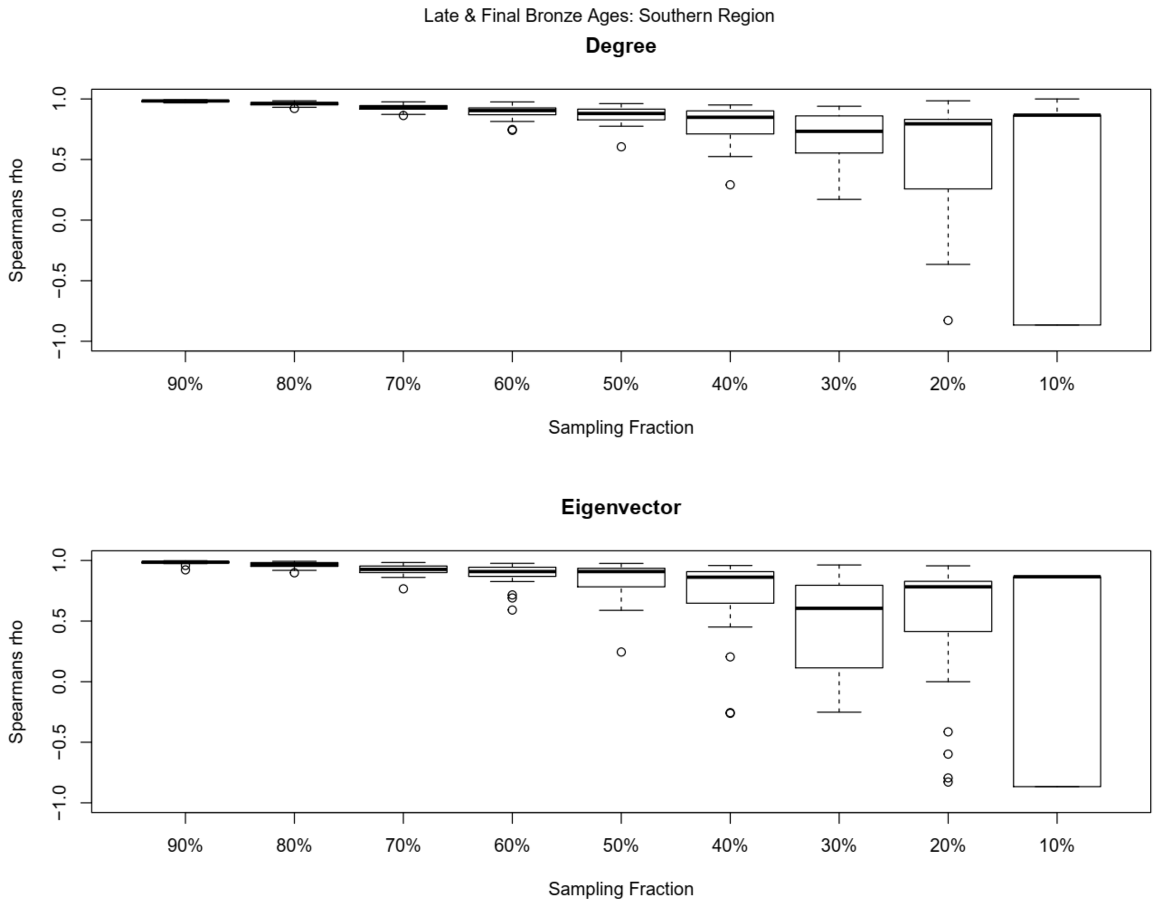


Figure 5.19. Robusticity results for the Late and Final, Southern Valencian Bronze Ages. Shows two different network metrics: network degree (top); eigenvector centrality (bottom).

Social Stability

The networks presented above for each of the six chrono-regions are robust and suggestive of several interesting regional differences between the socio-structural patterns of the Northern and Southern VBAs through time. However, up to this point, the results have been descriptive in nature, summarizing social relationships between VBA sites. The descriptive summaries tell us that neither VBA region remained stable through time. In a world characterized by constant change, this result should be expected. Social stability is relative. Since there is no absolute standard of social stability, social stability must be characterized comparatively. Therefore, the following discussion uses the results of both the Social Stability Index calculation and the structural cohesion analysis to answer the question, “Which region was more stable through time, the North or the South?”

Social Stability Index

Tables 5.3 and 5.4 present the Social Stability Index (SSI) results, defined in Chapter 4: Methods: Measuring Social Stability, for the Northern and Southern VBA’s. The absolute values of the percent changes in SSI from the Early Bronze Age to the Final Bronze Age are higher in the South than in the North. Thus, the Southern VBA was less stable than the Northern VBA through time.

Each Social Stability Dimension (SSD) reveals additional information about different aspects of each social structure. The Connectivity, Clustering, and Centralization and Power indices of the Northern VBA increase from the Early to Middle to Middle to Late periods. The Distance Index also increases while the Vulnerability Index decreases. (The Vulnerability Index consists of the modularity and cutpoints subcategories. Higher values of these two subcategories indicate more modularity and cutpoints, both potential threats to network stability.) Except for the increasing Distance Index, these patterns are in line with a region exhibiting social stability. However, these patterns change during the Late to Final Bronze Ages. Connectivity, Clustering, and Power and Centralization decrease while Vulnerability increases. Distance continues to increase. Therefore, even though the Northern VBA is more stable than the Southern VBA, a shift in the Northern VBA’s social trajectory occurs during the Late and Final Bronze Ages. More will be said on this in the next sections.

The trajectories of the Southern VBA's SSDs reveal noticeable differences in pattern. As with the Northern VBA, the Connectivity, Clustering, and Centralization and Power indices of the Southern VBA increase from the Early to Middle to Middle to Late periods. However, the Distance Index decreases while the Vulnerability Index increases. The increase in the Vulnerability Index suggests that the networks of the Southern VBA increase in modularity through time. Ostensibly, this means that the social organization of the Southern VBA was fissioning into densely connected sub-networks connected to each other by just a few ties. By the Late and Final VBA, as with the Northern VBA, the SSD trajectories shift. Connectivity, Clustering, and Centralization and power decrease. Distance increases and Vulnerability continues to increase. Again, more will be said about this shift in the next sections.

Table 5.3. Social Stability Index: Northern Region

Northern Region:	Early & Middle	Middle & Late	Late & Final	% Change Early to Middle	% Change Middle to Final
	Dimension 1: Connectivity				
Network size: giant component	0.33	0.82	1.00		
Average degree: giant component	0.22	1.00	0.98		
Connectivity Index (size/average degree)	0.28	0.47	0.38	65	-19
	Dimension 2: Distance				
	Early & Middle	Middle & Late	Late & Final	% Change Early to Middle	% Change Middle to Final
Diameter	1.00	1.00	1.00		
Average path length	1.00	0.66	0.72		
Average closeness	0.37	0.78	1		
Distance Index	0.79	0.81	0.91	3	11
	Dimension 3: Density				
	Early & Middle	Middle & Late	Late & Final	% Change Early to Middle	% Change Middle to Final
Density	0.19	0.43	0.43		
Global transitivity	0.48	0.68	0.60		
Clustering Index	0.33	0.56	0.51	67	-8
	Dimension 4: Centralization and Power				
	Early & Middle	Middle & Late	Late & Final	% Change Early to Middle	% Change Middle to Final
Global eigenvector centralization index	0.52	0.67	0.47		
Centralization and Power Index	0.52	0.67	0.47	29	-30
	Dimension 5: Vulnerability				
	Early & Middle	Middle & Late	Late & Final	% Change Early to Middle	% Change Middle to Final
Cut-points	1.00	0.44	0.18		
Modularity	1.00	0.42	0.57		
Vulnerability Index	1.00	0.43	0.38	-57	-13
				% Change Early to Final	
Stability Index	0.52	0.57	0.50	-4	

Table 5.4. Social Stability Index: Southern Region

Southern Region:	Early & Middle	Middle & Late	Late & Final	% Change Early to Middle	% Change Middle to Final
	Dimension 1: Connectivity				
Network size: giant component	1.00	0.71	0.48		
Average degree: giant component	0.97	1.00	0.59		
Connectivity Index (size/average degree)	0.16	0.23	0.21	43	-10
	Dimension 2: Distance				
	Early & Middle	Middle & Late	Late & Final	% Change Early to Middle	% Change Middle to Final
Diameter	1.00	0.80	0.80		
Average path length	0.95	0.73	1.00		
Average closeness	1.00	0.63	0.50		
Distance Index	0.98	0.72	0.77	-27	6
	Dimension 3: Density				
	Early & Middle	Middle & Late	Late & Final	% Change Early to Middle	% Change Middle to Final
Density	0.13	0.21	0.17		
Global transitivity	0.47	0.50	0.54		
Clustering Index	0.30	0.36	0.35	18	-1
	Dimension 4: Centralization and Power				
	Early & Middle	Middle & Late	Late & Final	% Change Early to Middle	% Change Middle to Final
Global eigenvector centralization index	0.58	0.70	0.69		
Centralization and Power Index	0.58	0.70	0.69	21	-2
	Dimension 5: Vulnerability				
	Early & Middle	Middle & Late	Late & Final	% Change Early to Middle	% Change Middle to Final
Cut-points	0.50	0.56	1.00		
Modularity	0.87	0.87	1.00		
Vulnerability Index	0.69	0.72	1.00	4	40
				% Change Early to Final	
Stability Index	0.45	0.49	0.52	15	

Structural cohesion analysis results

Figures 5.20 through 5.25 below show both the nested, cohesive block diagrams and the hierarchical trees from the cohesive blocking analysis for the Northern and Southern VBA's. The trajectory of structural cohesion through time was different for each region. Several exogenous pressures began to affect each region during the latter half of the Middle Bronze Age and into the Late and Final Bronze Ages. These pressures included the collapse of the Argaric culture, Phoenician and Greek incursions, and migrations from the *Meseta Central* and the south of modern France. These effects are discussed further in Chapter 6: Discussion.

Again, we can make some general observations. Neither region was static, yet the overall structural cohesion of the Northern VBA did not change. In other words, the branching pattern remained consistent while the number of cohesive blocks increased at the point during the Late Middle Bronze Age when both regions are affected by several exogenous pressures. A different trend is apparent for the Southern VBA where the branching pattern changed through time and the number of cohesive blocks decreased sometime after this 'crisis point.'

The structural cohesion of the Northern VBA during the Early and Middle Bronze Ages exhibited a high degree of embeddedness. Each cohesive block nests within increasingly cohesive blocks like Russian dolls in a simple hierarchy. This structure is maintained throughout the Bronze Age and even reinforced after the Northern VBA experienced several exogenous pressures. This deep connectivity is an indicator of the depth of involvement that sites as actors have in their social relationships. This direct involvement only increased through time.

In contrast, the structural cohesion of the Southern VBA during the Early and Middle Bronze Ages was characterized by a branching hierarchy. Thus, the difference in initial socio-structural conditions between the two regions boils down to the branching or lack thereof in underlying structural cohesion. The branching structure means that some social relationships must be conducted at arm's length through intermediaries in contrast to the direct relationships seen in linear nesting. The structure of the branches of the Southern VBA's hierarchy changed through time and by the Final Bronze Age, the branching structure is replaced by the same linear nesting seen in the North. While the structural cohesion of the Northern VBA strengthened through time, the structural cohesion of the South fluctuated.

Therefore, in the case of the VBA, structural cohesion correlates with social stability.

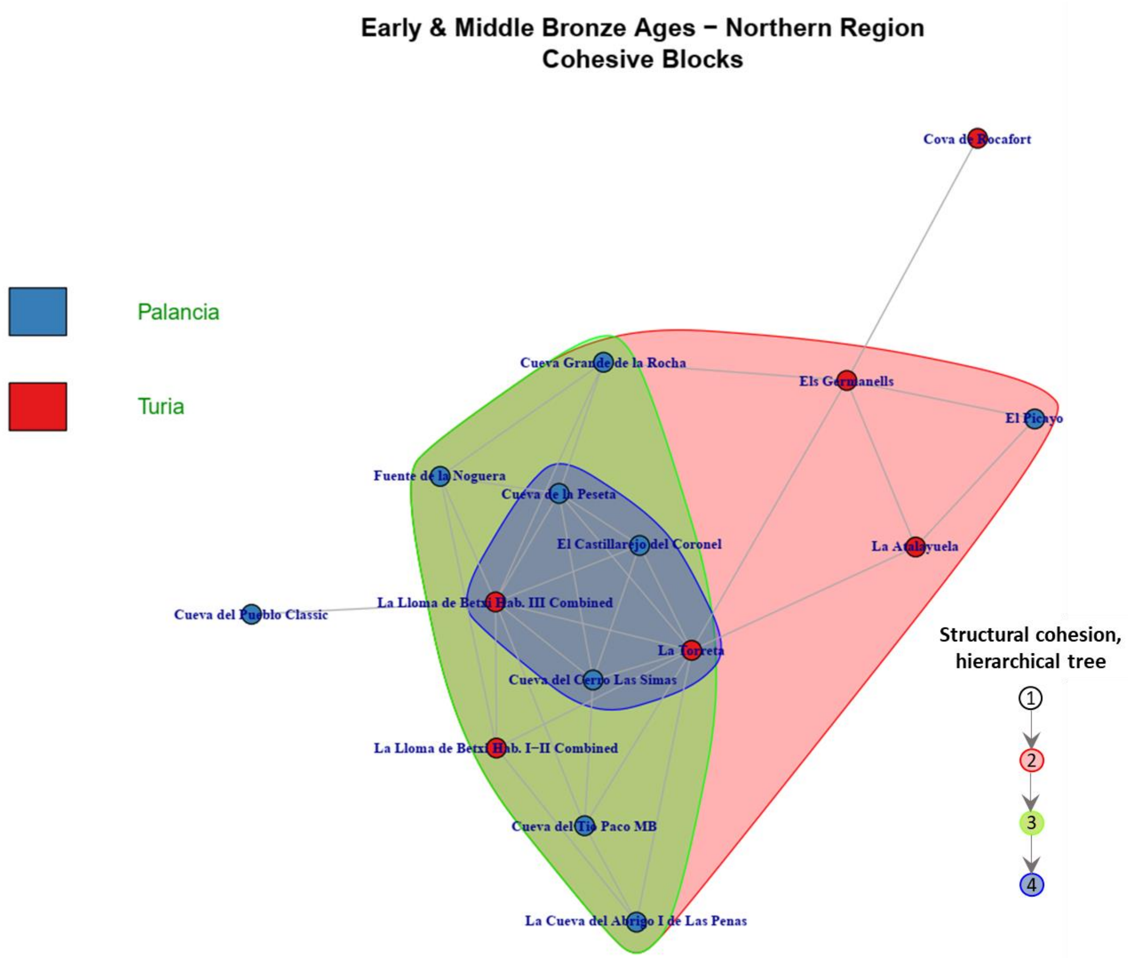


Figure 5.20. Structural cohesion graphics for the Early and Middle Northern Valencian Bronze Ages: cohesive block graph with each, successively nested block outlined in a unique color (left); structural cohesion, hierarchical tree with color-coded blocks matching the same nested blocks in the cohesive block graph (right). Node color indicates a site's river valley location.

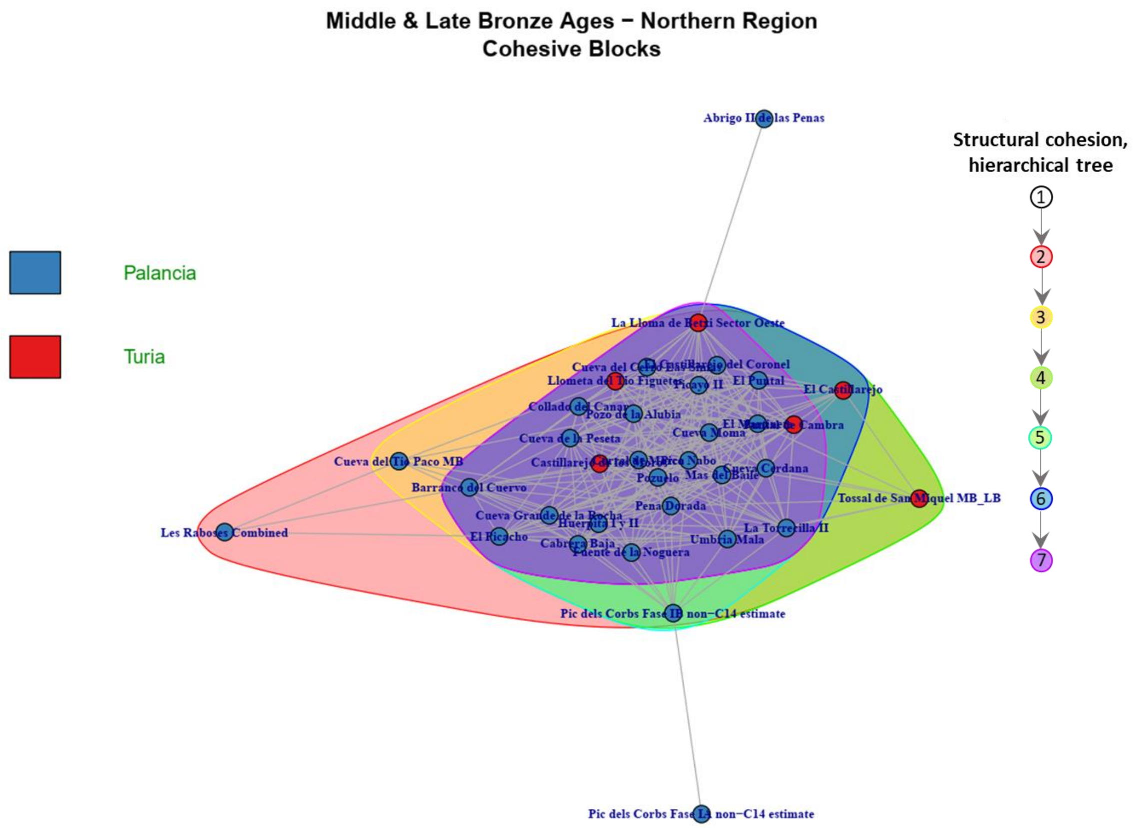


Figure 5.21. Structural cohesion graphics for the Middle and Late Northern Valencian Bronze Ages: cohesive block graph with each, successively nested block outlined in a unique color (left); structural cohesion, hierarchical tree with color-coded blocks matching the same nested blocks in the cohesive block graph (right). Node color indicates a site’s river valley location.

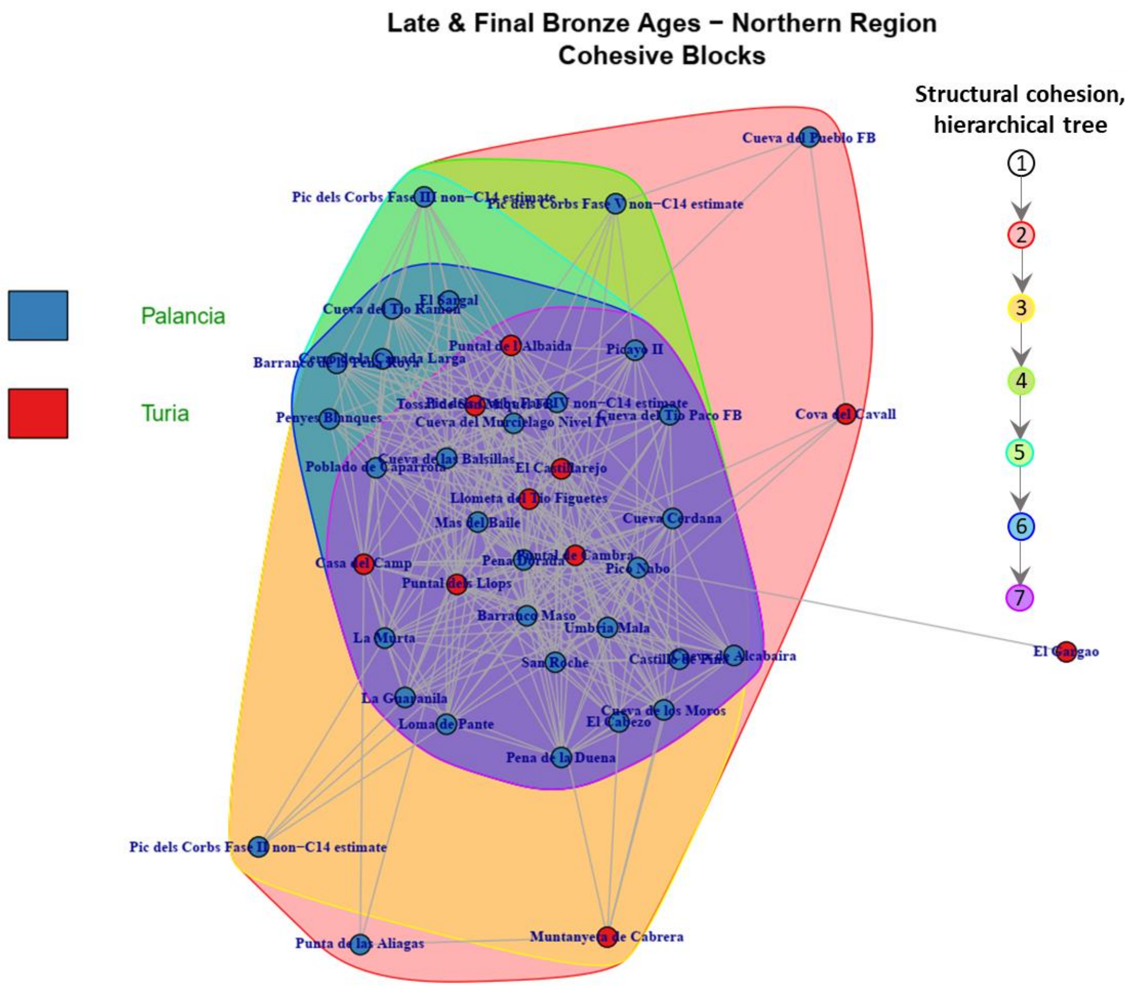


Figure 5.22. Structural cohesion graphics for the Late and Final Northern Valencian Bronze Ages: cohesive block graph with each, successively nested block outlined in a unique color (left); structural cohesion, hierarchical tree with color-coded blocks matching the same nested blocks in the cohesive block graph (right). Node color indicates a site's river valley location.

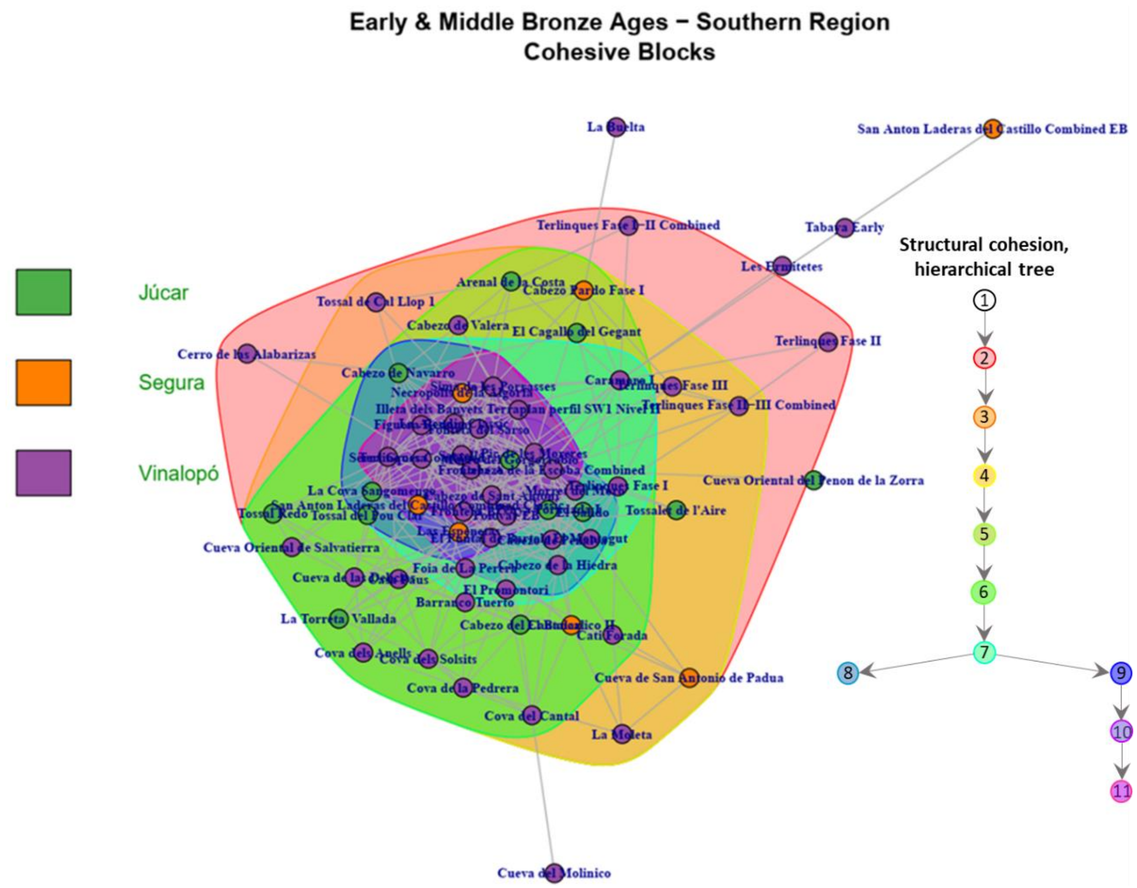


Figure 5.23. Structural cohesion graphics for the Early and Middle Southern Valencian Bronze Ages: cohesive block graph with each block outlined in a unique color (left); structural cohesion, hierarchical tree with color-coded blocks matching the same blocks in the cohesive block graph (right). Node color indicates a site’s river valley location.

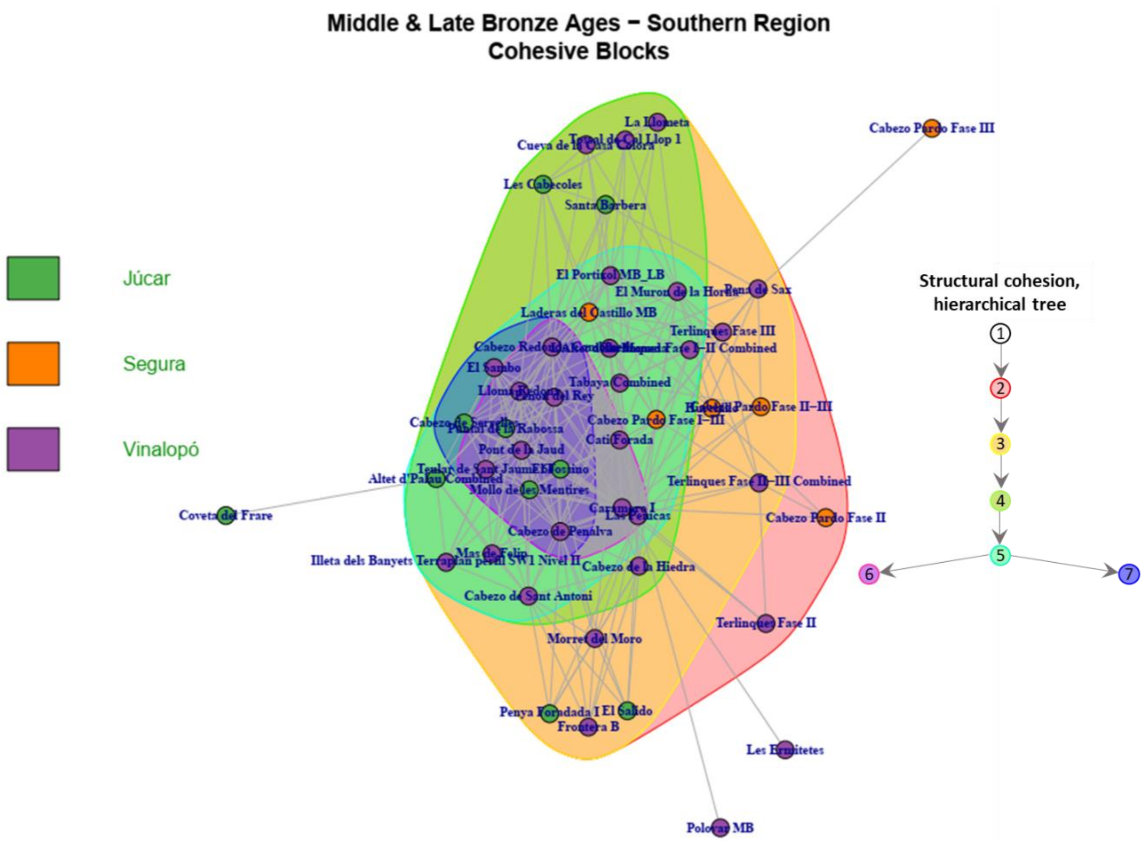


Figure 5.24. Structural cohesion graphics for the Middle and Late Southern Valencian Bronze Ages: cohesive block graph with each block outlined in a unique color (left); structural cohesion, hierarchical tree with color-coded blocks matching the same blocks in the cohesive block graph (right). Node color indicates a site's river valley location.

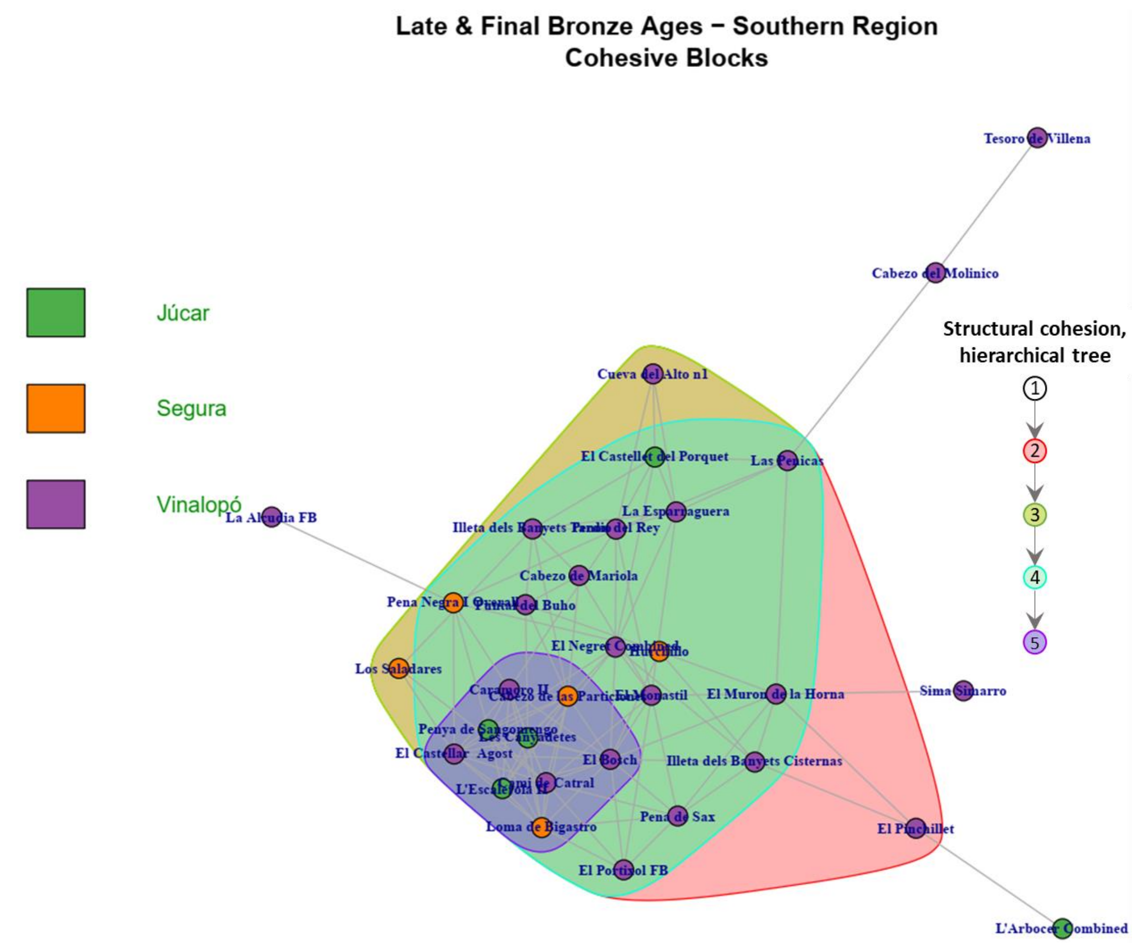


Figure 5.25. Structural cohesion graphics for the Late and Final Southern Valencian Bronze Ages: cohesive block graph with each block outlined in a unique color (left); structural cohesion, hierarchical tree with color-coded blocks matching the same blocks in the cohesive block graph (right). Node color indicates a site's river valley location.

The results from the structural cohesion analysis above implicate underlying social structures in the maintenance of social stability through time. The results of the Multiplexity and ERGM analyses provide further information about the role that social processes and other variables play in maintaining social stability. The discussion below organizes these results in terms of the three framing hypotheses presented in this research.

<u>Hypothesis 1 Social Processes</u>

The stronger the reinforcement of group norms (transitivity), of similarity in relationship (homophily), and/or of overlapping affiliations (multiplexity), the more stable the social system (Burt, 2000; Cook et al., 1983; McPherson et al., 2001; Rogan, 2013; Verbrugge, 1979).

Test implication: The higher the level of transitivity, homophily, and multiplexity in an observed archaeological network, the better the fit to a social system with a slow rate of change in network structure.

ERGM results

Tables 5.5 and 5.10 below show ERGM results and interpretations for both VBA regions. The first column contains the variables tested for each chronological period organized by summary statistics, dyadic dependence variables, main effects variables, and homophily variables. Estimates highlighted in green and/or bold indicate significant results.

The number of sites and edges between sites increased through time in the Northern VBA. The dyadic dependence variable GWESP is significant through time in the North. Based on GWESP, transitivity played a significant role in structuring the Northern VBA's social network. The significant positive GWD results during the Early and Middle Bronze Ages signify that this network tends to have a larger amount of nodes with middle degree values compared to a random network. In other words, the Northern Early and Middle VBA exhibits an even degree distribution among sites. GWD lessens as a significant influence on relationship formation through time.

In contrast, the influence of main effects variables that include geographic location, elevation, and site size was inconsistent through time in the Northern VBA. The only main effects variable with significant influence during the Early and Middle Bronze

Ages is visibility with sites with more visibility tending to have more connections. During this period, significant homophily variables indicate that sites in the Palancia River Valley were less likely to connect while those in the Turia River Valley were more likely to connect. Also, sites that were proximate to each other in an east-west direction had an increased likelihood of forming a relationship.

During the Middle to Late Bronze Ages of the Northern VBA, river valley homophily increased the likelihood of connection within the Palancia River Valley. In other words, sites within the Palancia River Valley were more likely to connect with other Palancia River Valley sites. This result confirms the importance of the sub-regional social networks described earlier using network visualizations alone. Also during this period, larger sites tend to have more connections. Moreover, differential homophily on elevation indicates heterophily, or the tendency to connect to sites at elevations different than one's own. These shifts possibly coincide with the increase in the number of sites and/or population in the Palancia River Valley.

By the Late to Final Bronze Ages, a trend toward assortativity based on degree that began in the earliest period continues, although attenuated. Assortativity based on degree describes the process where actors tend to connect with others who have a similar amount of connectivity. In other words, Middle to Final Northern VBA sites do not show a tendency toward preferential attachment or hierarchy. Also during this period, sites have a greater tendency to connect if located nearer to the Mediterranean coast. This could be a reflection of a shift toward new prospects introduced by Mediterranean culture contact. Furthermore, while GWESP remains significant, its value decreases during this late period further supporting the premise that relationships might have been shifting more outwardly from an inward, transitive focus.

Just as in the Northern VBA, GWESP was significant throughout the Southern VBA but with some important differences. GWESP decreases in influence through time with a substantial decrease during the Late and Final Bronze Ages. GWDSP remains a significant factor throughout all three periods in the South. GWDSP is typically analyzed in combination with GWESP. During the Early and Middle Bronze Ages, GWDSP is negative signaling a strong tendency to form closed triangles during relationship formation. This tendency to form closed social triangles decreases during the Middle and Late period of the Southern VBA. Positive GWDSP estimates combined with positive GWESP estimates indicate that untied partners share a 'friend.' In other words, this shared friendship is not reliant on a tie between the two other nodes, hence the interpretation given in Table 5.8 of attenuated transitivity in the Southern VBA. By the Late and Final Southern VBA, as in the North, transitivity in the form of GWESP decreases as an important social process.

The significance of GWDSP as a negative value during the earliest period reifies the significance of transitivity as a dominant social process responsible for the social structure of the Southern VBA. In other words, to share a friend, a pair of actors must already have a relationship. A high degree of clustering or closed triangles characterize networks with this type of transitivity. The presence of strong transitivity as a social process signifies the importance of local relationships. An actor's position in the social structure is dependent on local friendships.

Hypothesis 1 expects social stability to track with stronger transitivity and we have determined that the Southern VBA was less stable through time than the Northern VBA. More will be said on this in the next chapter, but the case will be made that the context in which it is operating influence a society's social stability outcomes.

Geographic and physical variables played a significant role in structuring the Southern social network. Through time, the ERGM results indicate a shift toward a tendency for bigger sites to connect and toward homophily on elevation and site size. The ERGM results also show a social shift away from the Segura River Valley toward a tendency for sites to connect based on near geographic proximity (see homophily variables). During the Early and Middle Bronze Ages, the Segura River Valley sites likely served as trade conduits for important Argaric materials like bronze. Iberian archaeologists have suggested a total reorganization of the Southern VBA after the Agaric collapse including a new geographic focus on settlement areas northward along the Vinalopó River. The changing influence of geographic and physical variables in the social structuring of the Southern VBA during the Late and Final Bronze Ages supports this archaeological interpretation. The next chapter provides a more detailed analysis of this reorganization.

Hypothesis 1 states that social stability should increase with homophily. The ERGM results indicate that homophily within the Palancia River Valley specifically played a role in structuring the more stable Northern VBA through time. Differential homophily significantly influenced the Southern VBA. During the later periods of the VBA, people of the Southern VBA tended to differentiate into like groups based on site attributes. For example, higher and bigger sites tended to connect with other higher and bigger sites. The differential homophily results suggest that many aspects of social differentiation characterize the Southern VBA, thus social differentiation may be associated with less stable societies.The appearance of the significance of differential homophily on variables like elevation and visibility in the Late and Final Southern VBA bolsters the case for the type of population and site aggregation described by Iberian archaeologists for this period.

Table 5.5. Northern Region ERGM results: Summary Statistics and Dyadic Dependence model.

Color key:	Significant result (p-value < 0.5)	Weak effect (p-value < 0.1)	Not significant	**Significant result in Full Model (p-value < 0.5)**

	ERGMs: Palancia & Turia River Valleys	Chronological Period			Interpretations		
		Early & Middle	Middle & Late	Late & Final	Early & Middle	Middle & Late	Late & Final
Summary Statistics	number of sites	19	36	45		increases	increases
	number of edges	32	272	322		connect-ivity increases	connect-ivity increases
	number of isolates	4	2	4			
	null model edges estimate	-1.4690000	-0.2747000	-0.7297000	not random	not random	not random
Dyadic Dependence Model Variables	GWD estimate	**0.1166007**	NA	NA	likelihood of ties to high degree nodes		
	GWESP estimate	**0.9321945**	**1.1393111**	**1.0182636**	strong transitivity	stronger transit-ivity	weaker transitivity
	GWDSP estimate	NA	NA	NA			

Table 5.6. Northern Region ERGM results: Main Effects model.

Color key:	Significant result (p-value < 0.5)	Weak effect (p-value < 0.1)	Not significant	**Significant result in Full Model (p-value < 0.5)**

	ERGMs: Palancia & Turia River Valleys	Chronological Period			Interpretations		
		Early & Middle	Middle & Late	Late & Final	Early & Middle	Middle & Late	Late & Final
Main Effects Model Variables	nodecov UTM.X estimate	0.0000138	**-0.0000512**	**0.0000299**		slightly more likely to connect as distance from coast increases	slightly less likely to connect as distance from coast increases
	nodecov UTM.Y estimate	0.00000340	**0.0000532**	**0.0000113**		slightly less likely to connect as one travels south	slightly less likely to connect as one travels south
	nodecov Elevation estimate	-0.0008706	**-0.0032546**	**0.0002842**		tendency for sites at lower elevations to connect	tendency for sites at higher eleva-tions to connect
	nodecov Visibility estimate	**0.0004494**	**0.0000776**	**0.0000784**	sites with more visibility have more connec-tions	sites with more visibility have more connections	sites with more visibility have more connec-tions
	nodecov Site.Site. m2 estimate	-0.0002064	**0.0000791**	-0.0000109		larger sites have more connections	
	nodefactor River. Valley Turia estimate	0.4486148	-0.4899699	**0.4371133**			more likely to connect in Turia River Valley

Table 5.7. Northern Region ERGM results: Homophily and Differential Homophily models.

Color key:	Significant result (p-value < 0.5)	Weak effect (p-value < 0.1)	Not significant	**Significant result in Full Model (p-value < 0.5)**

	ERGMs: Palancia & Turia River Valleys	Chronological Period			Interpretations		
		Early & Middle	Middle & Late	Late & Final	Early & Middle	Middle & Late	Late & Final
Homophily Model Variables	nodematch River. Valley Palancia estimate	**-0.4110489**	**0.3894891**	**-1.1303427**	less likely to connect with others in Palancia River Valley	more likely to connect to others in Palancia River Valley	less likely to connect with others in Palancia River Valley
Homophily Model Variables	nodematch River. Valley Turia estimate	**0.1837946**	**-0.7731862**	**-0.2425387**	more likely to connect to others in Turia River Valley	less likely to connect to others in Turia River Valley	less likely to connect to others in Turia River Valley
Differential Homophily Model Variables	absdiff UTM.X estimate	**-0.0000610**	**-0.0000288**	-0.0000097	east-west proximity increases connection likelihood	east-west proximity increases connec-tion likeli-hood	
Differential Homophily Model Variables	absdiff UTM.Y estimate	-0.0000283	-0.0000045	-0.0000080			
Differential Homophily Model Variables	absdiff Elevation estimate	0.0009244	**-0.0001538**	**-0.0005060**		tendency for hetero-phily on elevation	tendency for hetero-phily on elevation
Differential Homophily Model Variables	absdiff Visibility estimate	0.0001561	0.0000507	-0.0000729			
Differential Homophily Model Variables	absdiff Site.Site. m2 estimate	-0.0001710	-0.0000843	-0.0000256			
Differential Homophily Model Variables	absdiff numties estimate	**-0.2776143**	**-0.0888342**	**-0.0597353**	assort-ativity	assort-ativity	assort-ativity

Table 5.8. Southern Region ERGM Results: Summary Statistics and Dyadic Dependence model.

Color key:	Significant result (p-value < 0.5)	Weak effect (p-value < 0.1)	Not significant	**Significant result in Full Model (p-value < 0.5)**

	ERGMs: Júcar, Vinalopó, & Segura River Valleys	Chronological Period			Interpretations		
		Early & Middle	Middle & Late	Late & Final	Early & Middle	Middle & Late	Late & Final
Summary Statistics	number of sites	70	48	36		decreases	decreases
Summary Statistics	number of edges	324	240	105		connect -ivity decreases	connect-ivity decreases
Summary Statistics	number of isolates	6	2	4			
Summary Statistics	null model edges estimate	-1.8646000	-1.3083300	-1.6090000	not random	not random	not random
Dyadic Dependence Model Variables	GWD Estimate	NA	NA	**-1.3143901**			likelihood of ties to high degree nodes
Dyadic Dependence Model Variables	GWESP estimate	**3.8349125**	**3.5091163**	**1.1931709**	strong transit-ivity	attenuated transit-ivity	transit-ivity decreases
Dyadic Dependence Model Variables	GWDSP estimate	**-0.1105022**	**0.0495047**	**-0.1001691**	strong transit-ivity	untied pairs share a friend; friend-ship tie not reliant on a tie between the pair	strong transit-ivity

Table 5.9. Southern Region ERGM Results: Main Effects model.

Color key:	Significant result (p-value < 0.5)	Weak effect (p-value < 0.1)	Not significant	**Significant result in Full Model (p-value < 0.5)**

	ERGMs: Júcar, Vinalopó, & Segura River Valleys	Chronological Period			Interpretations		
		Early & Middle	Middle & Late	Late & Final	Early & Middle	Middle & Late	Late & Final
Main Effects Model Variables	nodecov UTM.X estimate	0.0000079	0.0000004	**-0.0000178**			less likely to connect as distance from coast increases
	nodecov UTM.Y estimate	-0.0000130	-0.0000047	**0.0000149**	more likely to connect as one travels south		less likely to connect as one travels south
	nodecov Elevation estimate	0.0005768	-0.0000047	**-0.0030086**	tendency for sites at higher elevations to connect		tendency for sites at lower elevations to connect
	nodecov Visibility estimate	0.0000123	**-0.0001029**	-0.0000522		sites with less visibility have more connec-tions	
	nodecov Site.Site.m2 estimate	-0.0000257	0.0000973	0.0000218		tendency for larger sites to have more connect-ions	
	nodefactor River. Valley Segura estimate	-0.1443139	**-1.1927577**	**-1.8582918**		less likely to connect if in Segura River Valley	less likely to connect if in Segura River Valley
	nodefactor River. Valley Vinalopó estimate	0.0090611	0.0019433	**-0.9006580**			less likely to connect if in Vinalopó River Valley

Table 5.10. Southern Region ERGM Results: Homophily and Differential Homophily models.

Color key:	Significant result (p-value < 0.5)	Weak effect (p-value < 0.1)	Not significant	**Significant result in Full Model (p-value < 0.5)**

	ERGMs: Júcar, Vinalopó, & Segura River Valleys	Chronological Period			Interpretations		
		Early & Middle	Middle & Late	Late & Final	Early & Middle	Middle & Late	Late & Final
Homophily Model Variables	nodematch River. Valley Segura estimate	0.3767544	**-0.0737586**	**-0.8541023**		less likely to connect to others in Segura River Valley	less likely to connect to others in Segura River Valley
	nodematch River. Valley Vinalopó estimate	0.0321659	**0.0296628**	**-0.2315246**		more likely to connect to others in Vinalopó River Valley	less likely to connect to others in Vinalopó River Valley
	nodematch River. Valley Júcar estimate	-0.4846271	-0.0072871	**0.7618665**			more likely to connect to others in Júcar River Valley
Differential Homophily Model Variables	absdiff UTM.X estimate	-0.0000059	**-0.0000119**	**-0.0000263**		east-west proximity increases connection likelihood	east-west proximity increases connection likelihood
	absdiff UTM.Y estimate	-0.0000004	**-0.0000104**	**-0.0000178**		north-south proximity increases likelihood to connect	north-south proximity increases likelihood to connect
	absdiff Elevation estimate	-0.0000008	0.0001739	**0.0017384**			tendency for homophily on elevation
	absdiff Visibility estimate	0.0000131	-0.0000512	0.0000393			
	absdiff Site.Site.m2 estimate	-0.0000117	**0.0001373**	0.0000056		site size homophily	
	absdiff numties estimate	**-0.0210967**	**-0.0264316**	**-0.2300265**	assortat-ivity	assortat-ivity	increased assortat-ivity

Of interest to this analysis is the influence that the trade of copper and bronze may have had on social stability, especially in light of the long-standing tradition of citing the introduction of bronze as an instigator of increases in social complexity. Tables 5.11 through 5.13 present ERGM results for networks based only on copper and bronze, through time and regardless of region. Two results stand out in relation to understanding the social processes of the VBA. First, during the Early to Middle Bronze Ages, sites were more likely to connect if they were located in the Segura River Valley or the Vinalopó River Valley. By the Middle to Late Bronze Ages, the opposite was true. In fact, sites were less likely to connect the further south that they were located as indicated by the main effects variable of UTM.Y. The exchange of copper and bronze shifts away from the South after the crisis point. Iberian archaeologists believe that bronze exchange in the Southern VBA was ordered by relationships with the Argaric further south, which collapses by the Late Middle Bronze Age.

Second, the differential homophily variable 'absdiff numties' indicates preferential attachment. This particular variable is a calculation of the absolute difference between the number of connections between pairs of nodes. The higher the estimate of this variable, the greater the tendency for sites with few connections and sites with many connections to form a relationship. During the Early and Middle Bronze Ages, coinciding with the existence of the Argaric, copper and bronze exchange was organized through an unequal exchange structure (a social hierarchy perhaps.)

Table 5.11. Copper and Bronze ERGM results: Summary Statistics and Dyadic Dependence model.

Color key:	Significant result (p-value < 0.5)	Weak effect (p-value < 0.1)	Not significant	**Significant result in Full Model (p-value < 0.5)**

	ERGMs: Copper & Bronze All River Valleys	Chronological Period			Interpretations		
		Early & Middle	Middle & Late	Late & Final	Early & Middle	Middle & Late	Late & Final
Summary Statistics	number of sites	89	84	81		decreases	decreases
	number of edges	123	44	21		connect-ivity decreases	connect-ivity decreases
	number of isolates	48	62	60			
	null model edges estimate	-3.4287300	-4.3569000	-5.0323000	not random	not random	not random
Dyadic Dependence Model Variables	GWD estimate	NA	NA	NA			
	GWESP estimate	**9.5362300**	**2.9622000**	**1.5896000**	strong transit-ivity	weaker transit-ivity	weaker transit-ivity
	GWDSP estimate	0.0405660	NA	NA	untied pairs share a friend; friend-ship tie not reliant on a tie between the pair		

Table 5.12. Copper and Bronze ERGM results: Main Effects model.

	Color key:	Significant result (p-value < 0.5)	Weak effect (p-value < 0.1)	Not significant	**Significant result in Full Model (p-value < 0.5)**		
	ERGMs: Copper & Bronze All River Valleys	Chronological Period			Interpretations		
		Early & Middle	Middle & Late	Late & Final	Early & Middle	Middle & Late	Late & Final
Main Effects Model Variables	nodecov UTM.X estimate	0.0000085	**-0.0000622**	0.3107000		more likely to connect as distance from coast increases	
	nodecov UTM.Y estimate	-0.0000101	**-0.0000354**	-0.0000048		less likely to connect in south	
	nodecov Elevation estimate	0.0008281	0.0010250	-0.0004582			
	nodecov Visibility estimate	-0.0419200	**-0.0726200**	-0.0080700	sites with less visibility less likely to connect	sites with less visibility less likely to connect	
	nodecov Site.Site.m2 estimate	0.0000287	**0.0002434**	0.0000566	bigger sites tend to have more connections	bigger sites tend to have more connect-ions	bigger sites tend to have more connect-ions
	nodefactor River.Valley Segura estimate	**1.8440000**	-1.3210000	-0.5429000	more likely to connect if in Segura River Valley		
	nodefactor River.Valley Vinalopó estimate	0.8771000	-0.0185700	0.4377000	more likely to connect if in Vinalopó River Valley		
	nodefactor River.Valley Júcar estimate	NA	NA	NA			
	nodefactor River.Valley Palancia estimate	0.6402000	1.4730000	-1.9600000			
	nodefactor River.Valley Turia estimate	2.8450000	2.0700000	0.2804000	more likely to connect if in Turia River Valley		

Table 5.13. Copper and Bronze ERGM results: Homophily and Differential Homophily models.

Color key:	Significant result (p-value < 0.5)	Weak effect (p-value < 0.1)	Not significant	**Significant result in Full Model (p-value < 0.5)**

	ERGMs: Copper & Bronze All River Valleys	Chronological Period			Interpretations		
		Early & Middle	Middle & Late	Late & Final	Early & Middle	Middle & Late	Late & Final
Homophily Model Variables	nodematch River.Valley Segura estimate	0.2891000	-1.6880000	NA			
Homophily Model Variables	nodematch River.Valley Vinalopó estimate	0.1880000	**1.0970000**	-0.0143200		more likely to connect to others within Vinalopó River Valley	
Homophily Model Variables	nodematch River.Valley Júcar estimate	NA	NA	NA			
Homophily Model Variables	nodematch River.Valley Palancia estimate	NA	NA	NA			
Homophily Model Variables	nodematch River.Valley Turia estimate	1.2360000	NA	NA			
Differential Homophily Model Variables	absdiff UTM.X estimate	0.0000067	-0.0000286	-0.0000654			
Differential Homophily Model Variables	absdiff UTM.Y estimate	0.0000030	0.0000025	-0.0000092			
Differential Homophily Model Variables	absdiff Elevation estimate	0.0001585	0.0009904	0.0006698			
Differential Homophily Model Variables	absdiff Visibility estimate	-0.0068430	-0.0511400	-0.0182000			
Differential Homophily Model Variables	absdiff Site.Site.m2 estimate	0.0000272	0.0000217	0.0004884			site size heterophily
Differential Homophily Model Variables	absdiff numties estimate	0.0945400	-0.0494100	0.0682400	preferential attachment		

Multiplexity

The results for the multiplex analysis are summarized in Table 5.14. Based on comparisons of the Global Overlay Clustering Coefficient for both regions, the Northern Region demonstrated the highest amount of overlay clustering through time. Hypothesis 1 predicts that greater multiplexity is associated with greater social stability. Therefore, Hypothesis 1 is supported. Yet, it is interesting to note that while the Northern VBA maintained higher levels of the Global Overlay Clustering Coefficient in every period in comparison to the South, the coefficient decreases steadily through time. In contrast, the Global Overlay Clustering Coefficient in the Southern VBA increases during the Middle to Late Bronze Ages and then decreases during the Late and Final Bronze Ages.

The dynamics produced by overlapping relationships are complex. Cooperative interactions along overlapping networks increase the opportunity for indirect exchanges and the conveyance of new information from distant actors. Sometimes, these increased opportunities result in an increase in competitive relationships or the formation of strategic alliances (Mattsson 2003). Regarding multiplexity's relationship with social stability, the analysis here suggests that types of material exchange and overlap in the networks of material exchange multiplied substantially during the height of Argaric influence in the Southern VBA, something that did not occur in the North. While more overlap in network relationships generally results in increased interdependence as Hypothesis 1 suggests, intensification of interdependence may increase a network's vulnerability when a strategic alliance fails, for example, the failure of the Argaric. Increased network overlap also increases the likelihood of exposure to new ideas and materials that can destabilize an existing social structure, something this analysis has already hypothesized for the Southern VBA. Moreover, the cohesive blocking, structural cohesion analysis supports the idea that the social structure of the Southern VBA was characterized by competing, interaction blocks.

Possibly the conclusion most clearly demonstrated here is this—multiplexity may have a complex and context-dependent relationship with social stability, one that requires further analysis. Simply possessing more overlapping relationships across material classes may not correlate with increased social stability without the consideration of other, not-yet-understood factors.

Table 5.14. Multiplexity results.

Multiplex:	Chronological Period		
Palancia & Turia River Valleys	Early & Middle	Middle & Late	Late & Final
Overlap index (number of overlapping connections > 2/number of connections)	0	0.0114504	0.0142857
Global overlay clustering coefficient	0.5500000	0.3401338	0.2929385
Number of overlapping connections > 2	0	6	10
Number of connections > 0	70	524	700
Number of sites	19	36	45
Júcar, Vinalopó, & Segura River Valleys	Early & Middle	Middle & Late	Late & Final
Overlap index (number of overlapping connections > 2/number of connections)	0.0403587	0.0817308	0.0459770
Global overlay clustering coefficient	0.1744919	0.1856474	0.2836041
Number of overlapping connections > 2	18	34	8
Number of connections > 0	446	416	174
Number of sites	70	48	36

Hypothesis 2 Geographic Isolation

The more geographically isolated, the less likely the system will change. Isolated groups have less opportunity for diverse exchange opportunities (Alderman, 2012).

Test Implication: Research on the VBA has suggested that geographic accessibility to more complex societies–the Argaric in the south and the seafaring Phoenicians–may influence rates of social change (Hernández Pérez, 1997). Thus, with increasing average distance from the south or the coast as measured from archaeological site locations, the better the fit to a social system with a slow rate of change.

The sites along the Palancia River corridor were the most geographically isolated and had the least contact with the Argaric. These sites make up the majority of the sites studied for the Northern VBA, the region where the percent change in the Social Stability Index is lowest. Concluding that geographic isolation is a cause of social stability is beyond the scope of this hypothesis, but it does appear that geographic isolation is correlated with a social system with a slow rate of change.

The ERGM results in Tables 5.5 and 5.10 above contain related results for this hypothesis in the form of the variables: 'nodecov UTM.X,' 'nodecov UTM.Y,' 'nodefactor River.Valley' for each river valley, 'absdiff UTM.X,' and 'absdiff UTM.Y.' In the Northern VBA, as the distance from the coast increases, so does the likelihood to connect during the Middle to Late Bronze Ages. Furthermore, greater east-west proximity increased the likelihood to connect during the Early to Late Bronze Ages. The likelihood of connection also increased between sites located within the Palancia River Valley during the Middle to Late Bronze Ages. The fact that the likelihood of connection increases as the distance from the coast increases indicates that these sites are inwardly focused within the Palancia River Valley and toward the *Meseta Central* and the *Sistema Iberica Turolense*.

During the Late to Final Bronze Age, Southern VBA sites were less likely to connect if located within the Segura River Valley. This pattern could be attributed to a shift in the focus of settlement after the Argaric collapse northward along the Vinalopó River Valley and elsewhere.

Based on the results of this analysis, the Mediterranean does not seem to play an essential role in relationship formation until the Final Bronze Age. Relationship patterns were focused inland and on those within the Iberian Peninsula. Metal ore sources are located in the interior, not along the coast, and most Iberian archaeologists contend that metallurgy was local. Therefore, it makes sense that changes in inland exchange, such as the collapse of the Argaric culture, would have had a more considerable influence on social stability patterns.

Finally, from the results of the comparative analysis of the diversity of materials, between the Northern and Southern VBA's (see Figure 5.4), it is evident that the peoples of the Southern VBA participated in a more diverse array of material exchange opportunities, from North African ivory to gold to bronze ingots. The differences in diversity of materials exchanged indicate that the Northern VBA sites were more isolated and as expected, this region was more stable through time. The Southern VBA is expected to be less socially stable based on the formulation of Hypothesis 2, and the SSI indicates that it was.

Hypothesis 3 Neutral

The system appears to change randomly, due to particularistic, local factors. This acts as a null model to evaluate the other hypotheses (Brantingham, 2003; Connor & Simberloff, 1986).

Test implication: Social networks do not appear to covary with any of the above factors.

All ERGM, null model edges estimates shown in Tables 5.5 and 5.13 are significant. The estimates are significantly different from a network where edges are added at random. Therefore, the networks of the VBA were not produced by chance. However, the null model tells us nothing about generative processes, or why a network is structured in a way that differs from chance. The inclusion in ERGMs of dyadic dependence, main effects, and homophily variables as described above, addresses generative processes of social networks.

The next chapter, Chapter 6: Discussion, contains a more nuanced discussion of all of the results presented above as they relate to the framing hypotheses.

CHAPTER 6

DISCUSSION

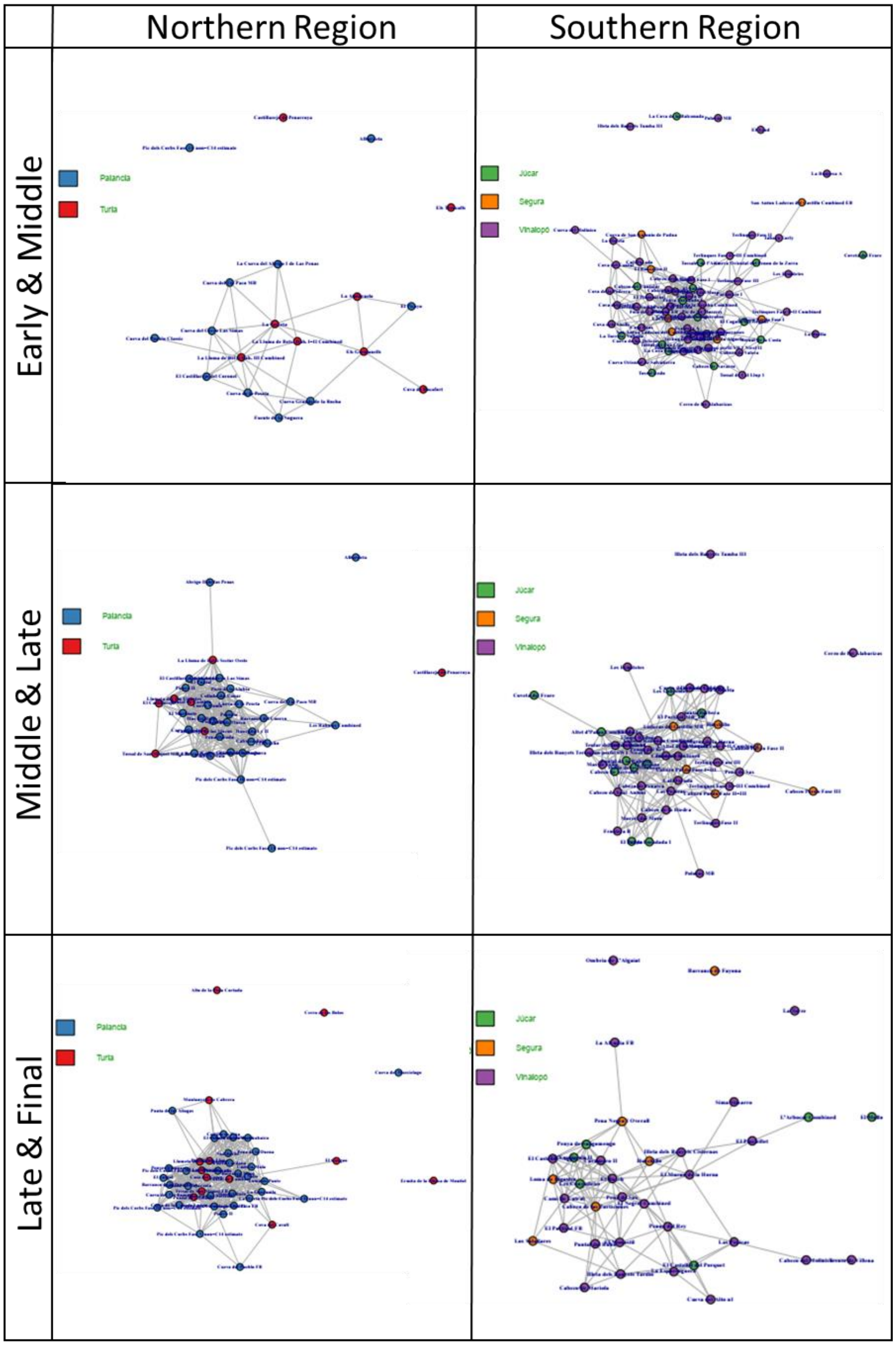


Figure 6.1. Social networks for all six chrono-regions of the Valencian Bronze Age.

Figure 6.1 above shows all six chrono-region network graphs side-by-side. It is evident from the comparison that neither region was static and that the Northern and Southern VBA each had distinct, nearly opposite, social trajectories. Based on observations of the VBA networks through time, the Northern VBA begins with few identified Bronze Age sites. By the Middle Bronze Age the number of sites and connections increases, a trend that continues through the Final Bronze Age. The Southern VBA begins with substantially more sites, but as time progresses, these numbers dwindle along with network density and cohesion.

While neither region was static, the Northern VBA was more stable than the Southern VBA through time. The results from the Social Stability Index indicate that the Northern Region underwent a 4% change in the Social Stability Index from the Early Bronze Age to the Final Bronze Age. The Southern VBA's percent change was approximately 15%.

If these two regions operated in cultural isolation apart from exogenous pressures, we would have an ideal experimental situation for understanding social stability based solely on endogenous processes. Instead, the social reality of the VBA was a complex mix of exogenous and endogenous processes. Furthermore, while a similar suite of exogenous processes affected each region, the results are differential. The following sections discuss these interlocking complexities and their relationships to social stability in each region.

Social Stability: Early and Middle Bronze Ages: Northern Region

During the Early and Middle Bronze Ages, the people of the Northern VBA lived in small, self-sustaining villages and relied upon agro-pastoralism as their primary mode of subsistence. Settlement in the Northern VBA was sparse during the Early Bronze Age. Archaeological evidence suggests that cultural elements in this period are an extension of the preceding Chalcolithic period. The evidence does not support a sudden, clear transition to Bronze Age organization.

Early VBA peoples exchanged information and materials through a social structure characterized by low connectivity and direct interactions that did not require an intermediary. Furthermore, the results of this analysis confirm that the social structure lacked social hierarchy. The Cumulative Degree Distribution (CDD) plot in Figure 6.2 shows the fraction of nodes with a degree smaller than *k* degree for the Early and Middle Bronze Ages of the Northern VBA. Most sites in the early Northern VBA have a degree less than four, and the number of connections per site is somewhat evenly distributed. If Northern VBA peoples organized themselves hierarchically, the CDD would exhibit a heavy-tailed distribution like the one pictured in Figure 6.3 for VBA copper and bronze networks.

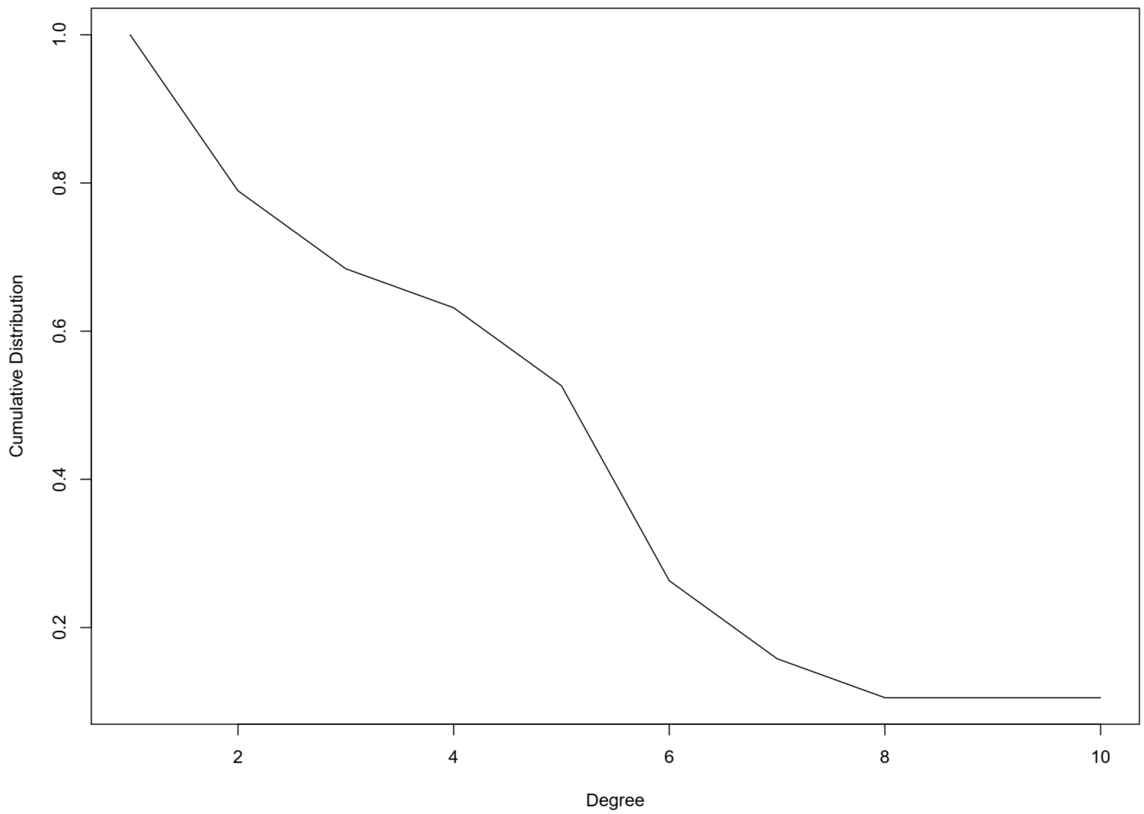


Figure 6.2. Cumulative Degree Distribution plot for the Early and Middle, Northern Valencian Bronze Ages.

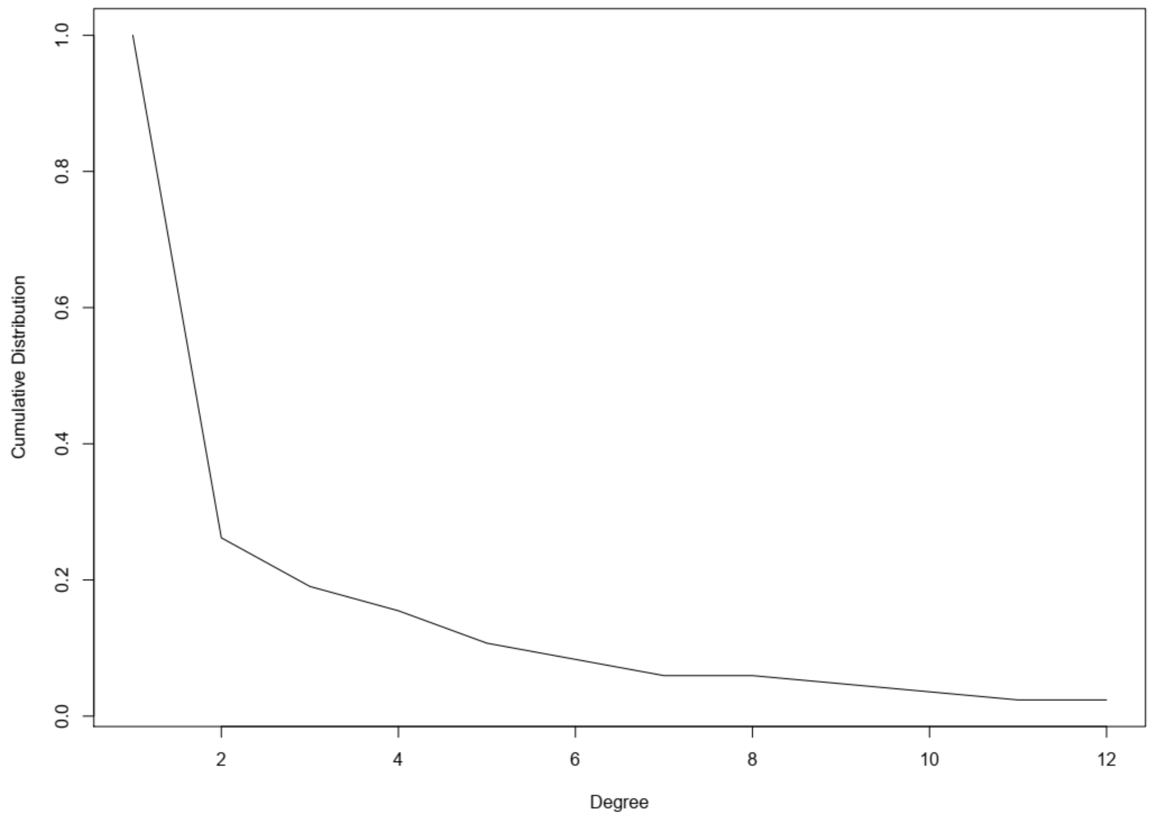


Figure 6.3. Cumulative Degree Distribution plot for a copper and bronze network derived from all river valleys of the Valencian Bronze Age.

Also, the Northern VBA is high in eigenvector centralization. Eigenvector centralization is a measure of influence, not a measure of preferential attachment nor the degree of inequality in the number of connections each actor has. It indicates that some sites in the VBA connected to other sites in the VBA who themselves connected to many sites. In other words, the social structure of the early Northern VBA was relatively egalitarian but certain sites acted as social influencers.

The hierarchical tree and cohesive block graph in Figure 5.20 from the previous chapter summarize structural cohesion in the Early and Middle Bronze Ages of the Northern VBA. The structure is simple with four, nested cohesive blocks, where the most cohesive block nests within the next most cohesive block. This funnel-like structure is highly stable since all blocks are successively dependent on each other (Torrents and Ferraro 2015). In other words, a site in the early Northern VBA would be operating in a siloed system characterized by *high interdependence, isolated from competing forces* of exchange.

The ERGM results shed additional light on early Northern VBA social organization. First, VBA peoples did not form relationships randomly, a statement that is true for all VBA periods and regions. Second, the lack of a tendency of sites to connect with other sites who have a different number of social connections ('absdiff numties') signals the absence of social processes that would increase the probability of formation of a social hierarchy. Social hierarchies often are produced through a rich get richer process where actors with many connections tend to attract new connections. Northern VBA peoples show no tendency to form relationships in this manner.

The GWESP ERGM results indicate that transitivity is a powerful force that influenced the likelihood to make connections among early Northern VBA peoples. Again, transitivity is a process where a friend of my friend is also my friend. The GWESP term indicates that people tend to close social triangles, increasing clustering. Closed social triangles are highly stable and promote interdependency. The ERGM results also implicate geographical factors as constraints on the likelihood of relationship formation during this early period. Northern VBA peoples tended to form relationships with sites in close proximity along an east-west axis, following the geographical constraints imposed by the east-west flow of major rivers and mountain ranges in the region.

In sum, the geographic and the socio-structural characteristics of the Early and Middle Bronze Ages of the Northern VBA tended to constrain opportunities for change.

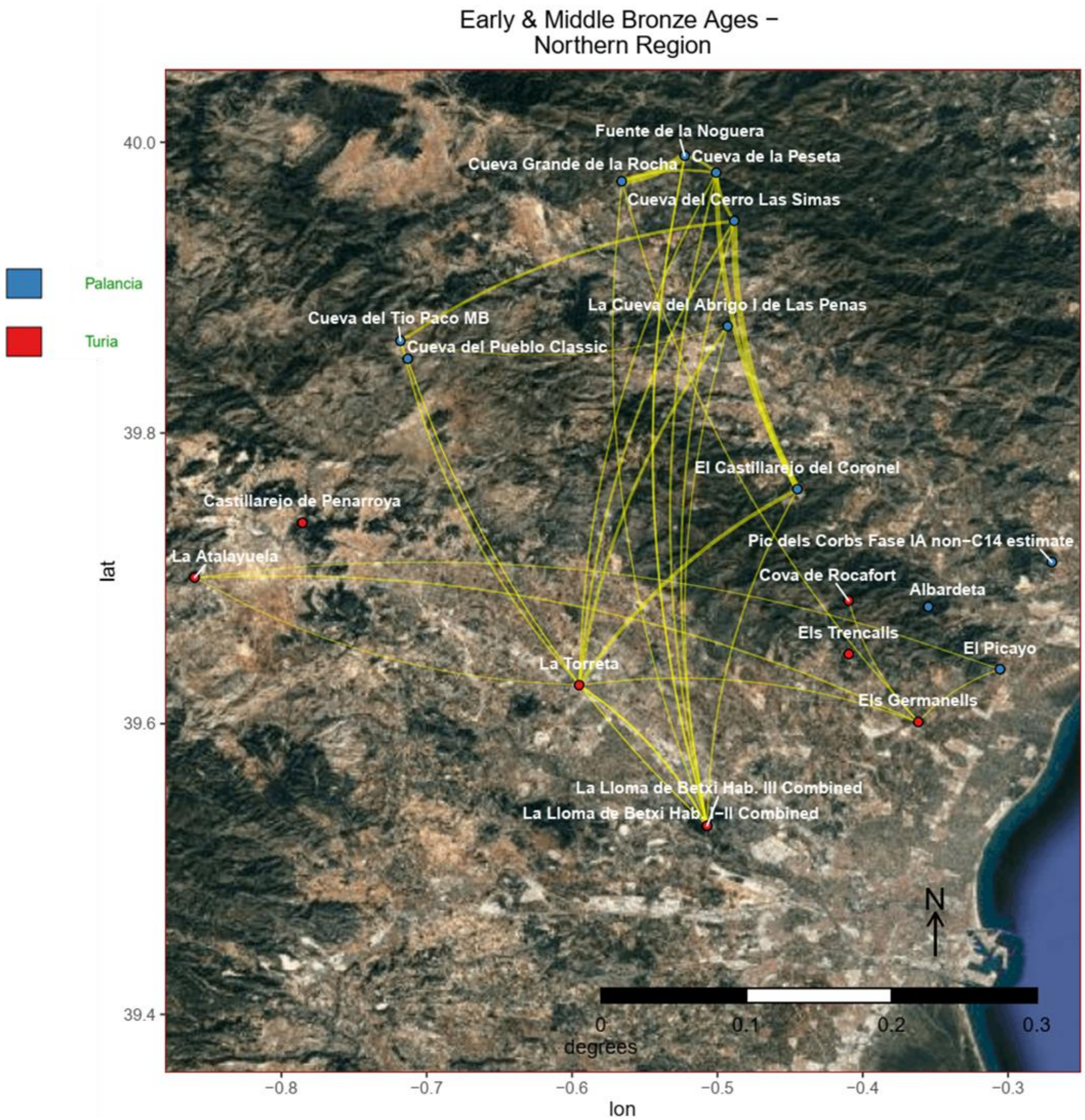


Figure 6.4. Early and Middle, Northern Valencian Bronze Ages network overlaid on a map of the Northern Valencian region. The geographic coordinate of each site controls the network layout. Thicker edges connect more closely related sites. Node color indicates a site's river valley location.

Social Stability: Middle and Late Bronze Ages: Northern Region

The changes in social structure during this period attest to VBA peoples adjusting to the exogenous shocks of the Late Bronze Age. Immigrants from Central Europe and the *Meseta Central* potentially replaced the entire male population during this period.

What was the nature of these adjustments, and how did they interact with the existing social system? Was the social system destabilized, or were the changes integrated?

The social network metrics from the SSI and the structural cohesion tree indicate that during the Middle and Late Bronze Ages of the Northern VBA, inhabitants implemented a "battening down the hatches" strategy. During this period, connectivity, and clustering increased substantially while vulnerability decreased. This response is not uncommon after shocks in a social network. Some networks tend to become denser and more clustered as noise increases (Burghardt and Maoz, 2018), solidifying and intensifying existing ties and structures.

The hierarchical tree for the Middle and Late Bronze Ages provides further evidence that Northern VBA peoples were implementing the above strategy. The vertical line structure remains intact, but additional blocks are added and further embedded within each other. Thus, there was an increase in social cohesion with no real change in structure. Torrents and Ferraro (2015) discuss the same type of hierarchical tree derived from their study of Debian Linux software developers. They state that the vertical, funnel-like pattern "is the result of formal and informal rules of collaboration that evolved over the years into a homogeneous hierarchical structure, where there is only one core of highly productive individuals at the center. Not surprisingly, perhaps, the Debian project has been particularly resilient to developers' turnover and splintering factions" (Torrents and Ferraro, 2018:23). In the same manner, *the embedded, funnel-like social structure of the Northern VBA helped integrate exogenous shocks, limited the propagation of alternative power centers, facilitated further interdependency, and promoted social stability.*

Beyond the structural elements, the ERGM GWESP results indicate that transitivity, as a mechanism that governs relationship formation and promotes stability, increased in importance. The nature of the influence of geographic variables shifted slightly. During the Middle and Late Bronze Ages, sites were more likely to connect within the Palancia River Valley. Two mountain ranges geographically bound the Palancia River corridor, in effect constraining opportunities for the flow of goods and information in the Northern VBA. Figure 6.5 displays the location of early Northern VBA sites, the networks of relationships between sites, and the regional topography. Thicker edges illustrate stronger relationships. While relationships are indicated that crossed river valleys, the greatest number of strong relationships are found along the Palancia River corridor.

Additionally, sites were more likely to connect if located further from the coast. The focus of relationships was inland and along river valleys, possibly toward migrating peoples and ideas from the *Meseta Central*. Figure 6.5 of the Middle and Late Bronze Age network overlaid on a map of the region clearly shows that the focus of connectivity is located inland along the Palancia River.

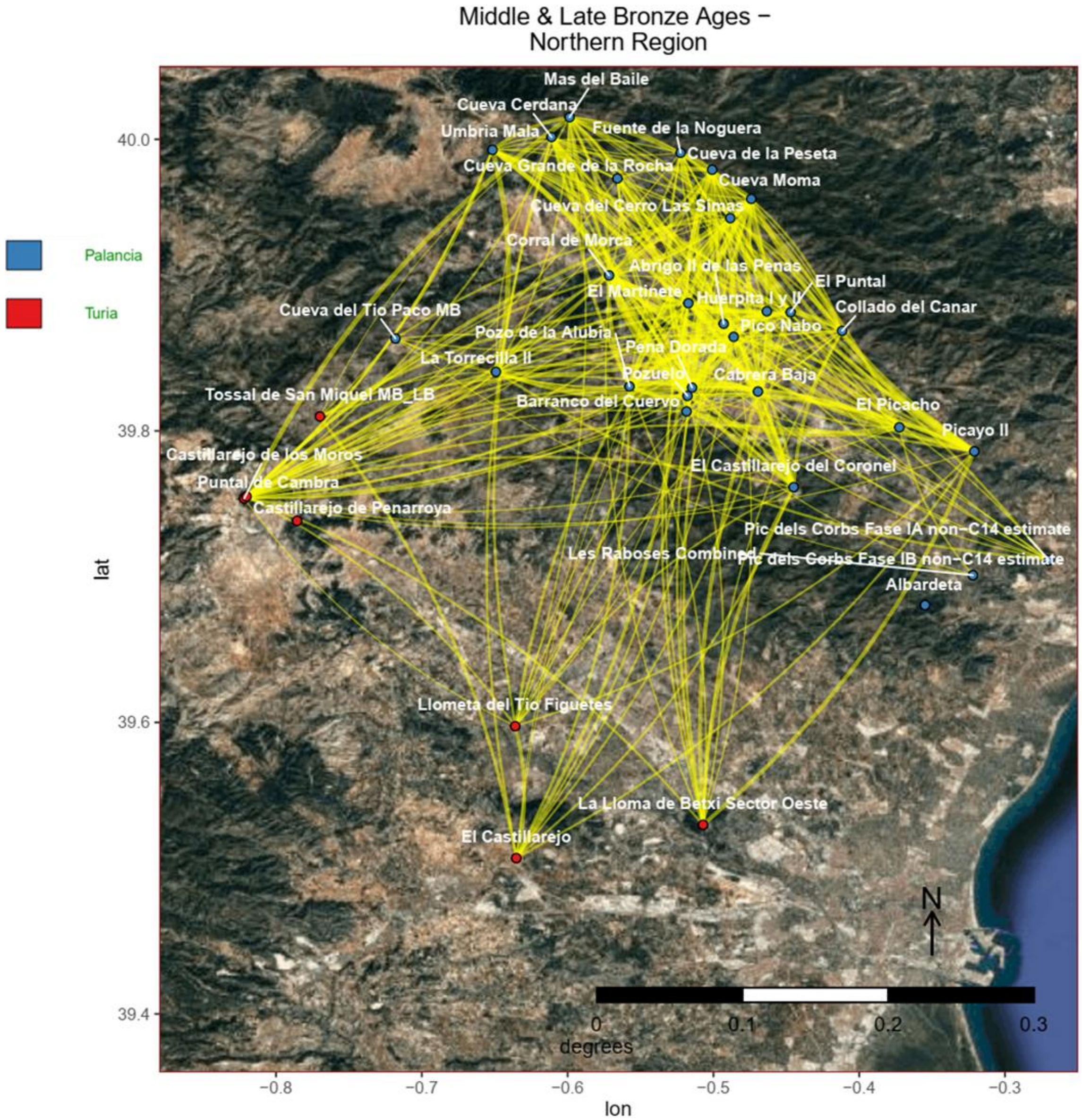


Figure 6.5. Middle and Late, Northern Valencian Bronze Ages network overlaid on a map of the Northern Valencian region. The geographic coordinate of each site controls the network layout. Thicker edges connect more closely related sites. Node color indicates a site's river valley location.

One variable that was not significant in the ERGMs derived from the Early and Middle Bronze Ages become significant in the Middle and Late Bronze Ages. Sites with greater square area were more likely to form connections with other sites. Were inhabitants reorganizing in such a way that required more land, possibly to support a growing population? The number of sites and connectivity between them increased substantially during this period. The increase may have forced a reorganization toward larger sites and greater interaction with other VBA sites in the area. Further work is needed to understand this trend.

The variable ‘absdiff numties’ continues to be signifant during this period. To review, assortativity describes a situation where connections tend to form between sites with the same amount of connectivity; in other words, homophily on degree. Small sites are connected to small sites, medium to medium, and so on. Assortativity is not associated with social hierarchies, in which low degree actors tend to connect with high degree actors. The CDD plot in Figure 6.6 for the Middle and Late Bronze Ages in the North lends support to this conclusion, as the distribution lacks a heavy tail. In general, networks with assortativity are less robust to shocks. However, D'Agostino et al. (2012) show that assortative networks allow a longer time for intervention before failure spreads. Again, this result requires further research to sort out any influence assortativity may have on Northern VBA networks.

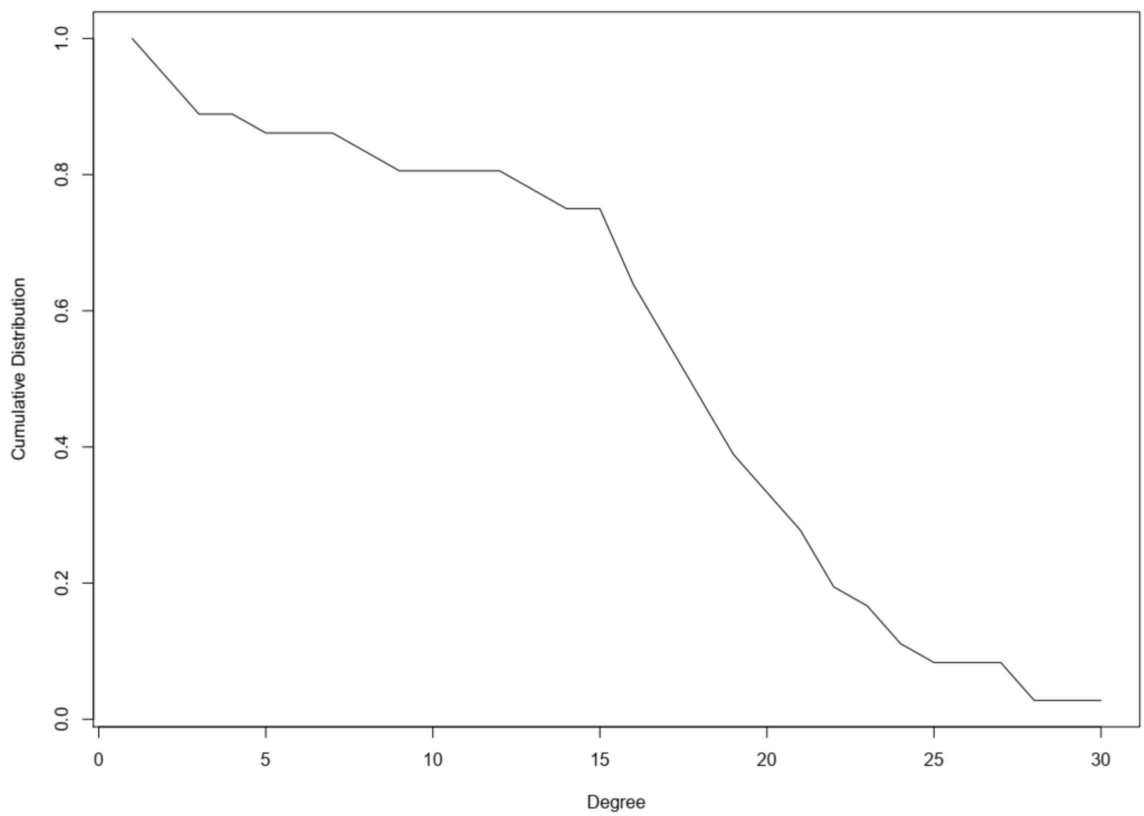


Figure 6.6. Cumulative Degree Distribution plot for the Middle and Late, Northern Valencian Bronze Ages.

In sum, the Northern VBA peoples during the Middle and Late Bronze Ages experienced several exogenous shocks. They reacted to these shocks by intensifying their social relationships, an intensification that strengthened rather than destabilized the entire system.

Social Stability: Late and Final Bronze Ages: Northern Region

The Late and Final Bronze Ages of the Northern Valencian Region demonstrate a change in some of the previous trends of earlier periods. The ERGM results show that increasing distance from the coast decreases the likelihood of connection. For example, the map in Figure 6.7 below shows the greater prominence through increased connectivity of the site of Pic dels Corbs near modern-day Sagunto along the coast. The

Final Bronze Age is marked by the establishment of Phoenician and Greek trading centers along the coast as well as verified incursions of the Urnfield culture from the north (see Figure 2.11). Urnfield material elements have been excavated and analyzed at the site of Pic dels Corbs (Barrachina 2012). Archaeologists agree that the Urnfield incursion followed the Mediterranean coast south from France. Potentially, by the Final Bronze, the focus of relationships began to shift toward these coastal events.

An additional change concerns the connectivity among the Turia River sites. Some sites near the Turia River increased in prominence through increases in connectivity as well as strength of relationships. For this period, the ERGM results show that sites located within the Turia River Valley were more likely to connect with each other than with sites outside of the valley. Furthermore, east-west proximity was no longer significant to the likelihood to form connections. Palancia River sites were connecting increasingly across the river valley with Turia River sites. Overall, Turia River sites were increasing in prominence during the Late and Final Bronze Ages. These sites would have had greater access to the coast as well as sites to the south along the Júcar and Vinalopó Rivers.

Iberian archaeologists contend that a trend toward population agglomeration at larger sites at higher elevations began during this period. The results of this analysis present a more complex pattern. Although sites at higher elevations tend to have more connections during this last period, site size is not a significant influence on relationship formation during this period. The summary statistics support population aggregation; both the median site elevation and median visibility are highest during the Late and Final Bronze Ages. The population may be aggregating but a transformation of the social structure into a social hierarchy is not a result of that aggregation at this point. The social structure remains stable despite signs of population change.

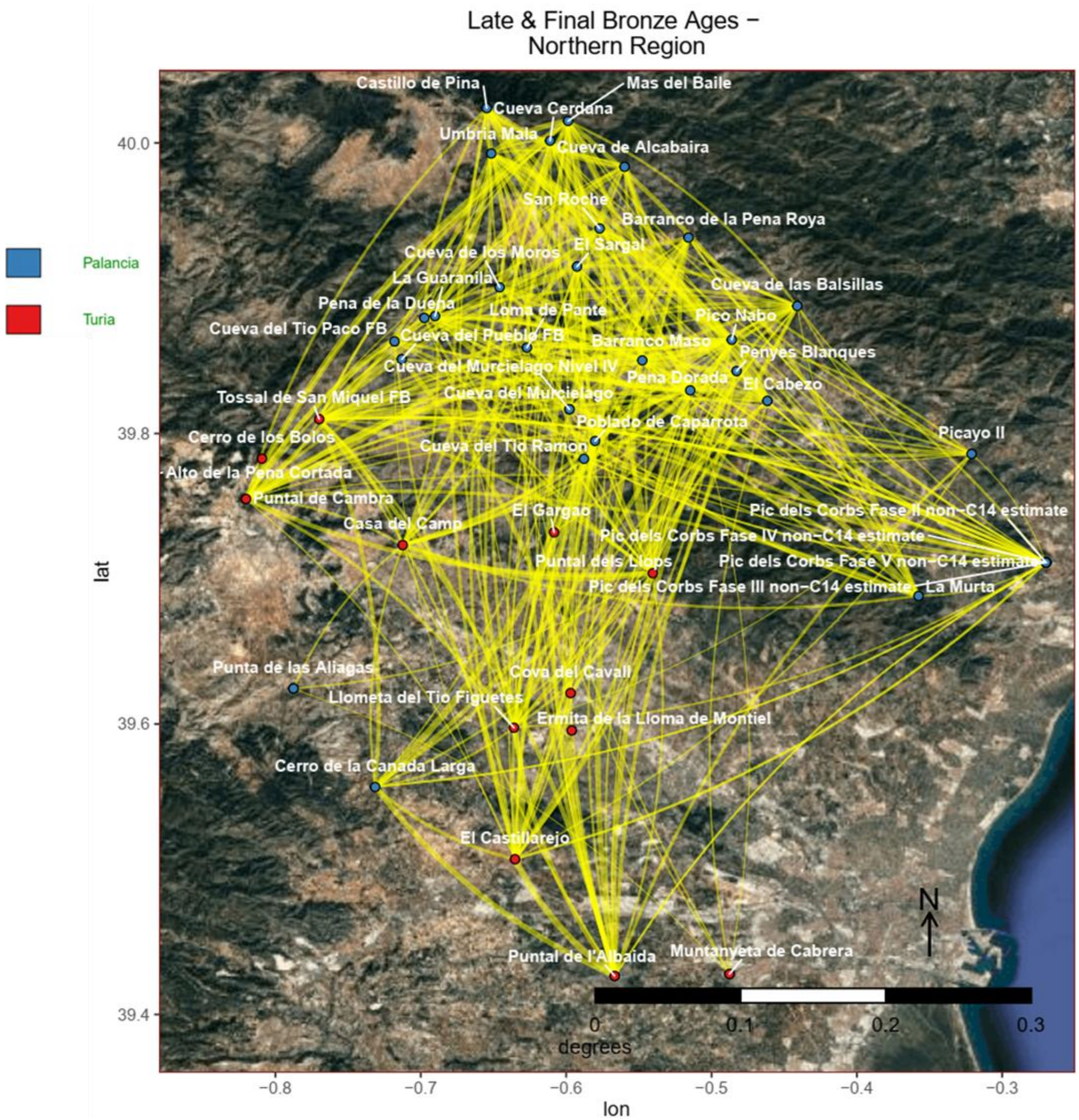


Figure 6.7. Late and Final, Northern Valencian Bronze Ages network overlaid on a map of the Northern Valencian region. The geographic coordinate of each site controls the network layout. Thicker edges connect more closely related sites. Node color indicates a site's river valley location.

Overall, the socio-structural metrics of connectivity and clustering decline in this final period, potentially reflecting reactions to culture contact. Yet, vulnerability decreases and the structural cohesion tree retains its vertical, funnel-like structure. The distribution of degrees does not change in a way that would suggest the formation of a social hierarchy (Figure 6.8) nor do the ERGM results for GWD shift toward a likelihood of connection to high degree nodes.

By the end of the Final VBA in the Northern Region, the social structure was still stable, even in the face of change.

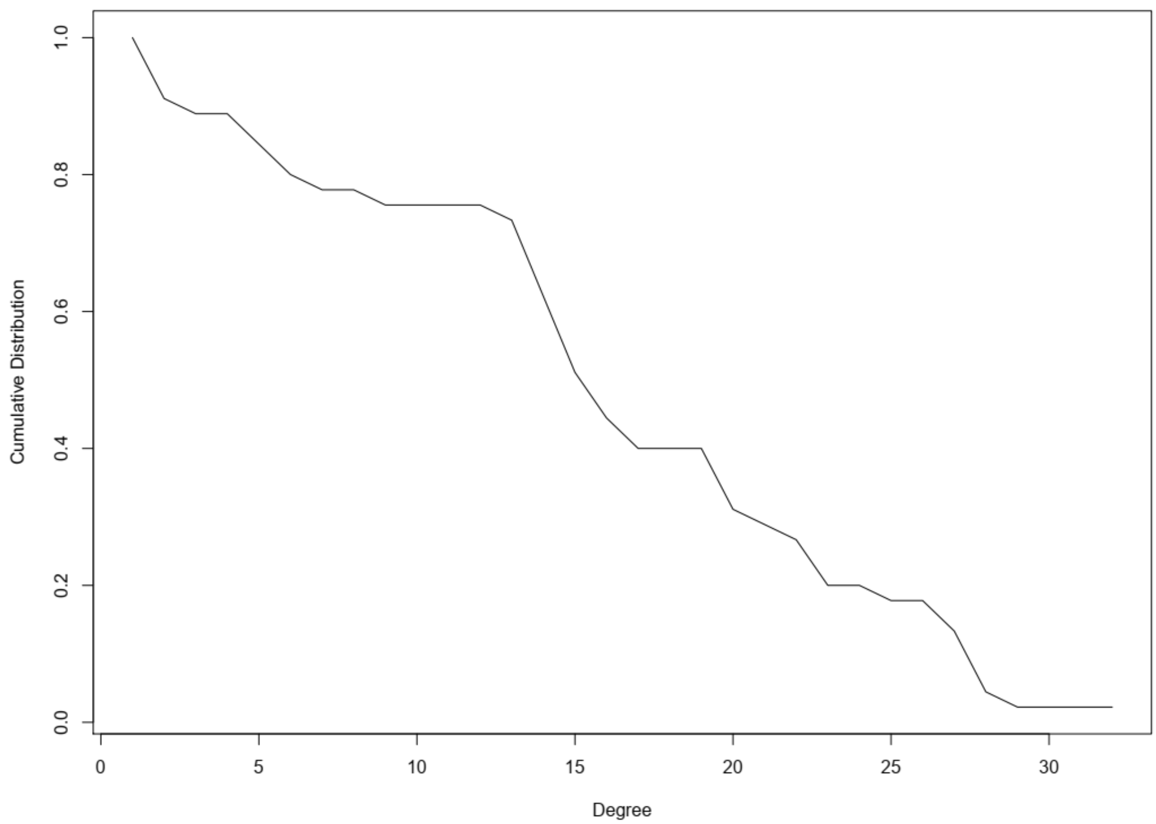


Figure 6.8. Cumulative Degree Distribution plot for the Late and Final, Northern Valencian Bronze Ages.

Social Stability: Early and Middle Bronze Ages: Southern Region

During the Early and Middle Bronze Ages in the Southern VBA, people organized their lifeways in a fashion similar to their northern neighbors. They lived in small, self-sustaining villages and relied upon agro-pastoralism as their primary mode of subsistence. However, social structure and exchange relationships manifested important differences in initial conditions. Iberian archaeologists contend that many sites along the Segura River in the southernmost area of the region were Argaric peripheral sites. Sites such as Laderas del Castillo, San Antón, Tabayá, Illeta dels Banyets, and Cabezo Pardo contain Argaric elements including copas, bronze halberds, highly polished tulip-shaped vessels, and intramural, single inhumations in small cists (Hernández Pérez 2009; Jover Maestre and López Padilla 2009; López Padilla 2009; Soler Díaz 2009). By the end of the Middle Bronze Age, the Argaric culture was at its height and sites within the Southern VBA actively participated in this sphere of exchange.

The Dimensions of the SSI show that social structures of the early VBA peoples in the South were less connected and clustered than their counterparts in the North. These factors often promote opportunities for destabilization. The social distance between sites is higher in the Southern VBA than in the North. Also, while the number of sites in the South is higher than in the North, the network density is lower. Again, higher social distances and lower network densities tend to decrease the cohesion and stability of the network. Interestingly, the Centralization and Power Index is higher in the South than in the North. Lull et al. (2013:285) state, "common and clearly recognizable ritual practices and aesthetic norms, as expressed in the burial customs and pottery production, from Granada in the west to Alicante in the east, and from Almeria at the coast to Ciudad Real in the Spanish Meseta, hints towards a high degree of communication and unification, at least between the ruling classes of the different regions." Thus, it appears likely that exchange with the Argaric 'ruling classes' promoted a more centralized organization in the Southern VBA. Later sections in this chapter and the next discuss the influence of centralization on social stability.

The map in Figure 6.9 displaying the Southern VBA's social network overlaid on a map, the comparative, network diagram in Figure 6.1, and the structural cohesion tree in Figure 5.23 for the early Southern VBA show a key structural difference between the Northern and Southern VBAs. All indicate that competing exchange loci characterize the structure. The hierarchical tree shows three competing loci—the vertical mainline and two competing branches. This branching structure is different than the highly streamlined and resilient social structure in the Northern VBA.

Does this branching structure mean that a social hierarchy existed in the Southern VBA? The CDD plot in Figure 6.10 from this period suggests that the answer is no, a conclusion that aligns with previous analyses conducted by Iberian archaeologists. Again, turning to Lull et al. (2013:285), "In short, El Argar reached a level of economic development that was far higher to that of the rest of the Iberian Peninsula and had a direct influence on its neighbours, a social and productive model from which to defend themselves collectively and, at the same time, something to be emulated by emerging local elites in other regions." The Southern VBA was a peripheral region to an Argaric core characterized by strong economic and social differentiation as well as monopolized control of valuable resources like bronze. As a periphery region, the Southern VBA would exhibit a complex combination of hierarchical controls, dependencies on the Argaric elite, and egalitarian tendencies.

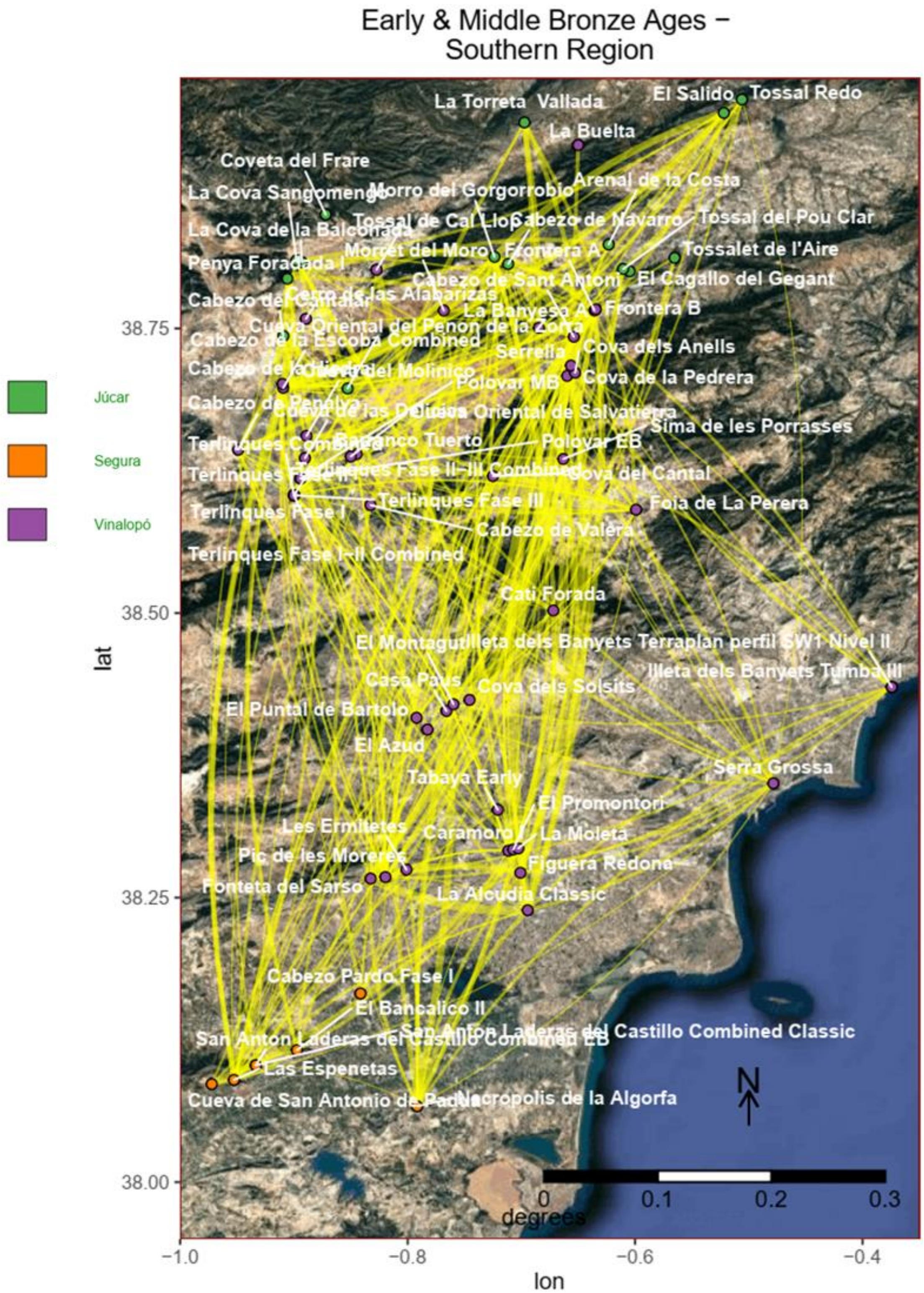


Figure 6.9. Early and Middle, Southern Valencian Bronze Ages network overlaid on a map of the Southern Valencian region. The geographic coordinate of each site controls the network layout. Thicker edges connect more closely related sites. Node color indicates a site's river valley location.

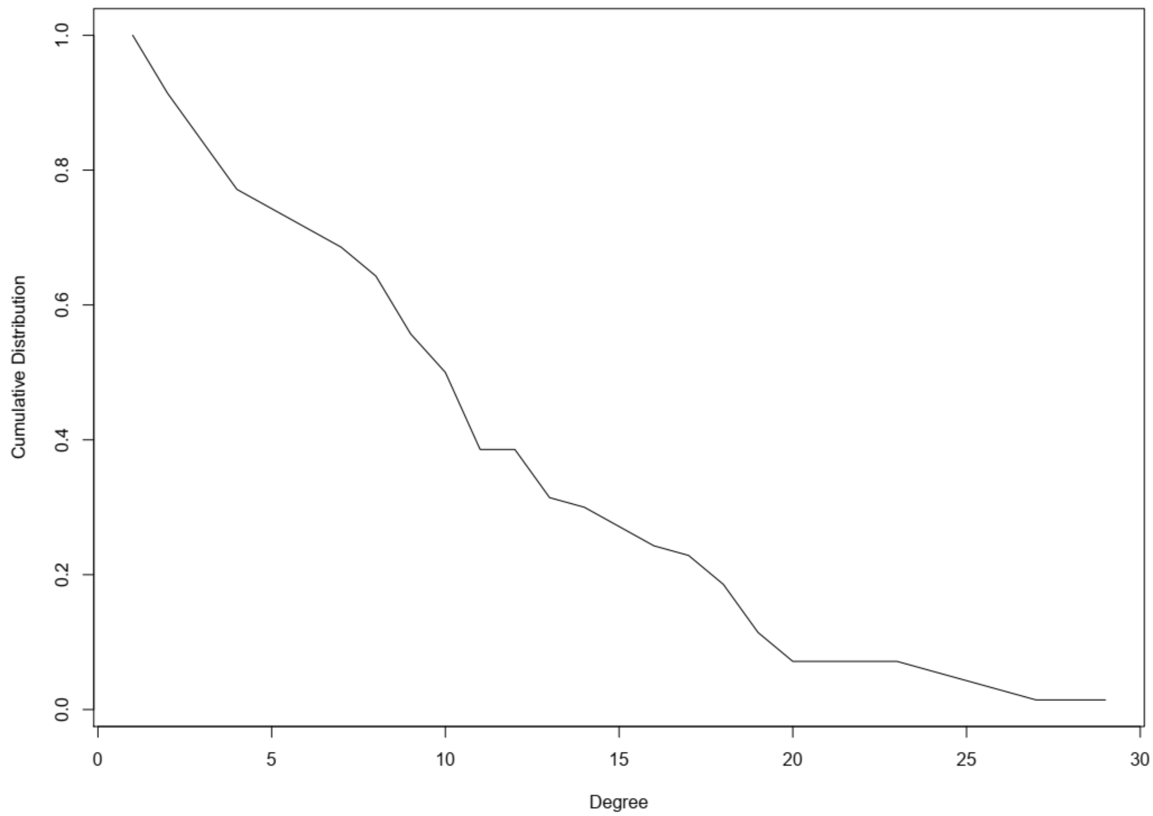


Figure 6.10. Cumulative Degree Distribution plot for the Early and Middle, Southern Valencian Bronze Ages.

The ERGM values for GWESP in the Southern VBA are much higher than those in the North during the Early and Middle Bronze Ages. GWESP values for the Southern VBA show that transitivity was a strong underlying social process governing the structure of social relationships. Also, GWDSP values are significantly negative. GWDSP counts social triangles that are not closed. If GWDSP were positive, then people were exercising multiple options when they form relationships, not just triangle closure. GWDSP is complicated to interpret, but this result implies that relationships were highly dependent on existing links and that transitive social processes controlled this network. Potentially, this tendency is reflective of the Southern VBA's dependency on the Argaric core.

In general, geographic and physical characteristics were not significant factors in the formation of links in the early Southern VBA with two exceptions. Sites further south tended to form more connections. Additionally, if a site was at a higher elevation, the tendency for that site to connect was higher. The Segura River is the southernmost major river corridor of the VBA and the nearest to the Argaric core. Several important sites with Argaric elements, including bronze weapons like the halberd, were located along the Segura. The trend toward higher connectivity along the Segura suggests the important influence of the Argaric on the Southern VBA during this earliest period.

As a whole, the Early and Middle Bronze Age peoples of the Southern VBA lived within a social structure characterized by some centralization and strong transitivity. Inhabitants along the Segura River participated in exchange relationships with the Argaric core in modern-day Andalusia, Spain. Finally, competing cores of exchange characterized the structural cohesion of this period.

Social Stability: Middle and Late Bronze Ages: Southern Region

An intensification of some of the characteristics seen earlier characterized the Middle and Late Bronze Ages of the Southern VBA. Connectivity, clustering, and centralization increased. However, the social distance between sites decreased while vulnerability increased. As a reminder, vulnerability, as measured in this analysis, is based on modularity, or the number of densely connected subnetworks or competing cores, and cut-points. The structural cohesion tree reveals that the Southern VBA's structure still consists of a vertical mainline composed of two competing branches. Furthermore, the tendency for bigger sites to have more connections is a significant factor during this period. The combination of the significant, positive GWESP term and now positive GWDSP term in the ERGM analysis suggests a decrease in the influence of transitivity on the evolution of the social structure. This does not occur in the North.

Iberian archaeologists mark the date of the Argaric collapse at 1550 BCE, a date that falls just after the end of the Middle Bronze Age. By the end of the Argaric culture, Argaric peoples were heavily fortifying their sites on hilltops, a strong hint that Argaric peoples faced a threatening situation. It would not be a stretch to argue that these changes affected the social organization in the Southern VBA. The collapse of the Argaric may be responsible for the positive GWDSP term. In other words, the collapse may have destroyed or reorganized many existing triadic relationships.

Iberian archaeologists suggest that remnant peoples after the Argaric collapse moved toward the Vinalopó River Valley of the Southern VBA. Lull et al. (2013:291) concerning the site of Cabezo Redondo located near modern-day Villena along the Vinalopó River state, "…beyond the northwestern border of the former Argaric territory, the rise of an architectural and economic organisation can be traced from 1550 cal. B.C.E., which strongly resembles the aforementioned structures of Late El Argar. The similarities between the buildings, infrastructures and macro-lithic assemblages is so marked, that the question emerges if formerly Argaric groups took shelter in the upper Vinalopó Valley after the 1550 B.C.E. collapse in an attempt to re-instate in this area the once known socio-economic system."

The results of the ERGMs in this analysis confirm the above claim that the focus of settlement (and social interaction) shifted toward the more northern areas of the Vinalopó. The geographic variables with significant ERGM results indicate that north-south proximity increased the likelihood of connections between sites. Sites along the

Segura River were less likely to form relationships while sites located within the Vinalopó River Valley were more likely to connect with each other. Therefore, the north-south axis along the Vinalopó River increased in importance during the Middle and Late Bronze Ages in the South. (The map in Figure 6.11 shows the geographic position of the network for this period.) The Vinalopó River has been the primary north-south conduit for exchange for thousands of years. (Hannibal's father is said to have drowned in the Vinalopó while commanding an expansion campaign for Carthage.) Instead of constraining exchange, the geography of the Vinalopó and the Southern VBA facilitated exchange along a north-south axis and parallel to the coast.

The results from the cut-points analysis add further confirmation to the claim that the focus of settlement shifted toward the more northern areas of the Vinalopó. The cut-point analysis identifies sites as cut-points, nodes that if removed would disconnect the network. The cut-points identified for the Middle and Late Bronze Ages in the Southern VBA are the sites of Las Peñicas, Peña de Sax, Caramoro I, and Altet d'Palau Combined. Generally, these four cut-points are located along the Vinalopó in a more northerly location than the majority of cutpoints identified in the prior period—the sites of Caramoro I, Cabezo Pardo Fase I, Tabayá Early, Cabezo de la Escoba Combined, and Cova del Cantal. In fact, several of these sites from the Early to Middle Southern VBA are located along the Segura River. Therefore, during the Middle to Late VBA in the South, the sites most critical to the network shifted northward and toward the Vinalopó.

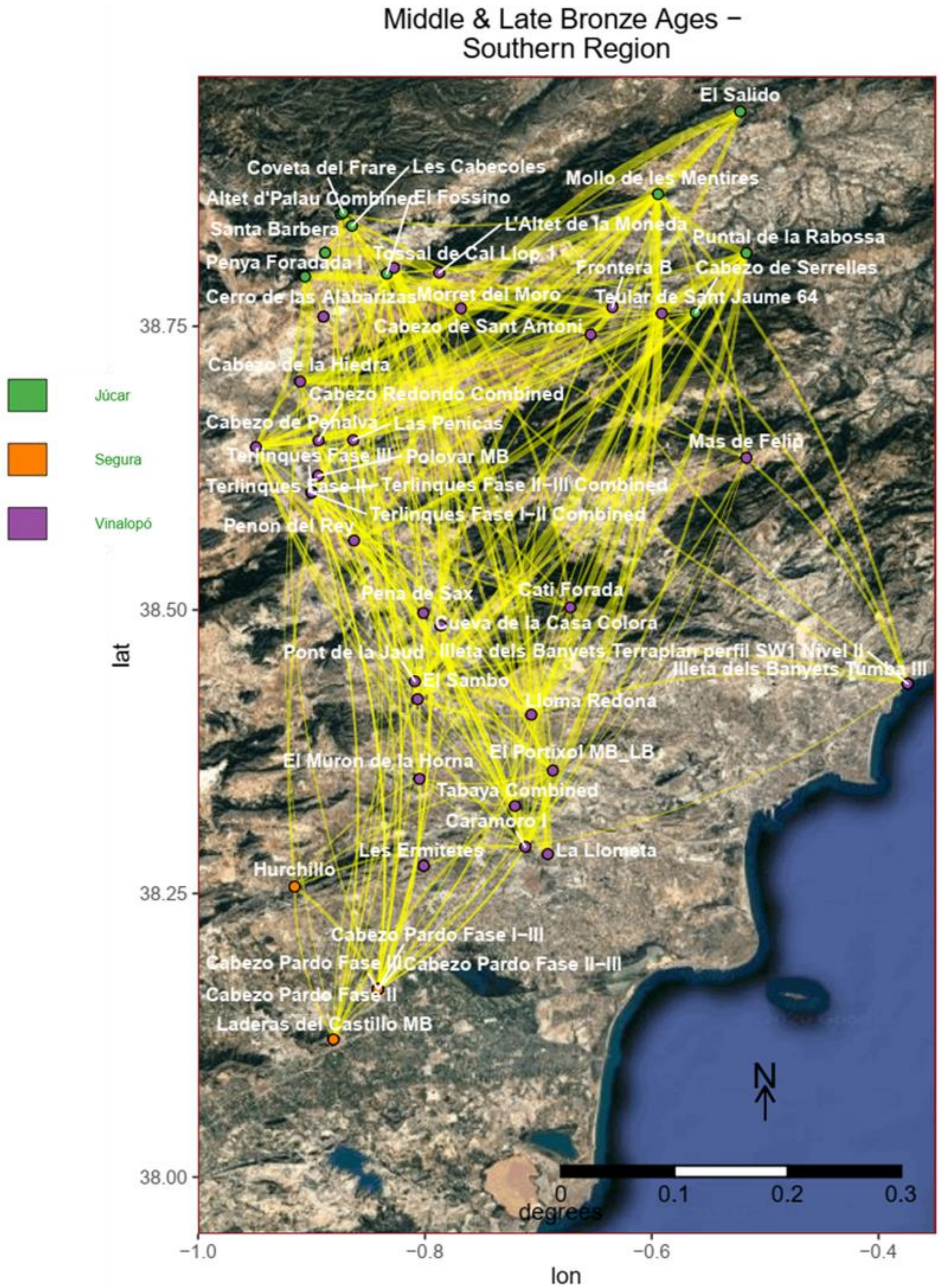


Figure 6.11. Middle and Late, Southern Valencian Bronze Ages network overlaid on a map of the Southern Valencian region. The geographic coordinate of each site controls the network layout. Thicker edges connect more closely related sites. Node color indicates a site's river valley location.

Social Stability: Late and Final Bronze Ages: Southern Region

By 1550 BCE, the Argaric collapses. Lull et al. (2013:283) describe the collapse of the Argaric in this manner:

> *All the settlements are abandoned or restructured according to new architectural principles at this time. Moreover, the strict observance of intramural burial rites, which serve to signify the position of the members of the Argaric society according to sex, age and class, disappear completely. Pottery and other aspects of material culture change in their form and structure as subsistence strategies suddenly become more diversified.*

Molina González (1978) argues that the Late Bronze Age should be classified as the post-Argaric period in the southeast, characterized by the appearance of elements from the Cogotas I culture. The SSI, network graphs, and structural cohesion trees for the Southern VBA all reflect structural reorganization. From the Early to the Final Bronze Ages, the Southern VBA experienced a 15% change in its SSI. The structural cohesion tree transformed completely to resemble the nested hierarchy of the North with no competing blocks. Figure 6.12 displays the network graph overlaid on a map of the region that clearly shows a reduction in the number of sites and connectivity. During this period, connectivity and clustering decreased, and the social distance between people increased. Centralization also decreased. The Southern VBA was reorganizing after the collapse of a powerful and centralized social system.

The strong transitivity prevalent in the Early and Middle Bronze Ages weakened substantially by the beginning of the Late Bronze Age. This weakening is potent evidence of the severing of the social dependencies on the Argaric prevalent in previous periods.

The ERGM results from geographic variables show that sites were less likely to connect further south.

Several results indicate that the sites in the Southern VBA were beginning to reorganize. Homophily variables in the ERGM results reflect a tendency toward differentiation. Sites at higher elevations tended to connect with other sites at higher elevations. Assortativity based on degree increases significantly. These trends appear to provide evidence of the population aggregation at higher elevations mentioned by archaeologists that occurred during the Final Bronze Age.

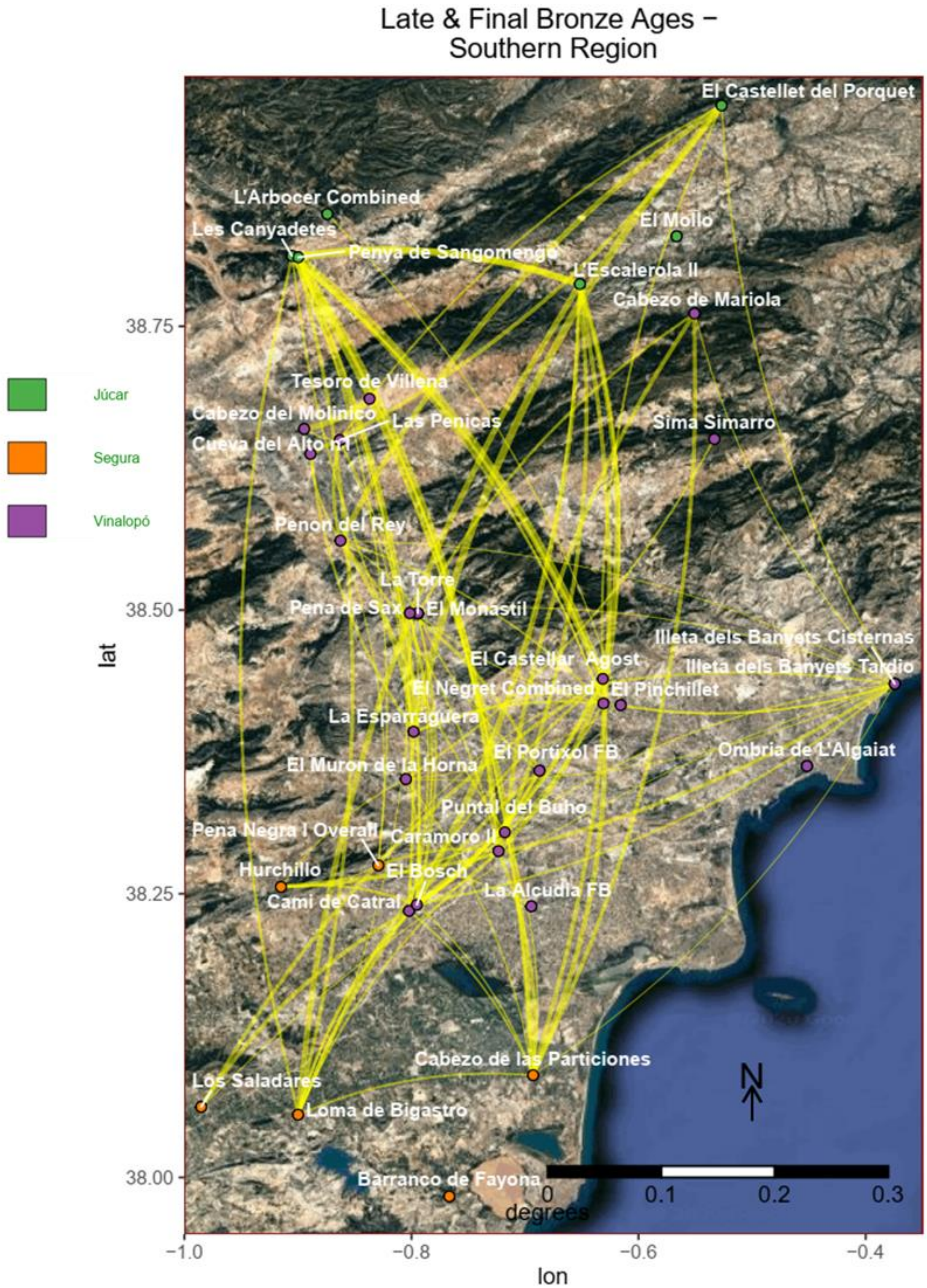


Figure 6.12. Late and Final, Southern Valencian Bronze Ages network overlaid on a map of the Southern Valencian region. The geographic coordinate of each site controls the network layout. Thicker edges connect more closely related sites. Node color indicates a site's river valley location.

The CDD plot in Figure 6.13 for the Late and Final Bronze Ages does not suggest a well-established social hierarchy. For this reason, *the most reasonable conclusion may be that the reorganization is signaling incipient inegalitarianism and incipient urbanization through population aggregation at similarly large sites*. If people migrated to this region after the collapse of the Argaric, then they may have brought ideas about social organization with them. It is possible that these groups were attempting to reestablish the hierarchy. The reappearance of the positive-negative combination of GWESP and GWDSP respectively, suggests that after the Argaric collapse, the people of the Southern VBA may have been reestablishing strong relationships through similar social processes of triadic closure evident during the earliest period.

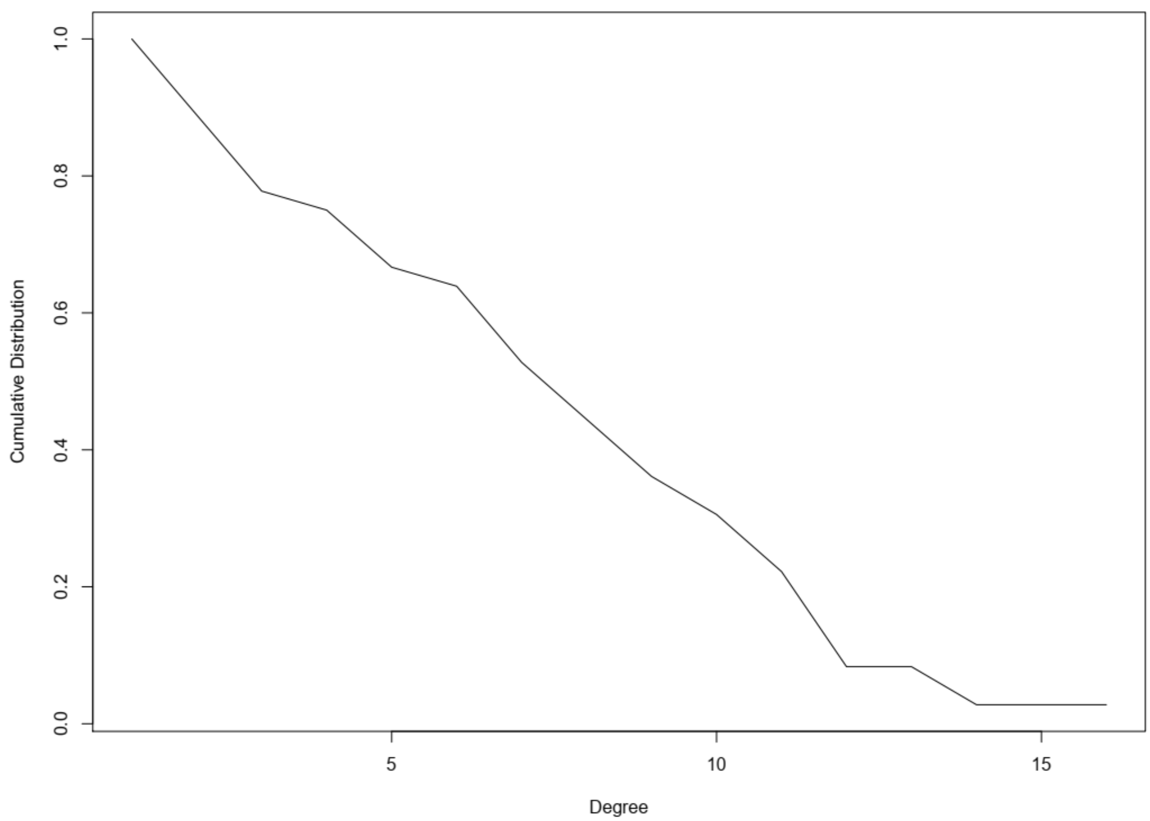


Figure 6.12. Cumulative Degree Distribution plot for the Late and Final, Southern Valencian Bronze Ages.

The Final Bronze Age sees the introduction of the Urnfields culture in the North at the site of Pic dels Corbs, but also in the South at the sites of Los Saladares and Peña Negra by the 8th century BCE. Also, the Greeks and Phoenicians established colonies during the Final Bronze Age (Martí and de Pedro Michó 1997). Sites like Los Saladares as well as the Tesoro de Villena contain indisputable evidence for “orientalization;” the assemblage from Los Saladares contains Phoenician amphorae. The existence of such a valuable cache of gold objects like that of the Tesoro de Villena implies the establishment of a social hierarchy capable of centralized gold production and hoarding. Martí and de Pedro Michó (1997) argue that the existence of the treasure near Cabezo Redondo marks the appearance of a new autonomous hierarchization of the region replacing the hierarchy of the Argaric. That the appearance of these new, foreign cultures is a possible cause for the development of a social hierarchy is an open question. Alternatively, and maybe more likely, the social organization of the Greeks and Phoenicians complimented autonomously developing trends toward a social hierarchy.

In sum, by the Final Bronze Age, Southern VBA peoples were slowly reorganizing into a new social hierarchy. The reorganization appears to have been semi-autonomous as Mediterranean influences only arrived late in the period. Also, this research indicates that reorganization into a social hierarchy had yet to be completed by the end of the Final Bronze Age.

More significant to the understanding of social stability, the results from this analysis show that the Late and Final Bronze Ages of the Southern VBA was a period of reorganization after the collapse of the Argaric. The Southern VBA people’s strong, transitive dependencies on the Argaric became a liability to the maintenance of social stability after the collapse. Additionally, the existence throughout most of the duration of the VBA in the South of competing cores of exchange correlates with an inability to integrate shocks evenly throughout the system; a system with competing cores must funnel information through each core. Moreover*, a system with multiple cores of exchange creates incentives for cores to outcompete one another. This type of competition often leads to power imbalances, conflict, and instability. Social systems without competing cores, like that of the Northern VBA, express robust interdependency.*

Copper and Bronze Networks

The exchange of copper and bronze produces network structural properties that differ from networks derived from all artifact classes. (As previously stated, this analysis combines both the Northern and Southern regions to obtain copper and bronze networks since the amount of these materials in Northern VBA assemblages is not sufficient for analysis.) Figure 6.3, pictured earlier in this chapter, shows the CDD plot for a network derived only from copper and bronze artifacts. The CDD plot indicates that the exchange of copper and bronze followed a pattern of preferential attachment, where most of the connections accrued to the most highly connected nodes. The 'absdiff numties' variable from the ERGM results also indicates that preferential attachment was the social mechanism underlying copper and bronze exchange during the period in which the Argaric culture thrived. The collapse of the Argaric may have allowed the exchange of bronze to spread outside of the monopoly of the Argaric core, hitchhiking along with remnant populations moving northward. The ERGM results for copper and bronze show that by the Late and Final Bronze Ages, trade once confined to sites within the same river valley spread across almost all river valleys.

Bronze production is a complex technology requiring multiple technological steps and components. Complex technologies tend to travel along centralized networks with asymmetric trade links. This results from the fact that complex technologies are produced by combining different several inputs and specific knowledge but also for the reason that these technologies are more difficult to export (Piccardi and Tajoli, 2018). They require institutions capable of exporting complex technologies, a factor that typically produces centralization. The ERGM results show that copper and bronze exchange promoted connectivity to bigger sites.

Copper is restricted to certain geographic locations in the VBA, a factor that increases the tendency toward network centralization. The CDD for copper and bronze networks is heavy-tailed. A heavy-tailed distribution can be indicative of preferential attachment, a social process that leads to wealth accumulation for the already wealthy (Barabási and Albert, 1999). Thus, while the network structures derived from all artifact classes show a more even density of links and interconnectivity, the network derived from copper and bronze reveals the coexistence of a bronze and copper network with controlled distribution by a limited number of central actors. The evidence suggests that the Southern VBA in particular was centralized in one industry but not in others.

Social stability is dependent on network properties and the ability of the network to withstand shocks. The production of complex metals creates a dangerous vulnerability. It creates hub nodes that if attacked or removed can destroy the network. Perhaps the starkest difference between the Northern and Southern VBAs is the presence of bronze in the South and the lack of it in the North for most of their prehistories. The collapse of the Argaric, a centralized source of bronze production, significantly affected the social stability of the Southern VBA. Here we have the existence of an interesting and perhaps overlooked paradox—the introduction of metal technologies in prehistory could increase social complexity while at the same time introduce new and different vulnerabilities.

The following chapter consolidates the discussion above under a few general principles of social stability, explores some research limitations, and proposes possible future directions for research.

CHAPTER 7

CONCLUSIONS

Toward a General Theory of Social Stability

The trajectories of the five Dimensions of Social Stability for the Northern and Southern VBAs during the Bronze Age share some similarities. By the Middle to Late Bronze Ages both regions increase in connectivity, clustering, and centralization and power. Therefore, the entire region experienced an increase in either people or social integration or both between the Early and Late Bronze Ages. Yet, the socio-structural and social stability outcomes for each region differ substantially. Why is this the case? One could argue the cause is related to the difference in exogenous shocks experienced by each region. The Southern VBA saw the collapse of its trading partner; the Northern VBA was affected by migrations and maybe, peripherally, the reorganization of its VBA neighbors to the South. The argument for the differential effects of various exogenous shocks on social stability is reasonable. However, as stated earlier, the goal of this research is to work toward developing a general theory of social stability. Any general theory should be broad enough to explain its occurrence across different and often overlapping contexts—political, economic, environmental, and religious, among others. Attributing differences in social stability to the nature of exogenous shocks is too particularistic to meet the requirements of a general theory.

This analysis suggests that social stability depends on a society's ability to integrate change and promote interdependency. In part, this ability is constrained or promoted by social structure and the different, relationship dependencies among individuals that lead to a particular social structure. Societies with competing cores of exchange and rigid dependencies are less stable than societies characterized by interdependencies funneled through a nested, cohesive social structure. Rigid dependency is different from interdependency. A rigidly dependent social relationship is one where one site is dependent on another for the continuance of that relationship. Mutual reliance characterizes an interdependent relationship. The following paragraphs explore the influences of these differences in more detail.

The results of this research illustrate that certain elements can significantly constrain or promote social stability. The following paragraphs delineate the four most important elements that constrain or promote a society's ability to integrate change and promote interdependency.

1) Structural cohesion

2) Transitivity and social dependency

3) Geographic isolation

4) Types of exchange

1) Structural cohesion

While the Northern and Southern VBAs shared some similarities in the Dimensions of Social Stability, they critically differed in their structural cohesion. The Northern VBA's structural cohesion displays a high degree of nestedness, where every cohesive social group nests within another social group emanating from a central, cohesive core. Competing branches of influence that might threaten the stability of the social structure do not exist. Also, shock in any form, whether it be the flow of new information, peoples, or technologies, is channeled through this cohesive core. Having a cohesive avenue to anneal change is an effective way to maintain social stability.

2) Transitivity and social dependency

Transitivity generally promotes social stability; however, transitivity in certain social contexts may lead to rigidity and maladaptive dependency. Strong transitivity often depends upon only one social mechanism—triadic closure. This reliance reduces the opportunity for transitive exchange along other avenues. Strong transitivity galvanizes social stability as long as these strong social relationships remain intact. However, if social relationships are destroyed for whatever reason, the unvariegated dependency on these social relationships may lead to system collapse. Strong transitivity and dependency on the Argaric characterized the Southern VBA during the Early and Middle Bronze Ages, a contributing factor to its inability to maintain social stability.

3) Geographic isolation

The ERGM results from this analysis support the premise that geographic isolation in prehistoric societies promotes social stability. Geographic isolation reduces the chance for perturbations caused by the introduction of new ideas, technologies, and materials. The ERGM results indicate that river valley location was a significant factor in the structuring the Northern VBA social relationships. The Northern VBA, especially along the Palancia River corridor, exhibits greater geographic isolation. Potentially, this geography was a causal factor of the funnel-like structural cohesion present in the North.

4) Types of exchange

The networks resulting from the exchange of ideas versus the exchange of complex technologies are different. This research demonstrates this using networks derived from this analysis. Figure 7.1 presents a network derived only from the ceramic decoration style *cordones*. (Note that this graphic indicates that by the Late Bronze Age, *cordones* spread to the Southern VBA as well but not in high numbers. Northern sites are represented in blue in Figure 7.1.) The network structure is circular. A circular network structure also called a ring network, is a highly clustered type of network, dependent on strong reciprocity (i.e., the Kula Ring of the Trobriand Islanders.)

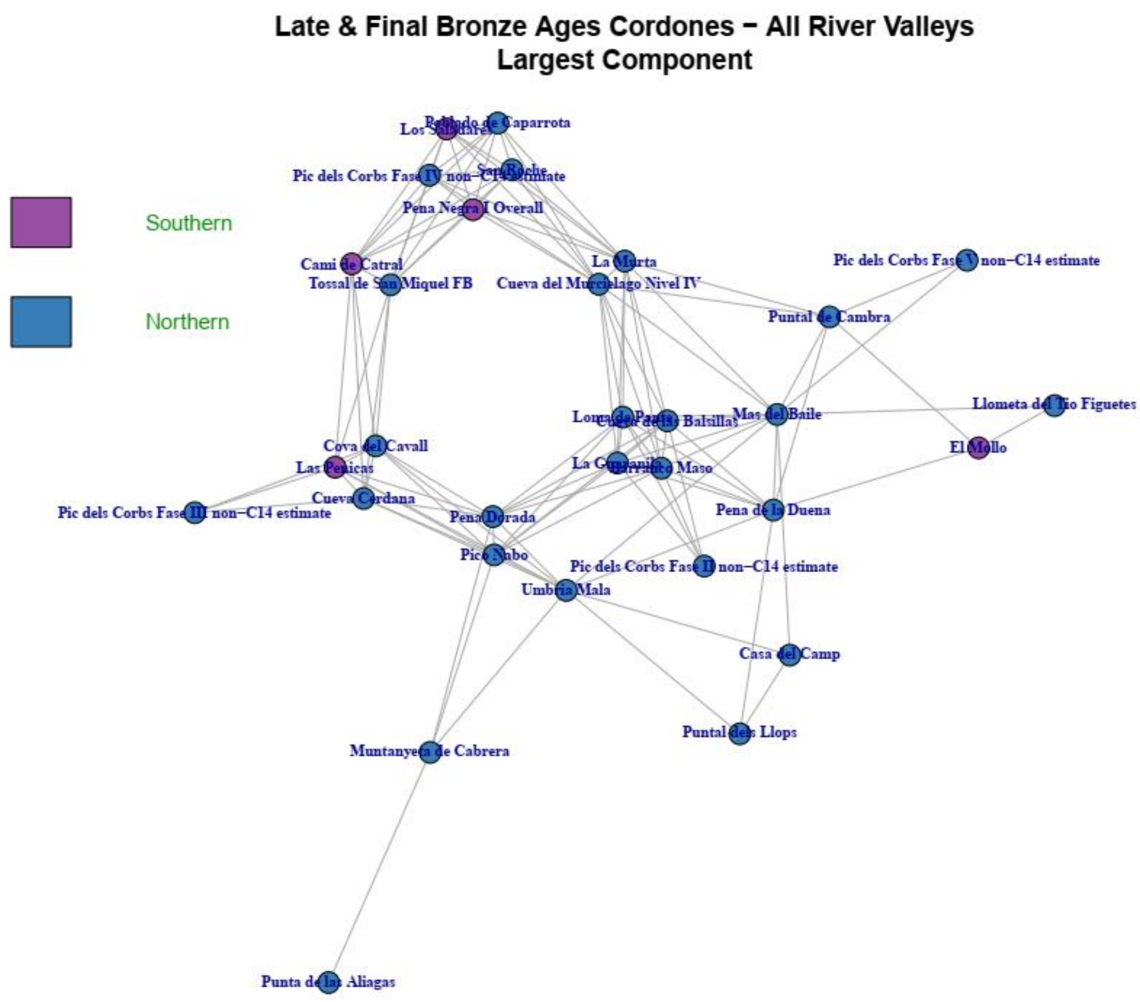


Figure 7.1. A network derived only from the ceramic decoration style ‘cordones’ from the Late and Final Bronze Ages. Both the Northern and Southern VBAs are represented. The Northern VBA sites are in blue. The Southern VBA sites are in purple.

Figure 7.2 presents a network derived only from copper and bronze objects for all regions during the Middle and Late Bronze Ages. (Note the dominance of sites from the

Southern VBA shown in purple.) This network displays a hub and spoke structure, where a few sites act as hubs of distribution. Hub and spoke is a typical network structure for technologies that are more highly complex to produce. Researchers in complexity and network science have quantitatively demonstrated for modern countries that "overall, products with higher complexity—i.e., with larger technological content and/or number of components—are traded through more centralized networks—i.e., with a smaller number of countries concentrating most of the export flow. Since centralized networks are known to be more vulnerable, we argue that the current composition of production and trading is associated to high fragility at the level of the most complex—thus strategic—products" (Piccardi and Tajoli, 2018).

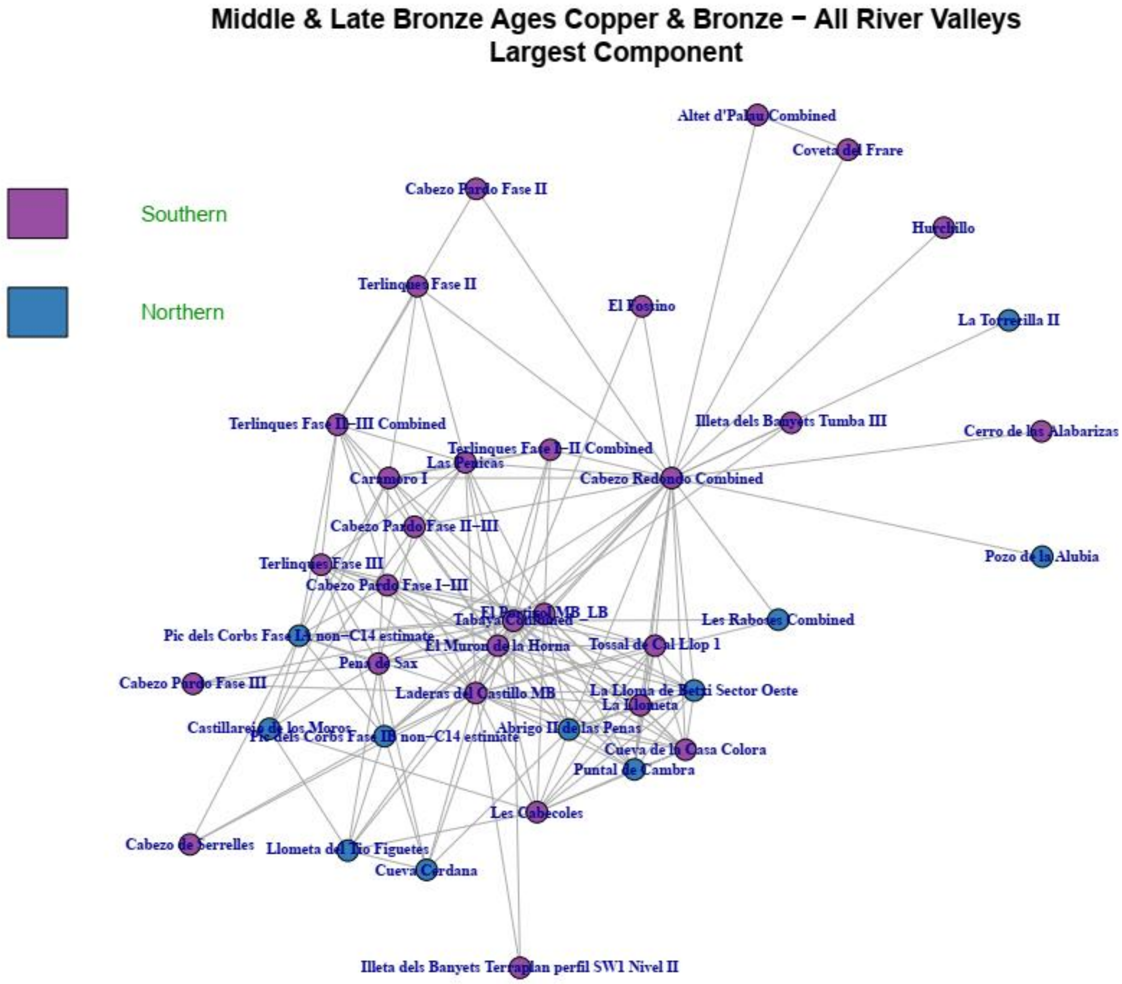


Figure 7.2: A network derived only from copper and bronze artifacts from the Middle and Late Bronze Ages. Both the Northern and Southern VBAs are represented. The Northern VBA sites are in blue. The Southern VBA sites are in purple.

The Southern VBA participated in the exchange of a more complex technology, traded through a hub and spoke structure characterized by high fragility due to centralization around a hub vulnerable to attacks and the asymmetric distribution of relationships decreasing tolerance to relationship losses. Spokes are highly dependent on hubs, and if a hub is destroyed, the social structure is vulnerable to collapse. This research has concluded that the Southern VBA, through strong transitivity, maintained high levels of potentially maladaptive dependency, increasing the vulnerability to reorganization and/or collapse through the loss of hubs. Lull et al. (2013) clearly show that this same pattern existed in the Argaric core. Bronze production was heavily monopolized and controlled by a few elites. Thus, the Southern VBA's participation in the exchange of a complex technology like bronze increased the chance that it might fail.

In contrast, even though the Northern VBA experienced exogenous shocks at this time, the shocks do not include the introduction of transformative, complex technologies. As already mentioned several times, the Northern VBA was characterized by a paucity of bronze until an increase during the Final Bronze Age. Even that increase was not truly meaningful. Northern VBA peoples participated in long-distance trade of certain items (i.e., ivory) but not in high quantities or high diversity. The most dominant exchange surrounded the exchange of ideas about ceramic style. As Figure 7.1 has already demonstrated, this type of exchange resulted in a stable network based on reciprocity.

Therefore, the type of exchange that a society relies upon influences the stability of a social structure.

In conclusion, ***social stability depends on a society's ability to integrate change and promote interdependency***. Four elements are important to constraining or promoting social stability—structural cohesion, transitivity and social dependency, geographic isolation, and types of exchange. These four elements may operate in isolation, or they may combine in various ways to constrain or promote stability. Through the framework provided in this research, an archaeologist can recognize patterns in the archaeological data that reflect and promote social stability, or lead to collapse.

Researchers outside the field of archaeology, working with modern social systems, can use this theoretical foundation as a heuristic tool to identify causes of social stability and social vulnerability. Generally, most people within a society desire social stability, but situations exist where social change is necessary for the overall good. This research can be used prescriptively in either circumstance to identify the socio-structural elements that are important to maintain or alter social stability. If the goal of an entity or policy is long-term social stability, then the findings of this research, arrived at through rigorous and quantitative testing, can be utilized for evidence-based practice. Examples of actions and decisions that meet the expectations of the evidence presented here include the breaking up of monopolies, the unrestricted sharing of knowledge about the production of complex technologies, and open-source publication of research. These actions increase interdependencies among groups that might otherwise form competing blocks.

Research Limitations

While broad and inclusive coverage of sites and site assemblages characterizes this research, several aspects of the VBA limited some aspects. The following section details these limiting factors.

Chronology

The temporal resolution of the VBA is coarse and limited to the broad categories of Early, Middle, Late, and Final. While the Bayesian estimation analysis was able to refine and confirm the chronological classification of many sites, the data available is not sufficient to subdivide chronological categories further. The currently available, numerical dates consist of a small number of radiocarbon dates with an uneven geographic distribution. More radiocarbon dates are available for the Southern VBA than for the Northern VBA, especially along the Palancia River corridor. Additionally, the homogeneity of ceramic assemblages during the Early and Middle VBA increases the difficulty of separating sites into these two time periods. As a result, many sites necessitated classification as EB_MB Classic sites, crossing both chronological categories.

Sample profile

Certain areas of the *Comunidad de Valencia* lack excavation or survey information due to factors outside of the control of this research. It is more than likely that sites are buried under modern cities, thus unavailable for analysis. Information is sparse about coastal sites near modern Dénia and areas near the Júcar River due to a lack of surveys and excavations. Researchers tended to collect data near the easiest to access locations. Site size is not reported for all sites, limiting the analyses based on site size.

Also, artifact assemblages derive from both prospections and excavations that occurred over the last 120 years. The types of artifacts in assemblages likely reflect ideas about what was important to collect at the time of collection or the goals of the project. While every effort was made to normalize classifications of the assemblage data, this analysis still relies upon published classification systems commonly used by Iberian archaeologists for decades. Therefore, the potential for collection bias is a real one. However, *the results of this analysis tend to align with conclusions reached by Iberian archaeologists, who utilized entirely different methods*. This alignment lends confidence to the network analysis despite the possibility of collection bias.

Boundaries and time

One of the defining characteristics of the VBA is the immense number of small sites. There are over 800 known VBA sites; the time limits of this project and unavailability of published reports for some prevented coverage of all of them. For this reason, this research introduced logical, geographic boundaries to focus the coverage area on regions with the most complete data sets most suitable for comparative analysis. Hence, some sites with potentially useful information were not included. (The sites of Mola D'Agres and Muntanya Assolada stand out as examples.) Moreover, the definition of a VBA site served as a cultural boundary limiting this dataset. VBA communities traded across "archaeological" boundaries into Argaric territories and the *Meseta Central*. In reality, the social network should include these trading partners, but time limitations prevented their inclusion.

Directional relationships

The nature of the archaeological data prevented any social network analysis based on directionality, i.e., which way do exchanges flow. For example, it would be useful to know if the site of Cabezo Redondo is the *source* of gold for neighboring sites. This type of source information is not available for the VBA. Data without directionality, referred to as symmetric, limits the ability to understand the level of balance in reciprocal relationships as well as entanglements involved in multiplex relationships. For example and hypothetically, Cabezo Redondo may provide gold to the site of Cabezo de Molinicos, while Cabezo de Molinicos provides silver to Cabezo Redondo. The exchange is reciprocal but over two different material classes.

Ideologies, languages, and beliefs

Little information exists in the VBA of the kind that would help infer ideologies, languages, beliefs, and values. This lack of data limits the types of interpretation that would help augment a social analysis such as the current research. For example, did religion play a vital role in structuring social stability? Would homophily on belief systems, language, or even gender be relevant to our understanding of the social stability of the VBA? The analysis conducted here is broad and general enough to generate conclusions about social stability without these contextual factors. However, if an investigation is to be conducted using the methods employed in this research and at the scale of contextual factors, the nature of the material record is a limiting factor. Burial data is a potential source for this type of analysis. While this analysis counted artifacts from burials, it did not use contextual burial data explicitly due to time constraints.

Future Research

I plan to conduct future analyses of the VBA as well as social stability through several avenues of research. The following paragraphs present each of these.

Radiocarbon dates

This portion of the research is already underway. Certain critical, geographic sub-areas in the VBA lack radiocarbon dates. Also, the chronological resolution could be improved for the Early and Middle Bronze Ages. By combining the results from the social network analysis, the Bayesian Estimations, and identification of sites with organic materials during data collection, this research proposes to add eight additional radiocarbon dates from sites strategically identified by this project as critical to understanding the VBA through time and space.

The radiocarbon dating process will employ local archaeologists in the work of identifying, collecting, and analyzing the samples.

Cut-points

One of the interesting outcomes derived from this research is the identification of cut-points. Table 7.1 below lists the names of sites identified as cut-points for each of the six chrono-regions of the VBA. Cut-points are sites that if removed from the network would disconnect the network. They are critical bridging sites. Iberian archaeologists have excavated many of these sites, but not within the context of what might qualify them as essential to social structure and stability.

Also, a few of these cut-point sites remain under-investigated, namely sites in the Northern VBA like Pico Nabo. Pico Nabo is located along the Palancia River corridor, an area in sore need of archaeological attention. With future funds, an investigation and/or excavation of Pico Nabo and other cut-point sites would contribute to our understanding of bridging sites and to the archaeological data available for the Palancia River corridor. Excavations would provide collaborative, fieldwork opportunities both for local and international archaeologists and students. Furthermore, work along the Palancia can be combined with other existing research aimed at understanding relationships with Indo-Europeans, Cogotas I cultures, and with the *Sistema Iberica Turolense*.

Table 7.1. Cut-point analysis results

Cut-points:	Early & Middle	Middle & Late	Late & Final
Northern VBA	La Lloma de Betxí Hab. III; Els Germanells	Pic dels Corbs Fase IB non-C14 estimate; La Lloma de Betxí Sector Oeste	Pico Nabo
Southern VBA	Caramoro I; Cabezo Pardo Fase I; Tabayá Early; Cova del Cantal; Cabezo de la Escoba Combined	Las Peñicas; Caramoro I; Altet d'Palau Combined; Peña de Sax	El Muron de la Horna; Cabezo del Molinico; Las Peñicas; El Pinchellet; Peña Negra I Overall

Shatter zone

As already briefly recounted, a series of exogenous shocks appears to affect the VBA starting with the Late Middle Bronze Age, especially in the North. The latest genetic evidence suggests that migrations from Central Europe replaced most of the male population and that the influence of the Cogotas I culture increased. The Late Bronze Age Collapse that began in the Near East may have resulted in a European shatter zone, with wave-like transformations that preceded the actual migrations of peoples into the VBA. The Late Bronze Age collapse potentially pushed Indo-European populations southward, in turn driving the native people from the *Meseta Central* and areas near the Ebro River into Northern Spain toward the communities of the VBA. Social network analysis, combining methods employed here with carefully selected assemblages associated with migrations from further north and Cogotas I materials from both inside the VBA and its neighbors, can be used to assess the timing and effects of these waves on social structure and stability.

Toward social stability as a general theory

This research proposes steps toward a general theory of social stability that is applicable across contexts and cultures. Using the methods employed in this research and targeted data collection, we should be able to answer questions for the Argaric like 1) Does the Argaric show similar social patterns to the Southern VBA? 2) Can we see the Argaric collapse coming in its socio-structural patterns? 3) How hierarchical was the Argaric and what social mechanisms or geographic constraints contributed to its social structure and social trajectory? 4) How stable was the Argaric? Future research using the Argaric as a comparative culture would further refine a general theory of social stability.

One of the more difficult results to interpret deriving from this analysis concerns multiplexity or the influence of overlapping relationships on social stability. Multiplexity, in this analysis, is measured by counts and clustering of overlapping affiliations across material exchange classes. The results suggest that overlapping affiliations positively correlate with social stability in the Northern VBA, however, further investigation would be useful. The results derived from particular material classes, namely copper and bronze and *cordones*, suggests that material class may factor into the structuring of a network. Thus, the type of multiplex analysis conducted here is insufficient to understand how material class affects the structure of social relationships, without first understanding how each material class affects exchange relationships.

A future research goal will be to identify the socio-structural exchange patterns of different ideas and technologies and how these relate to stability using network techniques.

Phoenicians, Greeks, and Iberian ethnogenesis

Iberian researchers suspect that the Final Bronze Age endured with some modifications for a few hundred years after the establishment of the first Phoenician and Greek colonies (Marti and de Pedro Michó, 1997; Gil-Mascarell, 1985). Gil-Mascarell (1985) notes two Final Bronze Age phases, Final Bronze I and Final Bronze II. Final Bronze I was an extension of Bronze Age culture even after contact with Iron Age societies, whereas, Final Bronze II societies showed signs of the completion of Iron Age Iberianization. Additionally, culture contact manifested in geographically specific ways. In other words, the interaction between cultures was gradual and geographically differentiated. Moreover, the social stability of the VBA may have influenced how this interaction and integration took place.

A better understanding of the cultural integration of the Phoenicians and Greeks using social network analysis would be an exciting avenue for future research. The ethnogenesis of the Iberian Iron Age culture is not well understood. By the 5th century BC, the Iberian culture dominated the former areas of the VBA. What social processes led to the Iberianization of the *Communidad de Valencia*? Why did some geographic areas retain their Bronze Age characteristics longer than other areas, and does this pattern relate to the elements of social stability as proposed by this research? This avenue would involve the collaborative efforts of Near Eastern and Mediterranean as well as Iberian Iron Age archaeologists. The initiative would focus specifically on the analysis of sites with Phoenician and Greek materials across Andalusia, Valencia, and Castellón provinces.

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APPENDIX A

MASTER TABLE OF ALL ARTIFACTS

For Appendix A, please follow the link: *http://www.diggingdenver.net/*

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APPENDIX B

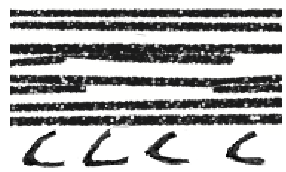
CERAMIC DECORATION TYPOLOGY

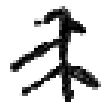
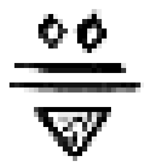
Border (rim) Techniques:

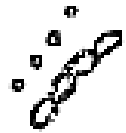
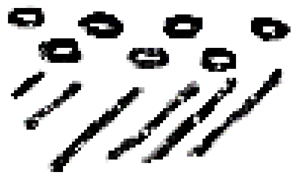
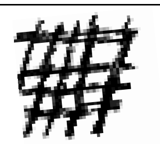
Finger or thumb impressions (impressions made with fingers or thumbs)	
Double nodes under border (two bumps in series just under the rim)	
Tool impressions or short incisions (small incisions or impressions made with a tool)	
Indentations (impressions that make an undulating effect; often includes a fingernail mark)	
Punctates (tiny circular impressions)	
Quintuple nodes under border (five bumps in series just under the rim)	
Double-stepped rim (a built-up rim with a built-up cord underneath)	

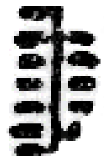
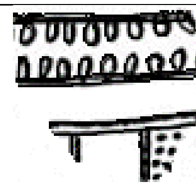
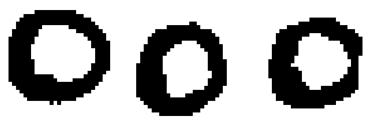
Diagonal wide incisions (diagonal wide incisions, oblique to edge)	
Zig-zag incisions (short incisions on the rim in zig-zag pattern)	
Triple nodes under border (three bumps in a series just under rim)	
Vertical incisions under border (short vertical incisions just under rim)	
Vertical nodes under border (elongated, vertical bumps in a series just under the rim)	

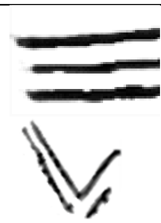
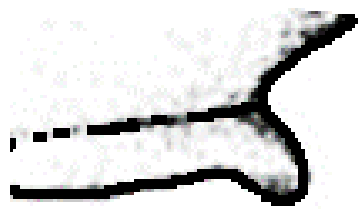
Body Techniques:

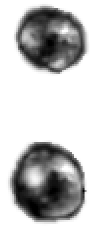
Linear ribs (linear parallel ribs)	
Linear ribs and finger or thumb impressions (linear parallel ribs and impressions made with fingers or thumbs)	
Linear ribs and tool impressions (linear parallel ribs and impressions made with a tool)	
Linear ribs and incisions (linear parallel ribs and incisions)	
Cords ("cordones" in Spanish; clay cords applied to surface)	
Finger or thumb impressions (impressions	

made with fingers or thumbs)	
Excision (clay is carved out in relief)	
Excisions with design leaf (clay is carved out in relief in the form of a leaf spine)	
Excisions and incisions and linear ribs (clay is carved out in relief, incisions, and linear parallel ribs)	
Excisions and lines made by combing (clay is carved out in relief, and parallel lines made using a comb-like instrument like the edge of a shell)	
Excisions and incisions and tool impressions (clay is carved out in relief, incisions, and impressions made with a tool)	
Excisions and incisions (clay is carved out in relief and small incisions)	
Large nodes in horizontal lines (large bumps arranged in horizontal lines)	

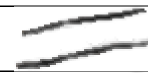
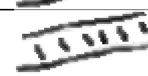
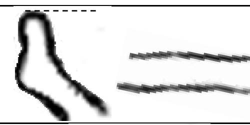
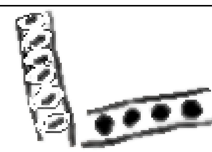
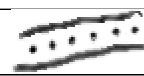
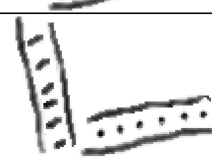
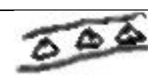
Simple tool impression (impressions made with a tool)	
Tool impressions and punctates (impressions made with a tool and tiny circular impressions)	
Tool impressions and incisions (impressions made with a tool and incisions)	
Tool impressions and incisions with design leaf (impressions made with a tool and incisions in the form of a leaf spine)	
Fine incision (incisions)	
Fine incision hatched (hatched incisions)	

Incisions with representative design (fine incisions with a concrete design)	
Incisions with design leaf (fine incisions with a representative design in the form of a leaf spine)	
Incisions and impressions and punctates (incisions, impressions made with a tool, and tiny circular impressions)	
Large circle impressions	
Large circle impressions and incisions (large circle impressions and incisions)	
Large circle impressions and punctates and excisions (large circle impressions, tiny circular impressions, and clay is carved out in relief)	
Large nodes over whole vessel (large bumps all over body)	La Lloma de Betxi Hab. I-II Combined or Cabezo Redondo
Lines made by combing ("peiñados" in Spanish; multiple lines, commonly made with the edge of a shell or other tool with tines)	

Lines made by combing and incisions ("peiñados" in Spanish; multiple lines, commonly made with the edge of a shell or other tool with tines, and incisions)	
Perforation (holes, commonly for a insertion of a string for suspension)	
Feet (ceramic feet attached to the base of vessel)	
Painted (painted, typically in red or white)	No color image available.
Painted and incisions (painted, typically in red or white, and incisions)	No color image available.
Painted and incisions and linear ribs (painted, typically in red or white, and incisions and linear parallel ribs)	No color image available.
Punctates (tiny circular impressions)	
Punctates and incisions (tiny circular impressions and incisions)	
Raised swirls (applied clay in swirling designs on vessel surface)	

Vertical deep linear ribs (deeply incised, linear parallel ribs arranged vertically)	
Nodes in vertical lines (large bumps all over body arranged in vertical lines)	

Cords ("cordones"):

Cords with finger or thumb impressions (cords with impressions made with fingers or thumbs)	
Cords no decoration (cords with no decorations)	
Cords with tool impressions (cords with impressions made with a tool)	
Cords no decoration under border (cord parallel with and just under rim; probably for suspension)	
Cords with indentations (cords with impressions that make an undulating effect; often includes a fingernail mark)	
Cords with finger or thumb impressions and indentations (cords with impressions made with fingers or thumbs and impressions that make an undulating effect; often includes a fingernail mark)	
Cords with punctates	
Cords with punctates and tool impressions (cords with tiny circular impressions and impressions made with a tool)	
Cords with pyramid impressions (cords with impressions made by a tool in the shape of pyramids)	
Cord with perforation (cords with a hole)	
Cords indeterminate (cords identified as present but no information on form)	NA

Boquique:

Refers to a type of decoration characterized by v-shaped impressions, punctates, and linear incisions

Examples of Boquique:

APPENDIX C

METALS TYPOLOGY

Hacha Plana (Planar axe)**:**

Dimensions:

angle = $\frac{\max width - base\ width}{length}$

area = $\frac{(base\ width + \max width) * length}{2}$

Type:

I – angle > 0.35

II – angle < 0.35

Subtypes for Types I and II:

G – area > 44 cm^2

P – area between 43 and 23 cm^2

MP – area < 22 cm^2

Punal de Remaches (Dagger with nails in base):

Type:

I – large with two nails (Blance 1971)

II – small with two or three nails

III – large with three nails

Base 1 – curved

Base 2 – squared/trapezoidal

Base 3 – triangular

Base 4 – with a tang

NR – number of nails

Punal de Lengueta (Dagger with a tang):

Type:

II – semi-ovular tang with a curvilinear union and a triangular body

Punales Nervados:

Dagger with a longitudinal rib

Punales Foliformes:

Dagger with leaf shape

Alabarda (Halberd):

Type:

II – concavity index between 0.52 and 1.10; dimension index between 0.44 and 0.52; base type arched or slightly arched; number of nails between 2 and 5

III – concavity index between 0.20 and 0.52; dimension index between 0.30 and 0.44; base type arched, slightly arched, or square/trapezoidal

Y – catchall category for halberds with base type arched or slightly arched, but ill-fitting with other types

Punta de Flecha (Point):

Type:

1 – "palmela" or leaf-shaped body, oval union of tang at base, and a tang.

2 – tang and "ears" present

3 – triangular body, angled union from tang to body

4 – concave base, no tang

Punta de Lanza:

Spearhead

Cincel (Chisel):

Type:

I – width < 0.4 cm

II – width between 0.4 and 0.9 cm

III – width > 0.9 cm

Arete/Anillo/Espiral:

Earrings/Rings/Spirals, all classed by number of turns.

Punzon (Punch):

Section (cross-section) Type:

C – quadrangular

O – ovular

M – ovular and quadrangular

R – trapezoidal

T – rhomboidal

Lingote:

Ingot

Brazalete:

Bracelets and “pulseras,” all classed by number of turns.

Cuenco:

Bowls and Jars

Conos and Troncoconos:

Small cones for adornment

APPENDIX D

BONE TYPOLOGY

A. Punzones (Punches):

A.1 Punches with epiphyseal base

A.11 Punches with epiphyseal base and no opening of the medullary canal

A.111 Punches with epiphyseal base and no opening of the medullary canal on ulna

A.112 Punches with epiphyseal base and no opening of the medullary canal on equine metapodial

A.12 Punches with epiphyseal base and with opening of the medullary canal

A.121 Punches with epiphyseal base and with opening of the medullary canal on tibia

A.121a Punches with epiphyseal base and with partial opening of the medullary canal on tibia conserving the distal epiphysis

A.121b Punches with epiphyseal base and with partial opening of the medullary canal on tibia conserving the proximal epiphysis

A.121c Punches with epiphyseal base and with complete opening of the medullary canal on tibia conserving the proximal epiphysis

A.122 Punches with epiphyseal base and with opening of the medullary canal on ruminant metapodial

A.122a Punches with epiphyseal base and with partial opening of the medullary canal on ruminant metapodial conserving the proximal epiphysis

A.122b Punches with epiphyseal base and with complete opening of the medullary canal on ruminant metapodial conserving the distal epiphysis

A.122c Punches with epiphyseal base and with complete opening of the medullary canal on ruminant metapodial conserving the proximal epiphysis

A.123 Punches with epiphyseal base and with opening of the medullary canal on radius

A.123a Punches with epiphyseal base and with partial opening of the medullary canal on radius conserving the proximal epiphysis

A.123b Punches with epiphyseal base and with partial opening of the medullary canal on radius conserving the distal epiphysis

A.123c Punches with epiphyseal base and with complete opening of the medullary canal on radius conserving the distal epiphysis

A.2 Punches without epiphyseal base

A.21 Punches without epiphyseal base and with opening of the medullary canal

A.211a Punches without epiphyseal base and with opening of the medullary canal on small ruminant metapodial

A.211b Punches without epiphyseal base and with opening of the medullary canal on large ruminant metapodial or tibia

A.22 Punches without epiphyseal base and without opening of the medullary canal

A.221 Punches without epiphyseal base and without opening of the medullary canal; canal section is circular or shank is pseudo-circular

A.221a Punches without epiphyseal base; canal section is small and is circular or pseudo-circular

A.221b Punches without epiphyseal base; canal section is large and is circular or pseudo-circular

A.222 Punches without epiphyseal base and without opening of the medullary canal; canal section or shank is planar.

A.222a Punches without epiphyseal base; canal section is small and is planar.

A.222b Punches without epiphyseal base; canal section is large and is planar.

A.223 Punches without epiphyseal base; shank is planar with central thinning.

A.23 Punches with a pointed base

A.231 Punches with a pointed base; shank section is rectangular

A.231a Punches with a pointed base; shank section is small and is rectangular

A.231b Punches with a pointed base; shank section is large and is rectangular

L. Alfileres (Pins)

L.1 Pins with epiphyseal head

L.111 Pins with epiphyseal head on swine fibula

L.111a Pins with epiphyseal head on swine fibula conserving the proximal epiphysis

L.111b Pins with epiphyseal head on swine fibula conserving the distal epiphysis

L.112 Pins with epiphyseal head on bird fibula

L.2 Pins with a modified head

G. Agujas (Needles)

G.1 Needles with epiphyseal base

G.111 Needles with epiphyseal base on swine fibula

G.111a Needles with epiphyseal head on swine fibula with one eye

G.111b Needles with epiphyseal head on swine fibula with two eyes

G.2 Needles without epiphyseal base

G.211 Needles without epiphyseal base on diaphyseal fragment with remains of medullary canal

G.212 Needles without epiphyseal base on diaphyseal fragment without remains of medullary canal

P. Picos (Picks)

P.1 Straight picks

P.111 Straight picks on principal branch of roe deer antler conserving part of base

P.121 Straight picks with circular shank section on longitudinal portion of principal branch of deer antler

P.122 Straight picks with planar shank section on longitudinal portion of principal branch or brow antler of deer; double, basal perforations

P.2 Curved picks

P.211 Curved picks on brow antler of deer without anatomical modification of the extreme distal end

P.22 Curved picks on brow antler of deer with anatomical modification of the extreme distal end

P.221 Curved picks on brow antler of deer with anatomical modification of the extreme distal end; no basal perforation

P.221a Curved picks on brow antler of deer with anatomical modification of the extreme distal end; no basal perforation; circular section

P.221b Curved picks on brow antler of deer with anatomical modification of the extreme distal end; no basal perforation; rectangular section

P.222 Curved picks on brow antler of deer with anatomical modification of the extreme distal end; basal perforation

P.223 Curved picks on brow antler of deer with hollowed-out base

F. Puntas de flecha (Points)

F.1 Arrow points on bone lamina

F.111 Arrow points on bone lamina without ears

F.111a Arrow points on bone lamina without ears; wide body

F.111b Arrow points on bone lamina without ears; narrow body

F.121 Arrow points on bone lamina with two incipient ears

F.121a Arrow points on bone lamina with two incipient ears; narrow body

F.121b Arrow points on bone lamina with two incipient ears; wide body

F.122 Arrow points on bone lamina with two pronounced ears

F.131 Arrow points on bone lamina with four pronounced ears

F.131a Arrow points on bone lamina with four pronounced ears; narrow body

F.131b Arrow points on bone lamina with four pronounced ears; wide body

F.2 Arrow points on bone sticks or shards

F.211 Arrow points on bone sticks or shards without ears; body with circular section

F.221 Arrow points on bone sticks or shards without ears; body with triangular section and solid tang

F.222 Arrow points on bone sticks or shards without ears; body with triangular section and hollow tang

F.231 Arrow points on bone sticks or shards with three ears; solid tang

F.232 Arrow points on bone sticks or shards with three ears; stop; solid tang

F.233 Arrow points on bone sticks or shards with three ears; stop; hollow tang

E. Cinceles y cuñas (Chisels and scoops)

E.1 Chisels and scoops with epiphyseal base

E.111 Chisels and scoops with epiphyseal base on metapodial

E.112 Chisels and scoops with epiphyseal base on ulna

E.2 Chisels and scoops on portions of long bones

E.211 Chisels and scoops without handles on diaphysis of long bone

E.221 Chisels and scoops without handles on longitudinal portion of deer antler

E.231 Chisels and scoops with no tang on diaphysis of long bone

E.232 Chisels and scoops with tang on diaphysis of long bone

H. Espatulas y alisadores (Spatulas and smoothers)

H.1 Spatulas and smoothers without handles on portions of long bones

H.111 Spatulas and smoothers on diaphysis of tibia or metapodial conserving part of the proximal epiphysis

H.112 Spatulas and smoothers on a longitudinal shard or stick from the base of a deer antler

H.113 Spatulas and smoothers on portions of long bones without conservation of the epiphysis

H.2 Spatulas and smoothers without handles on rib bones

H.211 Spatulas and smoothers without handles on rib bones; rounded on extreme ends

H.212 Spatulas and smoothers without handles on rib bones; squared on extreme ends

H.3 Spatulas and smoothers with handles

H.311 Spatulas and smoothers with handles on ruminant jawbone

H.312 Spatulas and smoothers with handles on shard or stick from a deer antler

H.313 Spatulas and smoothers with handles on trimmed portion of rib bone

S. Sierras (Saws)

S.111 Saws on ruminant scapula

S.112 Saws on rib bone

M. Mangos y empunaduras (Handles)

M.1 Handles with epiphyseal base

M.11 Handles with epiphyseal base on bone

M.111 Handles with epiphyseal base on ovicaprine or small ruminant metapodial

M.112 Handles with epiphyseal base on canine humerus

M.113 Handles with epiphyseal base on ovicaprine or small ruminant tibia

M.114 Handles with epiphyseal base on swine metapodial

M.12 Handles with epiphyseal base on antler

M.121 Handles with epiphyseal base on proximal portion of deer antler

M.121a Handles with epiphyseal base on proximal portion of deer antler conserving the rosetta

M.121b Handles with epiphyseal base on proximal portion of deer antler conserving the rosetta; perforation on extreme, base end of brow antler

M.131 Handles on ovicaprine horn bone peg

M.2 Handles without epiphyseal base

M.211 Handles without epiphyseal base on diaphyseal bone with medullary canal

M.221 Handles without epiphyseal base on cylindrical portion of deer antler or ivory

M.221a Handles without epiphyseal base on cylindrical portion of deer antler

M.221b Handles without epiphyseal base on cylindrical piece of ivory

M.231 Handles of ivory with a pommel in the form of a button and circular decorations in the center point

C. Cuentas y elementos de collar (Beads and necklace elements)

C.1 Beads on anatomical supports

C.111 Beads on vertebrae or vertebrae pieces

C.111a Beads on shark vertebrae

C.111b Beads on vertebral disc of large fish

C.112 Beads on skeleton fragment of turtle shell

C.2 Beads on ivory

C.211 Spherical or pseudo-spherical beads on ivory

C.3 Beads on diaphyseal bone supports

C.311 Elongated tubular beads on portions of small, diaphyseal bones

C.312 Short, pseudo-tubular on portions of diaphyseal bones

C.4 Necklace separators on bone plaques

C.411 Necklace separators with multiple perforations on ivory plaque

C.5 Beads or necklace elements on portion of solid bone

C.511 Fusiform bead on portion of solid bone with central perforation

K. Colgantes y pendientes (Pendants)

K.1 Pendants on fangs/tusks or dental pieces of animals

K.111 Pendants on tusks of swine

K.111a Pendants on upper tusks of swine

K.111b Pendants on lower tusks of swine

K.2 Pendants on trimmed portions of bone plaques

K.211 Pendants on long plaques trimmed from rib bones

K.211a Pendants on long plaques trimmed from rib bones with a perforation

K.211b Pendants on long plaques trimmed from rib bones with double perforations arranged longitudinally

K.211c Pendants on long plaques trimmed from rib bones with double perforations arranged transversally

K.212 Pendants on plaques trimmed transversally from rib bones

K.3 Pendants on ivory supports

K.311 Pendants on ivory bars

K.311a Pendants on ivory bars with circular section

K.311b Pendants on ivory bars with triangular section

K.321 Pendants on ivory in ring form

K.331 Pendants on ivory plaques with multiple perforations

Q. Botones y aderezos (Buttons and adornments)

Q.1 Buttons and adornments with perforation

Q.111 Pyramidal buttons with ‘V’ perforation

Q.121 Conical buttons with ‘V’ perforation

Q.131 Prismatic buttons with simple ‘V’ perforation

Q.132 Prismatic buttons with double ‘V’ perforation

Q.2 Adornments on triangular prismatic bar without perforations

Q.211 Prismatic piece with transversal recesses

Q.3 Adornments on cylindrical or fusiform bars without perforations

Q.311 Fusiform bars with carvings or notches at the extreme ends

T. Conteras y apliques ornamentals para mangos (Tips or ornamental appliques for handles)

T.1 Tips with perforations for nails

T.111 Tips on ivory with simple perforation for a nail

T.112 Tips on ivory with double perforations for nails

T.2 Tips without perforations for nails

T.211 Fusiform tip with spherical button on the extreme end

T.3 Appliques for handles

T.311 Jagged appliques for handles

B. Brazaletes (Bracelets)

B.111 Bracelets on ivory without perforations

B.111a Bracelets on ivory without perforations; quadrangular section

B.111b Bracelets on ivory without perforations; triangular section

B.112 Bracelets on ivory with perforation

N. Peines (Combs)

N.111 Combs on ivory plaques with decorative, geometric incisions

N.211 Combs on ivory plaques with two perforations

APPENDIX E

TYPOLOGY FOR ALL OTHER ARTIFACT MATERIAL TYPES

Amber:
Tubular bead
Perforated bead

Lignite:
Applique

Mother of pearl:
No form
Discoidal bead

Ochre:
Ochre

Pasta vitrea:
Perforated bead

Shell:
Bead with perforation
Bracelet
Button
Dentalium
Discoidal bead
Pendant
Perforated shell
Tubular bead

Stone:
Adze
Archer's brace
Axe
Bead with perforation
Bracelet
Button
Chisel
Crucible
Discoidal bead
Hammer
Horno (oven)
Idol
Mold
Necklace
Pendant
Plaque

Wood:
Pendant
Discoidal bead
Plaque

APPENDIX F

NETWORK INFERENCE, VISUALIZATION, DESCRIPTIVES, AND MAPPING

R Code: Network Inference, Visualization, and Analysis
DOI: 10.13140/RG.2.2.35335.34721
Wendy H. Cegielski

2020

```r
#Load Network Inference packages.
BiocManager::install("sand")

## Bioconductor version 3.9 (BiocManager 1.30.10), R 3.6.1 (2019-07-05)

## Installing package(s) 'sand'

library(devtools)

#used to clean-up messy listing of packages and libraries.
install.packages("easypackages", repos = "http://cran.us.r-project.org")

## Installing package into '/home/whcegielski/R/x86_64-pc-linux-gnu-library/3.6'
## (as 'lib' is unspecified)

library(easypackages)
packages("Hmisc", "knitr", "kableExtra", "geosphere", "tidyverse", "tidygraph",
       "ggmap", "statnet", "RgoogleMaps","igraph", "ggraph", "RColorBrewer",
       "leaflet", "reshape2", "rgdal", "shadowtext", "ggrepel")

## network: Classes for Relational Data
## Version 1.16.0 created on 2019-11-30.
## copyright (c) 2005, Carter T. Butts, University of California-Irvine
##                 Mark S. Handcock, University of California-

         Los Angeles
##                 David R. Hunter, Penn State University
##                 Martina Morris, University of Washington
##                 Skye Bender-deMoll, University of Washington
##  For citation information, type citation("network").
##  Type help("network-package") to get started.

##
## ergm: version 3.10.4, created on 2019-06-10
## Copyright (c) 2019, Mark S. Handcock, University of California – Los Angeles
##                 David R. Hunter, Penn State University
##                 Carter T. Butts, University of California -- Irvine
##                 Steven M. Goodreau, University of Washington
##                 Pavel N. Krivitsky, University of Wollongong
##                 Martina Morris, University of Washington
##                 with contributions from
##                 Li Wang
```

```
##                Kirk Li, University of Washington
##                Skye Bender-deMoll, University of Washington
##                Chad Klumb
## Based on "statnet" project software (statnet.org).
## For license and citation information see statnet.org/attribution
## or type citation("ergm").

## NOTE: Versions before 3.6.1 had a bug in the implementation of the bd()
## constriant which distorted the sampled distribution somewhat. In
## addition, Sampson's Monks datasets had mislabeled vertices. See the
## NEWS and the documentation for more details.

## NOTE: Some common term arguments pertaining to vertex attribute and
## level selection have changed in 3.10.0. See terms help for more
## details. Use 'options(ergm.term=list(version="3.9.4"))' to use old
## behavior.

## Loading required package: networkDynamic

##
## networkDynamic: version 0.10.1, created on 2020-01-16
## Copyright (c) 2020, Carter T. Butts, University of California -- Irvine
##                Ayn Leslie-Cook, University of Washington
##                Pavel N. Krivitsky, University of Wollongong
##                Skye Bender-deMoll, University of Washington
##                with contributions from
##                Zack Almquist, University of California -- Irvine
##                David R. Hunter, Penn State University
##                Li Wang
##                Kirk Li, University of Washington
##                Steven M. Goodreau, University of Washington
##                Jeffrey Horner
##                Martina Morris, University of Washington
## Based on "statnet" project software (statnet.org).
## For license and citation information see statnet.org/attribution
## or type citation("networkDynamic").

##
## tergm: version 3.6.1, created on 2019-06-12
## Copyright (c) 2019, Pavel N. Krivitsky, University of Wollongong
##                Mark S. Handcock, University of California -- Los Angeles
##                with contributions from
##                David R. Hunter, Penn State University
##                Steven M. Goodreau, University of Washington
##                Martina Morris, University of Washington
##                Nicole Bohme Carnegie, New York University
##                Carter T. Butts, University of California -- Irvine
```

```
##                  Ayn Leslie-Cook, University of Washington
##                  Skye Bender-deMoll
##                  Li Wang
##                  Kirk Li, University of Washington
## Based on "statnet" project software (statnet.org).
## For license and citation information see statnet.org/attribution
## or type citation("tergm").

##
## ergm.count: version 3.4.0, created on 2019-05-15
## Copyright (c) 2019, Pavel N. Krivitsky, University of Wollongong
##                  with contributions from
##                  Mark S. Handcock, University of California -- Los Angeles
##                  David R. Hunter, Penn State University
## Based on "statnet" project software (statnet.org).
## For license and citation information see statnet.org/attribution
## or type citation("ergm.count").

## NOTE: The form of the term 'CMP' has been changed in version 3.2 of
## 'ergm.count'. See the news or help('CMP') for more information.

##

## sna: Tools for Social Network Analysis
## Version 2.5 created on 2019-12-09.
## copyright (c) 2005, Carter T. Butts, University of California-Irvine
##  For citation information, type citation("sna").
##  Type help(package="sna") to get started.

##
## statnet: version 2019.6, created on 2019-06-13
## Copyright (c) 2019, Mark S. Handcock, University of California -- Los Angeles
##                  David R. Hunter, Penn State University
##                  Carter T. Butts, University of California -- Irvine
##                  Steven M. Goodreau, University of Washington
##                  Pavel N. Krivitsky, University of Wollongong
##                  Skye Bender-deMoll
##                  Martina Morris, University of Washington
## Based on "statnet" project software (statnet.org).
## For license and citation information see statnet.org/attribution
## or type citation("statnet").

## rgdal: version: 1.4-8, (SVN revision 845)
##  Geospatial Data Abstraction Library extensions to R successfully loaded
##  Loaded GDAL runtime: GDAL 2.2.3, released 2017/11/20
##  Path to GDAL shared files: /usr/share/gdal/2.2
##  GDAL binary built with GEOS: TRUE
```

```
##  Loaded PROJ.4 runtime: Rel. 4.9.3, 15 August 2016, [PJ_VERSION: 493]
##  Path to PROJ.4 shared files: (autodetected)
##  Linking to sp version: 1.4-1

## All packages loaded successfully

libraries("tidyverse", "Hmisc", "geosphere", "ggmap", "RgoogleMaps",
        "statnet", "knitr", "kableExtra")

## All packages loaded successfully

libraries("igraph", "tidygraph", "ggraph", "leaflet", "reshape2",
        "rgdal", "curl", "shadowtext", "ggrepel", "RColorBrewer")

##Load datasets and clean data.
WM3_all_rev <-
  read.csv("~/Dropbox/Dissertation/Databases/All Sites Master/WM3_all_rev_6_rev.csv
",
         na = "NA", check.names=FALSE, strip.white=TRUE)
WM3_all_rev <- WM3_all_rev[,-1]

######Merge columns and remove bad columns, as desired.
WM3_all_rev$Cer_x_Paint <- (WM3_all_rev$Cer_x_Pa + WM3_all_rev$Cer_x_Pa.inc
+
                        WM3_all_rev$Cer_x_Pa.inc.lri)
WM3_all_rev$Ochre <- (WM3_all_rev$Och + WM3_all_rev$St_Och)

WM3_all_rev <- WM3_all_rev[ , -which(names(WM3_all_rev) %in% c("Cer_x_Pa", "
Cer_x_Pa.inc",
                                          "Cer_x_Pa.inc.lri", "Cer_x_ArHan", "Cer_x_MN
o", "Cer_x_Mno","Qu", "Qu_Ham", "Och", "St_Och"))]

U2 <- read_csv("~/Dropbox/Dissertation/Databases/All Sites Master/U2_rev_chrono.csv
",
           na = "NA")

## Warning: Missing column names filled in: 'X1' [1]

## Parsed with column specification:
## cols(
##   X1 = col_double(),
##   Site.Name.abb = col_character(),
##   Site.Name = col_character(),
##   North.South.Central = col_character(),
##   UTM.X = col_double(),
##   UTM.Y = col_double(),
##   Chronological.Attribution = col_character(),
```

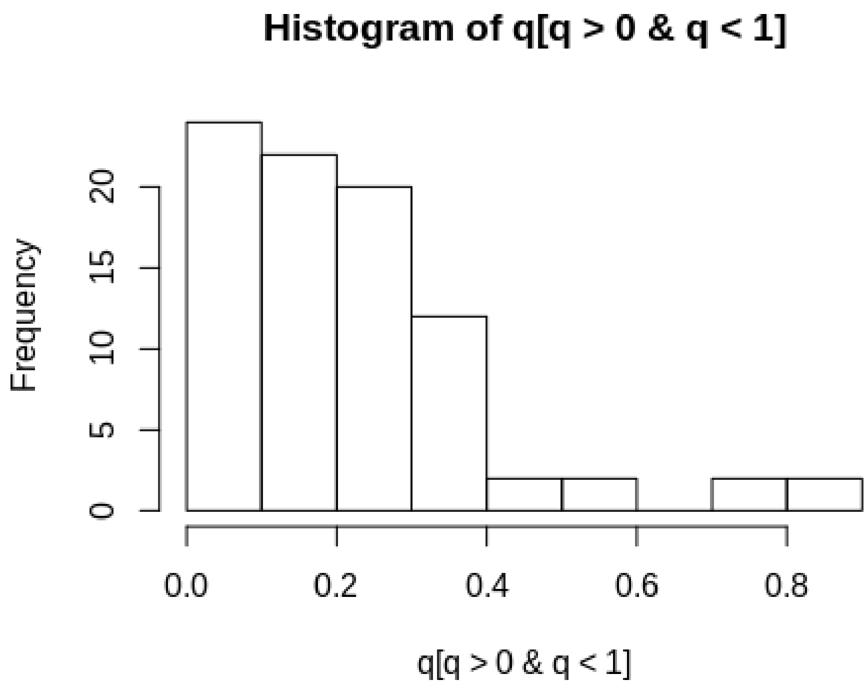
```
##   Chrono.Bayes = col_character(),
##   Site.Size.m2 = col_double(),
##   River.Valley = col_character(),
##   Elevation = col_double(),
##   Visibility = col_double()
## )

U2 <- U2[,-1]

corr_attr <- merge(U2,WM3_all_rev, by  = "Site.Name")
corr_attr <- tidyr::replace_na(corr_attr, list(Visibility=1))


#Designate chronologies and regions to subset, example for EB_MB.
EB_MB <- which((corr_attr$`Chrono.Bayes`=="EB" |
                corr_attr$`Chrono.Bayes`=="EB_MB Classic" |
                corr_attr$`Chrono.Bayes`=="MB") &
               (corr_attr$River.Valley=="Turia" |
                  corr_attr$River.Valley=="Palancia-Valls"))

#corr_attr$`Chrono.Bayes`=="LB_FB" | corr_attr$`Chrono.Bayes`=="MB_LB_FB") &
#"Jucar" | corr_attr$River.Valley=="Vinalopo-Alicante" |
###corr_attr$River.Valley=="Segura"))

EB_MB <- corr_attr[EB_MB ,]
EB_MB <- EB_MB[, -c(2:11)]

f = EB_MB  #insert desired subset

#Revise and transpose dataset.
y <- f[,-1]
rownames(y) <- f[,1]
#y <- y[,-c(1:8)]
#Transpose.
WM3.t <- t(y)
#Drops sites as desired.
WM3.t <- WM3.t[ , -which(colnames(WM3.t) %in% c("La Lloma de Betxi"))]

#Drops artifact categories with few instances
#rowSums(WM3.t)
WM3.t.drop <- WM3.t[rowSums(WM3.t) >= 2 ,]


##Network Inference
#Spearman's rho correlation
mycorr <- rcorr(WM3.t.drop, type=c("spearman"))
```

```
q = as.data.frame(mycorr$r)

##Formats table for RStudio, R Markdown.
kable(q, digits = 2, caption = "correlations") %>%
  kable_styling(font_size = 6, latex_options ="scale_down") %>% landscape() %>%
  kable_styling(full_width =F) %>%
  column_spec(1:3,width ="4.5em") %>% column_spec(4:20, width = "3em")
```

Table 1: correlations

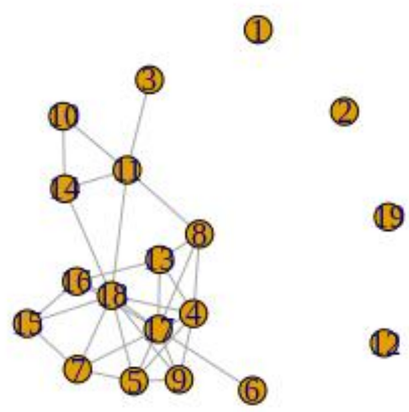
	Albardeta	Castillarejo de Penarroya	Cova de Rocafort	Cueva de la Peseta	Cueva del Cerro Las Simas	Cueva del Pueblo Classic	Cueva del Tio Paco MB	Cueva Grande de la Rocha	El Castillarejo del Coronel	El Picayo	Els Germanells	Els Trencalls	Fuente de la Noguera	La Atalayuela	La Cueva del Abrigo I de Las Penas	La Lloma de Betxi Hab. I-II Combined	La Lloma de Betxi Hab. III Combined	La Torreta	Pic dels Corbs Fase IA non-C14 estimate
Albardeta	1.00	1.00	-0.02	-0.03	-0.02	-0.02	-0.03	-0.03	-0.02	-0.02	-0.07	NaN	-0.02	-0.08	-0.06	-0.11	-0.09	-0.03	-0.07
Castillarejo de Penarroya	1.00	1.00	-0.02	-0.03	-0.02	-0.02	-0.03	-0.03	-0.02	-0.02	-0.07	NaN	-0.02	-0.08	-0.06	-0.11	-0.09	-0.03	-0.07
Cova de Rocafort	-0.02	-0.02	1.00	-0.03	-0.02	-0.02	-0.03	-0.03	-0.02	-0.02	0.16	NaN	-0.02	-0.08	-0.06	-0.11	-0.09	-0.03	-0.07
Cueva de la Peseta	-0.03	-0.03	-0.03	1.00	0.39	-0.03	-0.05	0.30	0.57	-0.03	-0.13	NaN	0.38	-0.14	-0.10	0.02	0.29	0.24	-0.13
Cueva del Cerro Las Simas	-0.02	-0.02	-0.02	0.39	1.00	-0.02	0.39	-0.04	0.70	-0.02	-0.10	NaN	-0.03	-0.11	-0.08	-0.06	0.27	0.31	0.07
Cueva del Pueblo Classic	-0.02	-0.02	-0.02	-0.03	-0.02	1.00	-0.03	-0.03	-0.02	-0.02	-0.07	NaN	-0.02	-0.08	-0.06	-0.11	0.11	-0.03	-0.07
Cueva del Tio Paco MB	-0.03	-0.03	-0.03	-0.05	0.39	-0.03	1.00	-0.05	-0.03	-0.03	0.04	NaN	-0.04	-0.14	0.08	0.07	0.11	0.26	0.01
Cueva Grande de la Rocha	-0.03	-0.03	-0.03	0.30	-0.04	-0.03	-0.05	1.00	-0.03	-0.03	0.20	NaN	0.82	-0.01	-0.10	0.05	0.19	-0.06	-0.13
El Castillarejo del Coronel	-0.02	-0.02	-0.02	0.57	0.70	-0.02	-0.03	-0.03	1.00	-0.02	-0.07	NaN	-0.02	-0.08	-0.06	-0.11	0.22	0.47	-0.07
El Picayo	-0.02	-0.02	-0.02	-0.03	-0.02	-0.02	-0.03	-0.03	-0.02	1.00	0.16	NaN	-0.02	0.13	-0.06	-0.11	-0.09	-0.03	-0.07
Els Germanells	-0.07	-0.07	0.16	-0.13	-0.10	-0.07	0.04	0.20	-0.07	0.16	1.00	NaN	0.07	0.21	0.02	0.05	-0.03	0.17	-0.21
Els Trencalls	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	1	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Fuente de la Noguera	-0.02	-0.02	-0.02	0.38	-0.03	-0.02	-0.04	0.82	-0.02	-0.02	0.07	NaN	1.00	0.04	-0.08	0.14	0.30	-0.04	-0.10
La Atalayuela	-0.08	-0.08	-0.08	-0.14	-0.11	-0.08	-0.14	-0.01	-0.08	0.13	0.21	NaN	0.04	1.00	-0.06	-0.05	-0.03	0.11	-0.24
La Cueva del Abrigo I de Las Penas	-0.06	-0.06	-0.06	-0.10	-0.08	-0.06	0.08	-0.10	-0.06	-0.06	0.02	NaN	-0.08	-0.06	1.00	0.17	-0.06	0.39	-0.20
La Lloma de Betxi Hab. I-II Combined	-0.11	-0.11	-0.11	0.02	-0.06	-0.11	0.07	0.05	-0.11	-0.11	0.05	NaN	0.14	-0.05	0.17	1.00	0.29	0.24	-0.11
La Lloma de Betxi Hab. III Combined	-0.09	-0.09	-0.09	0.29	0.27	0.11	0.11	0.19	0.22	-0.09	-0.03	NaN	0.30	-0.03	-0.06	0.29	1.00	0.26	0.01
La Torreta	-0.03	-0.03	-0.03	0.24	0.31	-0.03	0.26	-0.06	0.47	-0.03	0.17	NaN	-0.04	0.11	0.39	0.24	0.26	1.00	-0.15
Pic dels Corbs Fase IA non-C14 estimate	-0.07	-0.07	-0.07	-0.13	0.07	-0.07	0.01	-0.13	-0.07	-0.07	-0.21	NaN	-0.10	-0.24	-0.20	-0.11	0.01	-0.15	1.00

```r
#Threshold network by quantiles and binarize.
q[q <= 0 | q == 1] <- NA
hist( q[q > 0 & q < 1] )
```



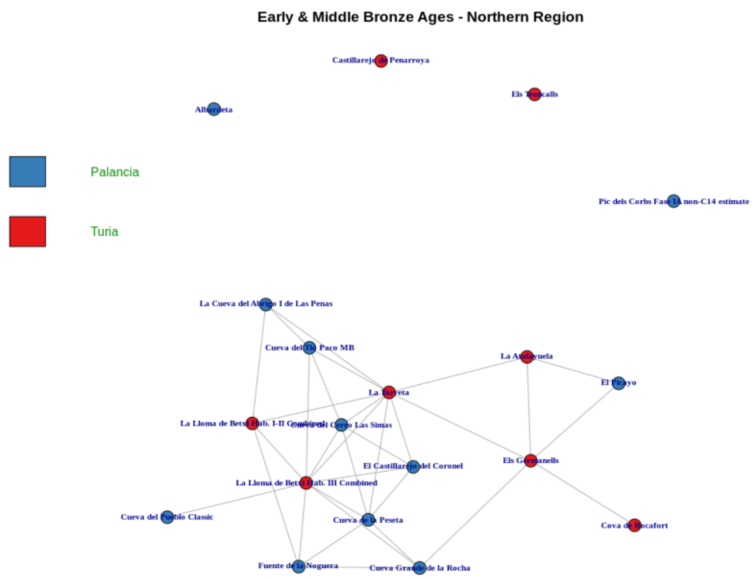

```r
quantq <- quantile(q, c(.25, .50), na.rm = TRUE)
q.vec<-q[lower.tri(q)]
n<-dim(WM3.t.drop)[2]
length(q.vec)

## [1] 171

qu = (q.vec > quantq[1]) #& s.vec > 0.01)
#qu = (q.vec == q.vec)
length(qu)

## [1] 171

length(q.vec[qu])

## [1] 160

q_redges <- (q.vec[qu])

#Create and plot network from correlation values.
pcorr.A <- matrix(0, n, n)
pcorr.A[lower.tri(pcorr.A)] <- as.numeric(qu)
```

```
g.pcorr <- igraph::graph.adjacency(pcorr.A, "undirected")
plot(g.pcorr, cex = 0.02)
```




```
#Assigns vertex attributes.
EB_MB_attr <- which((corr_attr$`Chrono.Bayes`=="EB" |
                     corr_attr$`Chrono.Bayes`=="EB_MB Classic" |
                     corr_attr$`Chrono.Bayes`=="MB") &
                    (corr_attr$River.Valley=="Turia" |
                      corr_attr$River.Valley=="Palancia-Valls"))

#"Jucar" | corr_attr$River.Valley=="Vinalopo-Alicante" |
##corr_attr$River.Valley=="Segura"))

EB_MB_attr <- corr_attr[EB_MB_attr ,]

x <- EB_MB_attr
#Drop sites as desired.
x <- subset(x, !( Site.Name == "La Lloma de Betxi"))

#Assign vertex attributes to network.
for (i in seq_len(ncol(x[1:11]))) {
  g.pcorr <- igraph::set.vertex.attribute(g.pcorr,
                                          colnames(x[1:11])[i],
                                          value=as.character(x[1:11][,i]))
```

```
}
g.pcorr

## IGRAPH 6a2c250 U--- 19 32 --
## + attr: Site.Name (v/c), Site.Name.abb (v/c), North.South.Central
## | (v/c), UTM.X (v/c), UTM.Y (v/c), Chronological.Attribution (v/c),
## | Chrono.Bayes (v/c), Site.Size.m2 (v/c), River.Valley (v/c), Elevation
## | (v/c), Visibility (v/c)
## + edges from 6a2c250:
##  [1]  3--11  4-- 5  4-- 8  4-- 9  4--13  4--17  4--18  5-- 7  5-- 9  5--17
## [11]  5--18  6--17  7--15  7--17  7--18  8--11  8--13  8--17  9--17  9--18
## [21] 10--11 10--14 11--14 11--18 13--16 13--17 14--18 15--16 15--18 16--17
## [31] 16--18 17--18

l <- igraph::layout.fruchterman.reingold(g.pcorr)

vlabel = x$Site.Name
V(g.pcorr)$name <- vlabel

#Create labeled, newtork graph.
coul = brewer.pal(9, "Set1")[c(2,1)]
my_color=coul[as.numeric(as.factor(V(g.pcorr)$River.Valley))]

plot(g.pcorr, layout = l, vertex.size = 5, rescale = TRUE, vertex.label=x$Site.Name,
    vertex.color=my_color,  vertex.label.cex = 0.7, margin = c(0,0,-0.05,0),
    vertex.label.font=2)
legend(-1.8, .8, c("Palancia", "Turia"),
      col = my_color,
      text.col = "green4", bty = "n", fill=coul)
title("Early & Middle Bronze Ages -Northern Region")
```




```
dev.off()

## null device
##          1

##Descriptives
#####Measures for Social Structure####################

# 1) Finds components. Finds cutpoints, or nodes that
#####destabilize a network or the network's largest component.
comps <- igraph::decompose.graph(g.pcorr)
comp_vert_count <- table(sapply(comps, vcount))
largest <- which.max(sapply(comps, vcount))
big <- comps[[largest]]
g.pcorr.gc <- big
apl.gc <- average.path.length(g.pcorr.gc)
diam.gc <- diameter(g.pcorr.gc)
trans.gc <- transitivity(g.pcorr.gc)
apl_diam_trans.gc <- rbind(apl.gc, diam.gc, trans.gc)
### Write files.
#write.csv(comp_vert_count, file = "LB_FB_JVS_comp_vert_count_per.csv")
#write.csv(apl_diam_trans.gc, file = "LB_FB_JVS_apl_diam_trans.gc_per.csv")

SN <- vertex_attr(big, "Site.Name")
Sabb <- vertex_attr(big, "Site.Name.abb")

V(big)$name <- SN
gc.cut.vertices <- articulation.points(big)
cut_length <- length(gc.cut.vertices)
cut_names <- names(gc.cut.vertices)
```

```
cut_points <- cbind(cut_length, cut_names)
### Write file.
#write.csv(cut_points, file = "LB_FB_JVS_cut_points_per.csv")

# 2) Finds density of global network
dens <- graph.density(g.pcorr)
dens.gc <- graph.density(g.pcorr.gc)
### Write file.
#write.csv(dens.gc, file = "LB_FB_JVS_dens.gc_per.csv")

# 3) Finds degree centrality; then closeness centrality;
##then eigenvector centrality
##degree centrality, measures actor prominence
##(how balanced is this network)
deg <- igraph::degree(g.pcorr, v = V(g.pcorr))
deg.gc <- igraph::degree(g.pcorr.gc, v = V(g.pcorr.gc))
sumdeg <- as.matrix(summary(deg))
sumdeg.gc <- as.matrix(summary(deg.gc))
dd <- degree_distribution(g.pcorr, cumulative = TRUE)
dd.gc <- degree_distribution(g.pcorr.gc, cumulative = TRUE)

##Plot cumulative degree distribution.
plot(dd, type = "l", ylab = "Cumulative Distribution", xlab = "Degree")
dev.off()

## null device
##          1

###Write files.
#write.csv(deg, file = "LB_FB_JVS_deg_per.csv")
#write.csv(deg.gc, file = "LB_FB_JVS_deg.gc_per.csv")
#write.csv(sumdeg, file = "LB_FB_JVS_sumdeg_per.csv")
#write.csv(sumdeg.gc, file = "LB_FB_JVS_sumdeg.gc_per.csv")
#write.csv(dd, file = "LB_FB_JVS_dd_per.csv")
#write.csv(dd.gc, file = "LB_FB_JVS_dd.gc_per.csv")

##closeness centrality, measures network reach
clo.gc <- igraph::closeness(g.pcorr.gc, vids = V(g.pcorr.gc),
                    mode = "all", weights = NULL, normalized = FALSE)
sumclo.gc <- as.matrix(summary(clo.gc))
##eigenvector centrality, bases centrality on th centrality of first order alters
ev <- igraph::evcent(g.pcorr)$vector
ev.gc <- igraph::evcent(g.pcorr.gc)$vector
ev_net <- igraph::evcent(g.pcorr)$value
ev.index <- igraph::centr_eigen(g.pcorr)$centralization
ev.index.gc <- igraph::centr_eigen(g.pcorr.gc)$centralization
```

```
### Write files.
#write.csv(clo.gc, file = "LB_FB_JVS_clo.gc_per.csv")
#write.csv(sumclo.gc, file = "LB_FB_JVS_sumclo.gc_per.csv")
#write.csv(ev, file = "LB_FB_JVS_ev_per.csv")
#write.csv(ev.gc, file = "LB_FB_JVS_ev.gc_per.csv")
#write.csv(ev_net, file = "LB_FB_JVS_ev_net_per.csv")

# 4) Finds transitivity
trans <- transitivity(g.pcorr)

trans_dens <- rbind(trans, dens)
### Write file.
#write.csv(trans_dens, file = "LB_FB_JVS_trans_dens_per.csv")

# 5) Finds modularity--counts of relations between and within subgroups,
#(want to see fewer between group ties)

#Use fast greedy algorithm
cfg <- cluster_fast_greedy(g.pcorr.gc)
modu_cfg <- modularity(cfg)
mem_cfg <- membership(cfg)
modumem_cfg_tab <- table(V(g.pcorr.gc), membership(cfg))
### Write files.
#write.csv(modu_cfg, file = "LB_FB_JVS_modu_cfg_per.csv")
#write.csv(modumem_cfg_tab, file = "LB_FB_JVS_modumem_cfg_tab_per.csv")

# 6) Cohesive blocking--looks at core/periphery. Cohesive blocking
#####is a method of determining hierarchical subsets of graph vertices
#####based on their structural cohesion (or vertex connectivity).
bloc <- cohesive_blocks(g.pcorr.gc, labels = TRUE)
numbloc <- length(bloc)
memblocs <- as.matrix(blocks(bloc))
coh <- cohesion(bloc, labels = TRUE)
maxcoh <- maxcohesion(bloc)
graphs_from_cohesive_blocks(bloc, g.pcorr.gc)[maxcoh]

colbar = rainbow(max(cohesion(bloc)) + 1)

dev.off

## function (which = dev.cur())
## {
##     if (which == 1)
##         stop("cannot shut down device 1 (the null device)")
##     .External(C_devoff, as.integer(which))
##     dev.cur()
```

```
## }
## <bytecode: 0x563d88ec1180>
## <environment: namespace:grDevices>

par(mfrow=c(1,3))
plot_hierarchy(bloc, main = "Early &\nMiddle Bronze Ages")
#plot_hierarchy(bloc, main = "Middle &\nLate Bronze Ages")
#plot_hierarchy(bloc, main = "Late &\nFinal Bronze Ages")

### Write files.
#write.csv(numbloc, file = "LB_FB_JVS_numbloc_per.csv")
#write.csv(memblocs, file = "LB_FB_JVS_memblocs_per.csv")
#write.csv(coh, file = "LB_FB_JVS_coh_per.csv")
#write.csv(maxcoh, file = "LB_FB_JVS_maxcoh_per.csv")

##Plot cohesive blocs.
coul = brewer.pal(9, "Set1")[c(2,1)]
my_color=coul[as.numeric(as.factor(V(g.pcorr.gc)$River.Valley))]
plot(bloc, g.pcorr.gc, vertex.label = SN, vertex.size = 5,
    colbar = rainbow(max(cohesion(bloc)) + 1),
    col = colbar[max_cohesion(bloc) + 1], mark.groups = blocks(bloc)[-1],
    vertex.label.cex = 0.7,
    vertex.label.font=2, main =
      "Early & Middle Bronze Ages – Northern Region\nCohesive Blocks")
dev.off()

## null device
##           1

##Mapping

#This code imports satellite maps from Google Maps.
#Also, uses a generated API key from Google Cloud
##in order to download Google Map images.
if(!requireNamespace("devtools")) install.packages("devtools")
devtools::install_github("dkahle/ggmap", ref = "tidyup")

## Skipping install of 'ggmap' from a github remote, the SHA1 (2d756e5e) has not chang
ed since last install.
##   Use `force = TRUE` to force installation

#ggmap(get_googlemap())
key = 'AIzaSyDTOx7zlyikIYMk5GJ0iVNKsnhPNOdM8Z8'
register_google(key = key)

#Creates node list from network inference graph 'x' and
##converts UTMs to LatLong.
```

```
nodes <- x[,c(1, 4:5, 9)]
nodes <- nodes %>% rowid_to_column("id")

nodes_utms <- SpatialPoints(nodes[, c("UTM.X", "UTM.Y")],
                        proj4string=CRS("+proj=utm +zone=30"))
nodes_longlats <- spTransform(nodes_utms, CRS("+proj=longlat"))
nodes_longlats <- as.data.frame(nodes_longlats)
nodes_ll <- cbind(nodes[,1:2, 5], nodes_longlats)

nodes_ll.2 <- subset(nodes_ll, select=c(1, 4:5, 2, 3))
names(nodes_ll.2) <- c("id", "lon", "lat", "Site.Name", “River.Valley”)

#Thresholds network correlation matrix by quantiles
##and creates edge list.
qmap = as.data.frame(mycorr$r)
qmap[qmap <= 0 | qmap == 1] <- NA
quantqmap <- quantile(qmap, c(.25, .50), na.rm = TRUE)
M2 <- qmap
is.na(M2) <- M2 <= quantqmap[1]
M2[is.na(M2)] <- 0

edge_A <- as.matrix(M2)

#Groups the data so it can be used for network visualization.
colnames(edge_A) <- x$Site.Name
edge_A <- melt(edge_A)
colnames(edge_A) <- c("source", "target", "weight")
edge_A_0 <- edge_A[which(edge_A$weight > 0), ]

sum_edge_A  <- edge_A_0 %>% group_by(source, target, weight)%>%
  dplyr::summarize(Frequency = n())

#Uses tidygraph to make one table of nodes and edges,
##as well as generates network measures that are added to table.
edges <- sum_edge_A %>%
  left_join(nodes_ll.2, by = c("source" = "Site.Name")) %>%
  rename(from = id)

## Warning: Column `source`/`Site.Name` joining factor and character vector,
## coercing into character vector

edges <- edges %>%
  left_join(nodes_ll.2, by = c("target" = "Site.Name")) %>%
  rename(to = id)
```

```
## Warning: Column `target`/`Site.Name` joining factor and character vector,
## coercing into character vector

edges <- dplyr::select(edges, from, to)

## Adding missing grouping variables: `source`, `target`

edges <- cbind(edges, sum_edge_A)
edges <- dplyr::select(edges, from, to, weight)

## Adding missing grouping variables: `source`, `target`

#mag <- graph_from_data_frame(
##edges[, 3:4], directed = FALSE, vertices = nodes_ll.2)

edges_for_plot <- edges %>%
  inner_join(nodes_ll.2 %>% dplyr::select(id, lon, lat),
           by = c('from' = 'id')) %>%
  rename(x = lon, y = lat) %>%
  inner_join(nodes_ll.2 %>% dplyr::select(id, lon, lat),
           by = c('to' = 'id')) %>%
  rename(xend = lon, yend = lat)

e_n <- which(edges_for_plot$x ==
             edges_for_plot$xend) #Don't use for LB_FB_South.
edges_for_plot <- edges_for_plot[-c(e_n),]

dupp <- edges_for_plot %>%
  group_by(grp = paste(pmax(from, to),
                  pmin(from, to), sep = "_")) %>%
  slice(1) %>%
  ungroup() %>%
  dplyr::select(-grp)
q <- quantile(dupp$weight, 0.5)

#nodes_ll.2$weight = degree(mag)

#generates map of Valencia, Spain using
##a "center" of geospatial coordinates.
center_ggmap_JVS = c(lon = -0.75, lat = 38.45)
center_ggmap_TPV = c(lon = -.5, lat = 39.8)

mg <- get_googlemap(center = center_ggmap_TPV, zoom = 9,
                maptype = "satellite", size = c(600, 600),
                scale = 2)
```

```
## Source : https://maps.googleapis.com/maps/api/staticmap?center=39.8,-0.5&zoom=9
&size=600x600&scale=2&maptype=satellite&key=xxx

mmg <- ggmap(mg)
mmg

maptheme <- theme(panel.grid = element_blank()) + #map aesthetics
  theme(axis.text = element_blank()) +
  theme(axis.ticks = element_blank()) +
  theme(axis.title = element_blank()) +
  #theme(legend.position = "bottom") +
  theme(panel.grid = element_blank()) +
  theme(panel.background = element_rect(fill = "#596673")) +
  theme(plot.margin = unit(c(0, 0, 0.5, 0), 'cm')) +
  theme(panel.border = element_rect(fill=NA, color="firebrick4"),
        plot.title = element_text(hjust = 0.5))

##Function to create a scalebar
scalebar = function(x,y,w,n,d, units="km"){
  # x,y = lower left coordinate of bar
  # w = width of bar
  # n = number of divisions on bar
  # d = distance along each division

  bar = data.frame(
    xmin = seq(0.0, n*d, by=d) + x,
    xmax = seq(0.0, n*d, by=d) + x + d,
    ymin = y,
    ymax = y+w,
    z = rep(c(1,0),n)[1:(n+1)],
    fill.col = rep(c("black","white"),n)[1:(n+1)])

  labs = data.frame(
    xlab = c(seq(0.0, (n+1)*d, by=d) + x, x),
    ylab = c(rep(y-w*1.5, n+2), y-3*w),
    text = c(as.character(seq(0.0, (n+1)*d, by=d)), units)
  )
  list(bar, labs)
}

mapcoords <- coord_fixed(xlim = c(-0.88, -0.25),
                         ylim = c(39.36, 40.05)) # for TPV
#mapcoords <- coord_fixed(xlim = c(-1.0, -0.35),
##ylim = c(37.95, 38.97)) # for JVS
sb = scalebar(-0.58, 39.408, 0.01, 2, .1, "degrees") # for TPV
#sb = scalebar(-0.68, 38.0, 0.01, 2, .1, "degrees") # for JVS
```

```
coul = brewer.pal(9, "Set1")[c(2,1)]
my_color=coul[as.numeric(as.factor(V(g.pcorr)$River.Valley))]
mmg + # scale for edge widths
  geom_point(aes(x = lon, y = lat), data=nodes_ll.2,  # draw nodes
           shape = 21, size = 2, fill = 'firebrick4',
           color = 'black', stroke = 0.5)+
  geom_curve(aes(x = x, y = y, xend = xend, yend = yend, # draw edges as arcs
               size = weight^3), color = "yellow",
           data = dupp, curvature = 0.13, #%>% filter(weight < q) #curvature = 0.33,
           alpha = 0.5) +
  geom_point(aes(x = lon, y = lat), data=nodes_ll.2,  # draw nodes
           shape = 21, size = 2, fill = my_color, #'darkorange1'  #'magenta4'
           color = 'black', stroke = 0.5)+
  scale_size_continuous(guide = FALSE, range = c(0.25, 2)) +  # scale for node size
  geom_text_repel(aes(x = lon, y = lat, label = Site.Name),
               data=nodes_ll.2, nudge_y = .015, color = "white", fontface = 'bold',
               size = 3) +
  coord_cartesian()+
  mapcoords +
  geom_rect(data=sb[[1]], aes(xmin=xmin, xmax=xmax, ymin=ymin, ymax=ymax, fill=z
),
          inherit.aes=F,
          show.legend = F,  color = "black", fill = sb[[1]]$fill.col) +
  geom_text(data=sb[[2]], aes(x=xlab, y=ylab, label=text),
          inherit.aes=F, show.legend = F) +
  geom_segment(arrow=arrow(length=unit(3,"mm")),
            aes(x=-0.35,xend=-0.35,y=39.44 ,yend=39.47), colour="black") +
  annotate(x=-0.35, y=39.48, label="N", colour="black", geom="text", size=6) +
  ggtitle("Early & Middle Bronze Ages - \nNorthern Region") +
  theme(panel.border = element_rect(fill=NA, color="firebrick4"),
      plot.title = element_text(hjust = 0.5))
```

APPENDIX G

MULTIPLEX ANALYSIS

R Code: Multiplex Analysis

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2020

```
library(devtools)
install_github("Achab94/mplex", quiet = TRUE)
install.packages("easypackages", repos = "http://cran.us.r-project.org")

## Installing package into '/home/whcegielski/R/x86_64-pc-linux-gnu-library/3.6'
## (as 'lib' is unspecified)

library(easypackages)
packages("Hmisc", "knitr", "kableExtra","tidyr", "tidygraph",
        "readr", "igraph")

## All packages loaded successfully

libraries("Hmisc", "knitr", "kableExtra","tidyr", "tidygraph",
         "readr", "igraph", "mplex")

## All packages loaded successfully

##Load datasets and clean data.
WM3_all_rev <-
  read.csv(
    "~/Dropbox/Dissertation/Databases/All Sites Master/WM3_all_rev_6_rev.csv",
                    na = "NA", check.names=FALSE, strip.white=TRUE)
WM3_all_rev <- WM3_all_rev[,-1]

######Merge columns and remove bad columns, as desired.
WM3_all_rev$Cer_x_Paint <- (WM3_all_rev$Cer_x_Pa + WM3_all_rev$Cer_x_Pa.inc
+
                         WM3_all_rev$Cer_x_Pa.inc.lri)
WM3_all_rev$Ochre <- (WM3_all_rev$Och + WM3_all_rev$St_Och)

WM3_all_rev <- WM3_all_rev[ , -which(names(WM3_all_rev) %in% c("Cer_x_Pa", "
Cer_x_Pa.inc",
                                                    "Cer_x_Pa.inc.lri",
                                                    "Cer_x_ArHan",
                                                    "Cer_x_MNo", "Cer_x_Mno",
                                                    "Qu", "Qu_Ham", "Och",
                                                    "St_Och"))]

U2 <- readr::read_csv(
  "~/Dropbox/Dissertation/Databases/All Sites Master/U2_rev_chrono.csv",
            na = "NA")
```

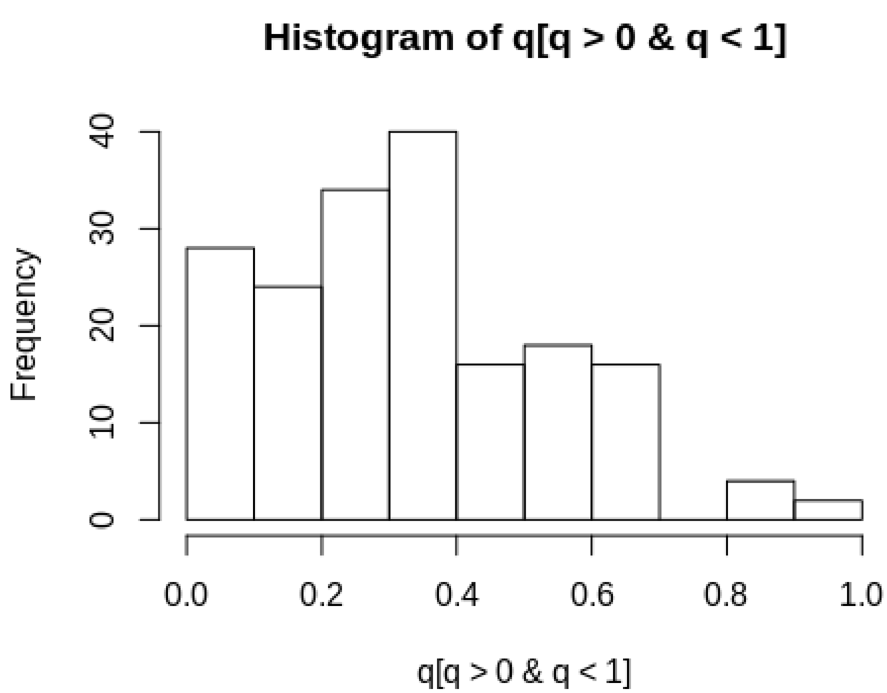
```
## Warning: Missing column names filled in: 'X1' [1]

## Parsed with column specification:
## cols(
##   X1 = col_double(),
##   Site.Name.abb = col_character(),
##   Site.Name = col_character(),
##   North.South.Central = col_character(),
##   UTM.X = col_double(),
##   UTM.Y = col_double(),
##   Chronological.Attribution = col_character(),
##   Chrono.Bayes = col_character(),
##   Site.Size.m2 = col_double(),
##   River.Valley = col_character(),
##   Elevation = col_double(),
##   Visibility = col_double()
## )

U2 <- U2[,-1]

corr_attr <- merge(U2,WM3_all_rev, by  = "Site.Name")
corr_attr <- tidyr::replace_na(corr_attr, list(Visibility=1))

##Subset main dataset by material type.
p1 <- c("Cer")
p2 <- c("Br_", "Cu", "CuBr")
p3 <- c("Os", "Ant", "Iv")
Ceramics <- corr_attr[ , grepl( p1 , names( corr_attr ) ) ]
Ceramics <- cbind(corr_attr[,1:11], Ceramics)

Combo <- corr_attr[ , grepl(paste(p3, collapse = "|"), names (corr_attr))]
Combo2 <- corr_attr[ , grepl(paste(p2, collapse = "|"), names (corr_attr))]
Bones <- cbind(corr_attr[,1:11], Combo)
CuBr <- cbind(corr_attr[,1:11], Combo)

#Designate chronologies and regions to subset, example for LB_FB.
LB_FB_cer <- which((corr_attr$`Chrono.Bayes`=="LB" | corr_attr$`Chrono.Bayes`=="
FB" |
                    corr_attr$`Chrono.Bayes`=="EB_MB_LB_FB" |
                    corr_attr$`Chrono.Bayes`=="LB_FB" |
                    corr_attr$`Chrono.Bayes`=="MB_LB_FB") &
                   (Ceramics$River.Valley=="Jucar" |
                     Ceramics$River.Valley=="Vinalopo-Alicante" |
                     Ceramics$River.Valley=="Segura"))
LB_FB_cer <- Ceramics[LB_FB_cer , -c(2:11)]
```

```r
f = LB_FB_cer #insert desired subset

#Revise and transpose dataset.
y <- f[,-1]
rownames(y) <- f[,1]
#y <- y[,-c(1:8)]
#Transpose.
WM3.t <- t(y)
#Drops sites as desired.
 #(None needed for LB_FB.)

#Drops artifact categories with few instances
#rowSums(WM3.t)
WM3.t.drop <- WM3.t[rowSums(WM3.t) >= 2 ,]

#Pearson's Correlation Association Network Inference
###(adapted from Kolaczyk & Csardi (2014),
     #"Statistical Analysis of Network Data with R." New York: Springer.)
#Spearman's rho correlation.
mycorr <- rcorr(WM3.t.drop, type=c("spearman"))
q = as.data.frame(mycorr$r)

##formatting for RStudio R markdown.
kable(q, digits = 2, caption = "correlations") %>%
  kable_styling(font_size = 6, latex_options ="scale_down") %>%
  landscape() %>% kable_styling(full_width =F) %>%
  column_spec(1:3,width ="4.5em") %>% column_spec(4:20, width = "3em")
```

Table 1: correlations

[illegible]

```r
#Threshold network by quantiles and binarize.
q[q <= 0 | q == 1] <- NA
hist( q[q > 0 & q < 1] )
```



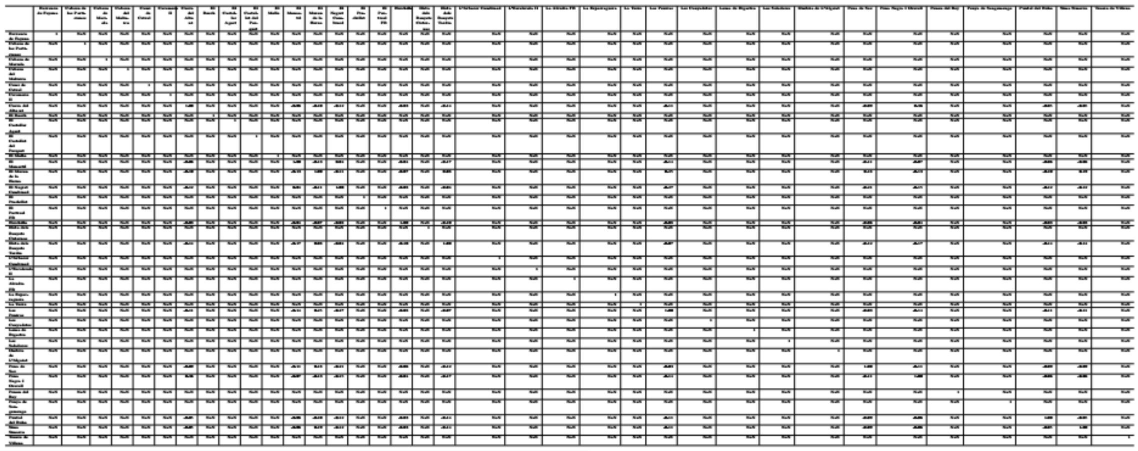

```r
quantq <- quantile(q, c(.25, .50), na.rm = TRUE)
q.vec<-q[lower.tri(q)]
```

```
n<-dim(WM3.t.drop)[2]
length(q.vec)

## [1] 630

qu = (q.vec > quantq[1]) #& s.vec > 0.01)
#qu = (q.vec == q.vec)
length(qu)

## [1] 630

length(q.vec[qu])

## [1] 607

q_redges <- (q.vec[qu])

#Create and plot network from correlation values.
pcorr.A <- matrix(0, n, n)
pcorr.A[lower.tri(pcorr.A)] <- as.numeric(qu)
g.pcorr.c <- igraph::graph.adjacency(pcorr.A, "undirected")
plot(g.pcorr.c, cex = 0.02)
```

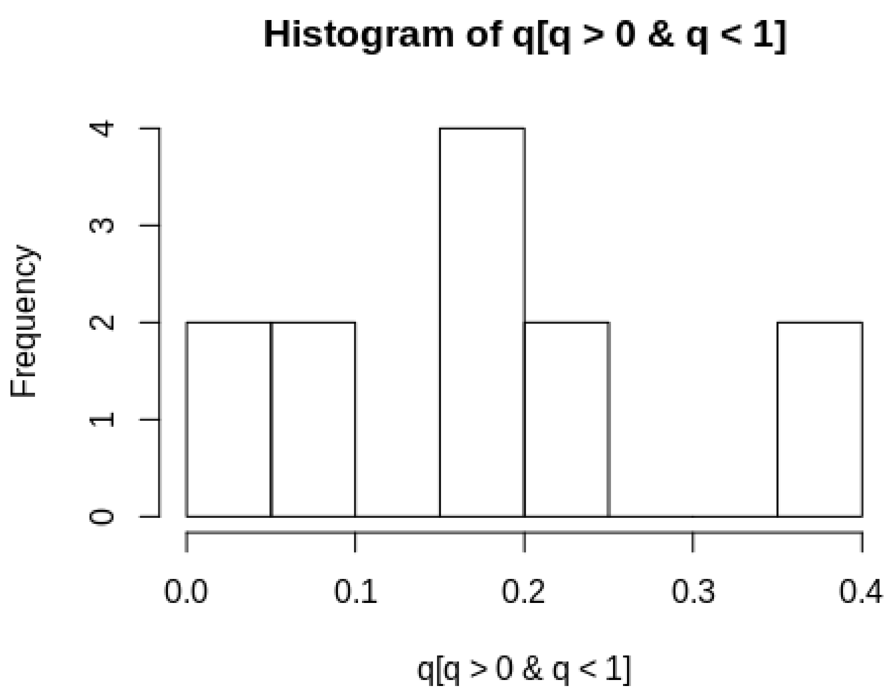

```
LB_FB_bo <- which((corr_attr$`Chrono.Bayes`=="LB" | corr_attr$`Chrono.Bayes`=="F
B" |
                  corr_attr$`Chrono.Bayes`=="EB_MB_LB_FB" |
```

```
            corr_attr$`Chrono.Bayes`=="LB_FB" |
            corr_attr$`Chrono.Bayes`=="MB_LB_FB")
          & (Bones$River.Valley=="Jucar" |
             Bones$River.Valley=="Vinalopo-Alicante" |
             Bones$River.Valley=="Segura"))
LB_FB_bo <- Bones[LB_FB_bo , -c(2:11)]

f = LB_FB_bo #insert desired subset

#Revise and transpose dataset.
y <- f[,-1]
rownames(y) <- f[,1]
#y <- y[,-c(1:8)]
#Transpose.
WM3.t <- t(y)
#Drops sites as desired.
#(None needed for LB_FB.)

#Drops artifact categories with few instances
#rowSums(WM3.t)
WM3.t.drop <- WM3.t[rowSums(WM3.t) >= 1 ,]

#Spearman's rho correlation.
mycorr <- rcorr(WM3.t.drop, type=c("spearman"))
q = as.data.frame(mycorr$r)

##formatting for RStudio R markdown.
kable(q, digits = 2, caption = "correlations") %>%
 kable_styling(font_size = 6, latex_options ="scale_down") %>%
 landscape() %>% kable_styling(full_width =F) %>%
 column_spec(1:3,width ="4.5em") %>% column_spec(4:20, width = "3em")
```

Table 2: correlations

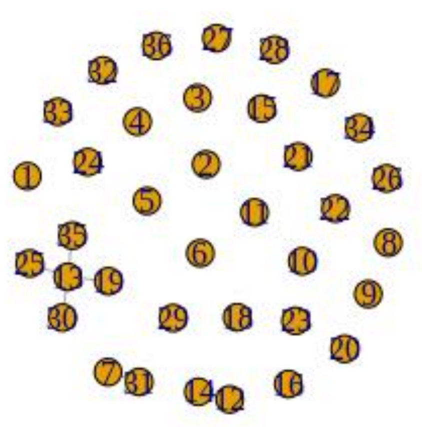


```r
#Threshold network by quantiles and binarize.
q[q <= 0 | q == 1] <- NA
hist( q[q > 0 & q < 1] )
```




```r
quantq <- quantile(q, c(.25, .50), na.rm = TRUE)
q.vec<-q[lower.tri(q)]
n<-dim(WM3.t.drop)[2]
length(q.vec)

## [1] 630
```

```
#qu = (q.vec > quantq[1]) #& s.vec > 0.01)
qu = (q.vec == q.vec)
length(qu)

## [1] 630

length(q.vec[qu])

## [1] 630

q_redges <- (q.vec[qu])

#Create and plot network from correlation values.
pcorr.A <- matrix(0, n, n)
pcorr.A[lower.tri(pcorr.A)] <- as.numeric(qu)
g.pcorr.b <- igraph::graph.adjacency(pcorr.A, "undirected")
plot(g.pcorr.b, cex = 0.02)
```



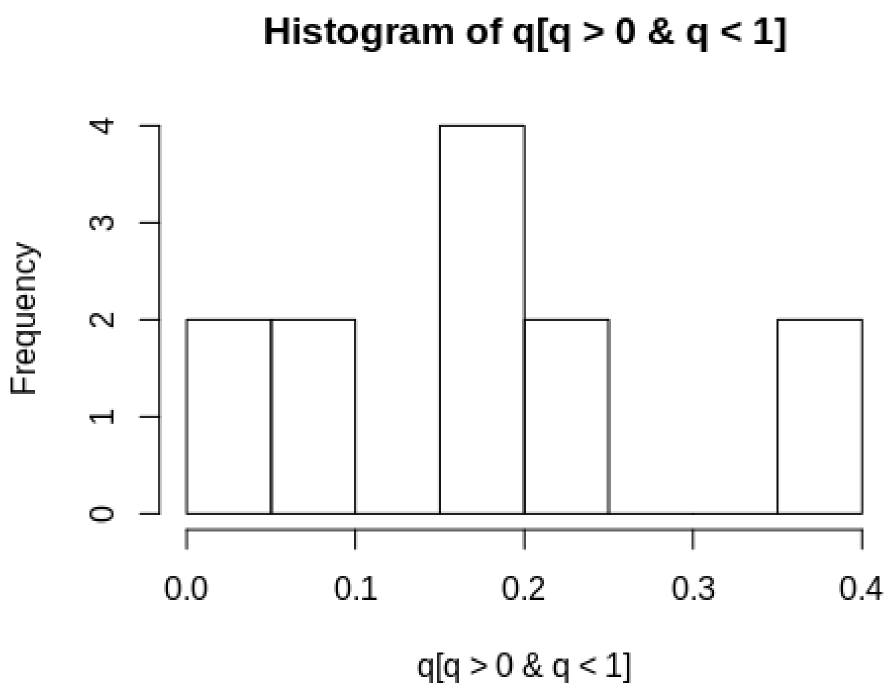
```
LB_FB_CuBr <- which((corr_attr$`Chrono.Bayes`=="LB" | corr_attr$`Chrono.Bayes`==
"FB" |
                 corr_attr$`Chrono.Bayes`=="EB_MB_LB_FB" |
                 corr_attr$`Chrono.Bayes`=="LB_FB" |
                 corr_attr$`Chrono.Bayes`=="MB_LB_FB")
               & (CuBr$River.Valley=="Jucar" |
                  CuBr$River.Valley=="Vinalopo-Alicante" |
```

```
                         CuBr$River.Valley=="Segura"))
LB_FB_CuBr <- CuBr[LB_FB_CuBr , -c(2:11)]

f = LB_FB_CuBr #insert desired subset

#Revise and transpose dataset.
y <- f[,-1]
rownames(y) <- f[,1]
#y <- y[,-c(1:8)]
#Transpose.
WM3.t <- t(y)
#Drops sites as desired.
#(None needed for LB_FB.)

#Drops artifact categories with few instances
#rowSums(WM3.t)
WM3.t.drop <- WM3.t[rowSums(WM3.t) >= 1 ,]

#Spearman's rho correlation.
mycorr <- rcorr(WM3.t.drop, type=c("spearman"))
q = as.data.frame(mycorr$r)

##formatting for RStudio R markdown.
kable(q, digits = 2, caption = "correlations") %>%
  kable_styling(font_size = 6, latex_options ="scale_down") %>%
  landscape() %>% kable_styling(full_width =F) %>%
  column_spec(1:3,width ="4.5em") %>% column_spec(4:20, width = "3em")
```

Table 3: correlations

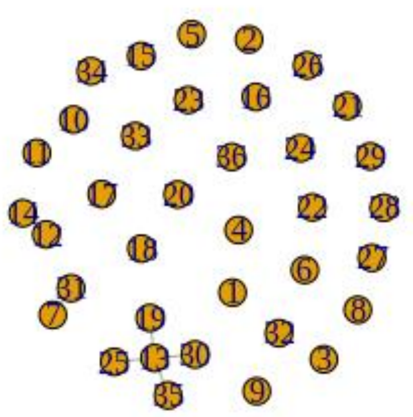
[illegible]

```r
#Threshold network by quantiles and binarize.
q[q <= 0 | q == 1] <- NA
hist( q[q > 0 & q < 1] )
```




```r
quantq <- quantile(q, c(.25, .50), na.rm = TRUE)
q.vec<-q[lower.tri(q)]
n<-dim(WM3.t.drop)[2]
length(q.vec)
```

```
## [1] 630

#qu = (q.vec > quantq[1]) #& s.vec > 0.01)
qu = (q.vec == q.vec)
length(qu)

## [1] 630

length(q.vec[qu])

## [1] 630

q_redges <- (q.vec[qu])

#Create and plot network from correlation values.
pcorr.A <- matrix(0, n, n)
pcorr.A[lower.tri(pcorr.A)] <- as.numeric(qu)
g.pcorr.cb <- igraph::graph.adjacency(pcorr.A, "undirected")
plot(g.pcorr.cb, cex = 0.02)
```




```
#Using mplex package.
#save the main data as vectors.
LB_FB <- which((corr_attr$`Chrono.Bayes`=="LB" | corr_attr$`Chrono.Bayes`=="FB" |
              corr_attr$`Chrono.Bayes`=="EB_MB_LB_FB" |
              corr_attr$`Chrono.Bayes`=="LB_FB" |
```

```
               corr_attr$`Chrono.Bayes`=="MB_LB_FB") &
              (corr_attr$River.Valley=="Jucar" |
                 corr_attr$River.Valley=="Vinalopo-Alicante" |
                 corr_attr$River.Valley=="Segura"))
#corr_attr$`Chrono.Bayes`=="LB" | corr_attr$`Chrono.Bayes`=="FB" |
#corr_attr$`Chrono.Bayes`=="LB_FB" | corr_attr$`Chrono.Bayes`=="MB_LB_FB") &
##"Jucar" | Ceramics$River.Valley=="Vinalopo-Alicante" | Ceramics$River.Valley=="S
egura"
##corr_attr$River.Valley=="Turia" | corr_attr$River.Valley=="Palancia-Valls"
LB_FB <- corr_attr[LB_FB ,]
LB_FB <- LB_FB[, -c(2:11)]

y <- f[,-1]
rownames(y) <- f[,1]
#y <- y[,-c(1:8)]
#Transpose and remove sites with no data
WM3.t.m <- t(y)

nodes <-as.data.frame(colnames(WM3.t.m))
nodes <- cbind(rownames(nodes), data.frame(nodes, row.names=NULL))
colnames(nodes)<- c("nodeID","nodeLabel")

##Create multiplex layers from already-created networks for each material type.
L1 <- as.data.frame(igraph::get.edgelist(g.pcorr.c)) #Ceramics
L1$Weight <- rep(1,nrow(L1))
colnames(L1)<- c("ID_Start","ID_Arrive", "Weight")

L2 <- as.data.frame(igraph::get.edgelist(g.pcorr.b)) #Bones
L2$Weight <- rep(1,nrow(L2))
colnames(L2)<- c("ID_Start","ID_Arrive", "Weight")

L3 <- as.data.frame(igraph::get.edgelist(g.pcorr.cb)) #Copper & Bronze
L3$Weight <- rep(1,nrow(L3))
colnames(L3)<- c("ID_Start","ID_Arrive", "Weight")

layersNames <- as.character(c("Ceramics", "Bones", "Copper & Bronze"))
#"Ceramics", "Gold & Silver", "Shell, "Stone"))

#Create multiplex network.
#Citation: Package 'mplex', Version: 1.0, Date: 2017-01-07, Author: Emanuele Degani
plex <- mplex::create.multiplex(nodes = nodes,
                        layersNames = layersNames,
                        layer1 = L1,
                        type1 = "undirected",
                        L2,
```

```
                    L3)

##Calculate Aggregated Overlappping Index.
ag_ov <- mplex::aggregatedOverlapping.multiplex(plex)
row.names(ag_ov) <- colnames(ag_ov)
overlap <- sum(ag_ov >= 2)
sum(ag_ov)

## [1] 160

#Calculate centrality and clustering measures from multiplex network.
dCM <- degreeCentrality.multiplex(plex)
over_clus <- globalOverlayClustering.multiplex(plex)

##Generate multiplex graph.
g.ag_ov <- igraph::graph.adjacency(ag_ov, "undirected")
plot(g.ag_ov, cex = 0.02, vertex.label.cex = 0.6)
```

APPENDIX H

SPECIFICATIONS AND VALUES FOR ERGM MODELS

Maximum number of iterations = 20

MCMC.samplesize = default or 10,000

MCMC.burnin=1000 (Burn-in allows the model to stabilize before actual estimation)

MCMC.interval = 1000 (Sampling interval, every 1000th graph is sampled to lower autocorrelation.)

Parallel cores = 16 (The number of computer cores engaged in processing.)

Seed = 42 (A standard value to start every simulation.)

APPENDIX I

BAYES ESTIMATES AND CHRONOLOGICAL ATTRIBUTIONS

Site Name	Empirical Bayes Estimation by Chronological Period				Bayes Estimation	Estimated Chronological Attribution	Notes
	EB	MB	LB	FB			
Abrigo II de las Penas	0.09709	0.52303	0.29003	0.08985	MB_LB	EB_MB Classic	Refined by Bayes
Albardeta	0.00000	1.00000	0.00000	0.00000	MB	No info	Established by Bayes
Altet d'Palau Combined	0.39927	0.21425	0.35978	0.02669	MB_LB	LB	Refined by Bayes (Early attribution is a misnomer)
Alto de la Pena Cortada	0.00000	0.00000	1.00000	0.00000	LB	EB_MB Classic	Established by Bayes
Arenal de la Costa	0.05019	0.57434	0.36760	0.00787	MB	EB	Misattribution by Bayes, retained estimate
Barranco de Fayona	NA	NA	NA	NA	NA	FB	Retained estimate
Barranco de la Pena Roya	0.00000	0.00000	0.23171	0.76829	LB_FB	MB	Refined by Bayes
Barranco del Cuervo	0.08456	0.31467	0.52668	0.07409	MB_LB	MB	Refined by Bayes
Barranco Maso	0.02792	0.15650	0.18667	0.62891	LB_FB	MB_LB	Refined by Bayes
Barranco Tuerto	0.32520	0.04818	0.38954	0.23708	EB	EB	Match
Cabezo de la Escoba Combined	0.06478	0.45827	0.20266	0.27429	MB_LB	EB_MB Classic	Refined by Bayes
Cabezo de la Hiedra	0.04613	0.69712	0.06468	0.19208	MB	EB_MB Classic	Refined by Bayes
Cabezo de las Particiones	0.01826	0.01054	0.23941	0.73179	LB_FB	LB_FB	Match
Cabezo de Mariola	0.52417	0.15844	0.31739	0.00000	LB	LB_FB	Refined by Bayes (Early attribution is a misnomer)
Cabezo de Navarro	0.10887	0.81061	0.06091	0.01960	EB_MB Classic	EB_MB Classic	Match
Cabezo de Penalva	0.05352	0.69087	0.15224	0.10337	MB	LB	Possible but unlikely, retained estimate
Cabezo de Serrelles	0.08698	0.22042	0.65881	0.03380	MB_LB	EB_MB Classic	Refined by Bayes
Cabezo de Valera	0.11029	0.88971	0.00000	0.00000	EB_MB Classic	EB_MB Classic	Match
Cabezo del Cantalar	0.03900	0.15974	0.18224	0.61902	EB_MB Classic	EB_MB Classic	Match
Cabezo del Molinico	0.00000	0.00000	0.06070	0.93930	FB	LB	Refined by Bayes
Cabezo Pardo Fase I	0.13344	0.57594	0.19110	0.09951	EB_MB Classic	EB_MB Classic	Match
Cabezo Pardo Fase IC III	0.05708	0.30829	0.16369	0.47094	EB_MB_LB	EB_MB_LB	Match
Cabezo Pardo Fase II	0.00299	0.31385	0.52384	0.15932	MB_LB	MB	Refined by Bayes
Cabezo Pardo Fase II-III	0.00000	0.49959	0.50041	0.00000	MB_LB	MB_LB	Match
Cabezo Pardo Fase III	0.00000	0.86589	0.12471	0.00940	MB_LB	LB	Refined by Bayes
Cabezo Redondo Combined	0.05723	0.16966	0.72064	0.05247	MB_LB	LB	Refined by Bayes
Cabrera Baja	0.01355	0.23502	0.40218	0.34925	MB_LB	MB	Refined by Bayes
Cami de Catral	0.01066	0.03043	0.22172	0.73718	FB	FB	Match
Caramoro I	0.06342	0.51432	0.29020	0.13206	MB	EB_MB Classic	Refined by Bayes
Caramoro II	0.00144	0.00579	0.18372	0.80905	FB	FB	Match
Casa del Camp	0.01402	0.21502	0.51428	0.25668	LB	LB	Match

Site Name	Empirical Bayes Estimation by Chronological Period				Bayes Estimation	Estimated Chronological Attribution	Notes
	EB	MB	LB	FB			
Casa Paus	0.11733	0.02903	0.85364	0.00000	EB	EB	Match
Castillarejo de los Moros	0.06360	0.15431	0.40991	0.37218	MB_LB	MB	Refined by Bayes
Castillarejo de Penarroya	0.00000	1.00000	0.00000	0.00000	MB	No info	Established by Bayes
Cati Forada	0.03809	0.13580	0.20012	0.62599	MB_LB	MB	Refined by Bayes
Cerro de El Cuchillo Combined	0.01481	0.93471	0.04570	0.00478	MB_LB	MB_LB	Match
Cerro de El Cuchillo Dept. 1 Nivel III	0.04887	0.90840	0.04274	0.00000	MB	MB	Match
Cerro de El Cuchillo Dept. IV Fase III	0.04791	0.87432	0.04774	0.03004	MB	MB	Match
Cerro de El Cuchillo Dept. V Nivel II	0.04839	0.89209	0.04514	0.01439	MB	MB	Match
Cerro de El Cuchillo Dept. VI Nivel I	0.04885	0.90821	0.04280	0.00014	MB	LB	Refined by Bayes
Cerro de El Cuchillo Fase I	0.04804	0.86075	0.04796	0.04325	MB	MB	Match
Cerro de El Cuchillo Fase II	0.04874	0.90420	0.04341	0.00365	MB	MB	Match
Cerro de El Cuchillo Fase III	0.00000	0.32610	0.46625	0.20764	MB_LB	MB	Refined by Bayes
Cerro de la Canada Larga	0.00000	0.00000	0.23171	0.76829	LB_FB	No info	Established by Bayes
Cerro de las Alabarizas	0.00000	0.00000	1.00000	0.00000	LB	MB	Refined by Bayes
Cerro de los Bolos	NA	NA	NA	NA	NA	FB	Retained estimate
Collado del Canar	0.03538	0.15434	0.14831	0.66197	MB_LB	MB_LB	Match
Corral de Morca	0.03151	0.34658	0.18147	0.44044	MB_LB	MB_LB	Match
Cova de la Pedrera	0.00000	0.00000	0.73872	0.26128	LB_FB	EB	Retained estimate (Early attribution is a misnomer)
Cova de Rocafort	NA	NA	NA	NA	NA	EB	Retained estimate
Cova del Cantal	0.00000	0.00000	1.00000	0.00000	LB	EB	Retained estimate (Early attribution is a misnomer)
Cova del Cavall	0.00279	0.04107	0.01072	0.94543	FB	FB	Match
Cova dels Anells	0.70937	0.03899	0.25165	0.00000	EB	LC_EB	Match
Cova dels Solsits	0.64444	0.00000	0.26428	0.09128	EB	EB	Match
Coveta del Frare	0.00000	0.59961	0.40039	0.00000	MB	NA	Established by Bayes
Cueva Cerdana	0.03234	0.23510	0.14278	0.58977	MB_LB_FB	MB_LB_FB	Match
Cueva de Alcabaira	0.04857	0.03724	0.23975	0.67444	LB_FB	MB_LB	Refined by Bayes
Cueva de la Casa Colora	0.10906	0.04268	0.84752	0.00075	LB	EB_MB Classic	Refined by Bayes
Cueva de la Peseta	0.03255	0.30062	0.12896	0.53787	MB	EB_MB Classic	Refined by Bayes
Cueva de las Balsillas	0.01892	0.16698	0.20184	0.61226	LB_FB	LB	Refined by Bayes
Cueva de las Delicias	0.96969	0.00344	0.02660	0.00027	EB	LC_EB	Match

Site Name	Empirical Bayes Estimation by Chronological Period				Bayes Estimation	Estimated Chronological Attribution	Notes
	EB	MB	LB	FB			
Cueva de los Moros	0.05190	0.03138	0.23745	0.67927	LB_FB	MB	Refined by Bayes
Cueva de San Antonio de Padua	0.00000	0.41499	0.58501	0.00000	EB	EB	Match
Cueva del Alto n1	0.08978	0.27137	0.61183	0.02702	LB	LB	Match
Cueva del Cerro Las Simas	0.04515	0.77636	0.06210	0.11639	MB	MB	Match
Cueva del Molinico	NA	NA	NA	NA	NA	EB_MB Classic	Retained estimate
Cueva del Murcielago	0.00000	0.00000	1.00000	0.00000	LB	MB_LB	Refined by Bayes
Cueva del Murcielago Nivel	0.02071	0.11881	0.13081	0.72967	FB	FB	Match
Cueva del Pueblo	0.00658	0.00159	0.02881	0.96302	EB_MB Classic and FB	EB and FB	Refined by Bayes
Cueva del Tio Paco	0.03906	0.59100	0.09231	0.27762	MB and FB	MB and FB	Match
Cueva del Tio Ramon	0.00000	0.00000	0.23171	0.76829	FB	MB	Refined by Bayes
Cueva Grande de la Rocha	0.03564	0.29447	0.04795	0.62194	MB	MB	Match
Cueva Moma	0.02553	0.16052	0.20338	0.61057	MB_LB	MB	Refined by Bayes
Cueva Oriental de Salvatierra	0.99951	0.00000	0.00049	0.00000	EB	EB_MB Classic	Refined by Bayes
Cueva Oriental del Penon de la Zorra	NA	NA	NA	NA	NA	LC_EB	Retained estimate
El Azud	NA	NA	NA	NA	NA	LB_FB	Retained estimate
El Bancalico II	0.00000	0.39473	0.60527	0.00000	EB_MB Classic	EB	Refined by Bayes
El Bosch	0.01803	0.01090	0.19299	0.77808	FB	FB	Match
El Cabezo	0.05190	0.03138	0.23745	0.67927	LB_FB	MB	Refined by Bayes
El Cagallo del Gegant	1.00000	0.00000	0.00000	0.00000	EB	EB_MB Classic	Refined by Bayes
El Castellar Agost	0.02647	0.01600	0.23544	0.72209	LB_FB	LB	Refined by Bayes
El Castellet del Porquet	0.09027	0.27189	0.61109	0.02675	LB	EB_MB Classic	Refined by Bayes
El Castillarejo	0.04209	0.12575	0.29686	0.53530	MB_LB_FB	MB	Refined by Bayes
El Castillarejo del Coronel	0.02807	0.16968	0.15107	0.65119	MB	MB	Match
El Fossino	0.05484	0.74236	0.15643	0.04637	MB_LB	LB	Refined by Bayes
El Gargao	0.00000	0.00000	0.47500	0.52500	LB_FB	EB_MB Classic	Refined by Bayes
El Martinete	0.03380	0.13641	0.17185	0.65794	MB_LB	MB	Refined by Bayes
El Mollo	0.00000	0.18110	0.40309	0.41582	LB	EB_MB Classic	Refined by Bayes
El Monastil	0.07957	0.04576	0.26604	0.60863	LB_FB	LB	Refined by Bayes
El Montagut	0.08338	0.23564	0.55528	0.12570	EB_MB Classic	EB	Refined by Bayes
El Muron de la Horna	0.05075	0.24158	0.19337	0.51431	MB_LB_FB	LB	Refined by Bayes
El Negret Combined	0.08566	0.26190	0.58271	0.06973	LB	LB	Match
El Picacho	0.08441	0.32618	0.54158	0.04782	MB_LB	MB_LB	Match
El Picayo	0.73593	0.00000	0.26407	0.00000	EB	NA	Established by Bayes
El Pinchillet	0.07326	0.05413	0.17526	0.69735	LB_FB	LB	Refined by Bayes
El Portixol	0.03026	0.24368	0.20694	0.51911	MB_LB_FB	MB_LB and FB	Match
El Promontori	0.04631	0.02799	0.23700	0.68870	EB	LC_EB	Match
El Puntal	0.02807	0.16968	0.15107	0.65119	MB_LB	MB	Refined by Bayes

Site Name	Empirical Bayes Estimation by Chronological Period				Bayes Estimation	Estimated Chronological Attribution	Notes
	EB	MB	LB	FB			
El Puntal de Bartolo	0.09992	0.15965	0.72533	0.01510	EB	LC_EB	Match
El Salido	0.04625	0.69894	0.06223	0.19258	MB	EB_MB Classic	Refined by Bayes
El Sambo	0.08883	0.25275	0.60632	0.05210	MB_LB	EB_MB Classic	Refined by Bayes
El Sargal	0.00000	0.00000	0.23171	0.76829	LB_FB	MB	Refined by Bayes
Els Germanells	0.99956	0.00005	0.00012	0.00027	EB	EB_MB Classic	Refined by Bayes
Els Trencalls	NA	NA	NA	NA	NA	EB_MB Classic	Retained estimate
Ermita de la Lloma de Montiel	0.17111	0.00000	0.82889	0.00000	LB	LB	Match
Figuera Redona	0.34113	0.09749	0.45068	0.11069	EB	LC	Match
Foia de La Perera	0.48685	0.13280	0.25998	0.12036	EB_MB Classic	EB_MB Classic	Match
Fonteta del Sarso	0.43675	0.11563	0.38693	0.06069	EB	FB	Misattribution by Bayes, retained estimate
Frontera A	0.13887	0.04917	0.27338	0.53859	EB and LB	EB_MB Classic	Misattribution by Bayes, retained EB estimate
Frontera B	0.04625	0.69894	0.06223	0.19258	MB	EB_MB Classic	Refined by Bayes
Fuente de la Noguera	0.06178	0.44349	0.08313	0.41161	MB	MB	Match
Huerpita I y II	0.02637	0.41027	0.22073	0.34263	MB_LB	MB	Refined by Bayes
Hurchillo	0.00000	0.00000	0.17071	0.82929	MB_LB_FB	MB	Refined by Bayes
Illeta dels Banyets Cisternas	0.00298	0.00180	0.17247	0.82275	LB_FB	MB_LB	Refined by Bayes
Illeta dels Banyets Tardio	0.10788	0.04524	0.84444	0.00245	LB	LB	Match
Illeta dels Banyets Terraplan perfil SW1	0.06467	0.89269	0.04264	0.00000	MB	MB_LB	Refined by Bayes
Illeta dels Banyets Tumba	0.00000	1.00000	0.00000	0.00000	MB	MB	Match
L'Altet de la	0.03128	0.16972	0.15590	0.64309	MB_LB	EB_MB Classic	Refined by Bayes
L'Arbocer Combined	0.00000	0.00000	0.67633	0.32367	LB	LB	Match
L'Escalerola II	0.05190	0.03138	0.23745	0.67927	LB	EB_MB Classic	Refined by Bayes
La Alcudia	0.29545	0.06495	0.39033	0.24926	LB_FB	LC_EB_MB and FB	Refined by Bayes
La Atalayuela	0.97827	0.01279	0.00805	0.00089	EB	EB_MB Classic	Refined by Bayes
La Banyesa A	NA	NA	NA	NA	NA	EB_MB Classic	Retained estimate
La Buelta	0.55329	0.00000	0.44671	0.00000	EB	EB_MB Classic	Refined by Bayes
La Cova de la	NA	NA	NA	NA	NA	EB_MB Classic	Retained estimate
La Cova Sangomengo	0.99963	0.00000	0.00027	0.00010	EB	EB_MB Classic	Refined by Bayes
La Cueva del Abrigo I de Las Penas	0.99872	0.00016	0.00105	0.00007	EB	EB_MB Classic	Refined by Bayes
La Esparraguera	0.09064	0.26999	0.61123	0.02814	LB	LB	Match
La Guaranila	0.00000	0.06832	0.72997	0.20170	LB	MB	Refined by Bayes
La Lloma de Betxi Hab. I-II Combined	0.65364	0.07965	0.23828	0.02843	EB	EB_MB Classic	Refined by Bayes
La Lloma de Betxi Hab. III Combined	0.66226	0.08229	0.22544	0.03002	EB	MB	Refined by Bayes
La Lloma de Betxi Sector Oeste	0.02641	0.21136	0.24813	0.51411	MB_LB	MB	Refined by Bayes

Site Name	Empirical Bayes Estimation by Chronological Period EB	MB	LB	FB	Bayes Estimation	Estimated Chronological Attribution	Notes
La Llometa	0.00000	0.72311	0.23944	0.03745	MB_LB	EB_MB_LB	Refined by Bayes
La Moleta	0.26460	0.27422	0.46117	0.00000	EB_MB_LB	EB_MB_LB	Match
La Murta	0.04326	0.05579	0.57668	0.32427	LB_FB	LB	Refined by Bayes
La Torre	0.00000	0.00000	1.00000	0.00000	LB	NA	Established by Bayes
La Torrecilla II	0.03903	0.21466	0.30030	0.44601	MB_LB	MB	Refined by Bayes
La Torreta	0.86482	0.03323	0.07282	0.02913	EB	EB_MB Classic	Refined by Bayes
La Torreta Vallada	0.73593	0.00000	0.26407	0.00000	EB	EB_MB Classic	Refined by Bayes
Laderas del Castillo	0.11766	0.57678	0.14751	0.15806	MB	EB and MB	Refined by Bayes
Las Espenetas	0.08966	0.46828	0.28541	0.15665	EB	LC	Match
Las Penicas	0.92313	0.03042	0.03758	0.00887	EB_MB_LB_FB	MB_LB	Refined by Bayes
Les Cabecoles	0.13885	0.36655	0.47532	0.01927	EB_MB_LB	EB_MB Classic	Refined by Bayes
Les Canyadetes	0.11012	0.02888	0.84779	0.01321	LB	EB_MB Classic	Refined by Bayes
Les Ermitetes	NA	NA	NA	NA	NA	MB	Retained estimate
Les Raboses Combined	0.09459	0.17477	0.68064	0.04999	MB_LB	EB_MB_LB	Refined by Bayes
Lloma Redona	0.07269	0.55599	0.35659	0.01473	MB_LB	MB	Refined by Bayes
Llometa del Tio Figuetes	0.05559	0.14294	0.37683	0.42464	MB_LB_FB	LB	Refined by Bayes
Loma de Bigastro	0.05131	0.03102	0.23542	0.68225	LB_FB	LB_FB	Match
Loma de Pante	0.00000	0.06832	0.72997	0.20170	LB	MB	Refined by Bayes
Los Saladares	0.08078	0.00000	0.13664	0.78258	FB	FB	Match
Mas de Felip	0.48643	0.14703	0.36654	0.00000	EB_MB_LB	EB_MB Classic	Refined by Bayes
Mas del Baile	0.02385	0.14881	0.25314	0.57420	MB_LB_FB	MB_LB_FB	Match
Mollo de les Mentires	0.06587	0.22328	0.39462	0.31623	MB_LB	EB_MB Classic	Refined by Bayes
Morret del Moro	0.04618	0.69793	0.06214	0.19375	MB	EB_MB Classic	Refined by Bayes
Morro del Gorgorrobio	0.15039	0.58116	0.11783	0.15062	EB_MB Classic	EB_MB Classic	Match
Muntanyeta de Cabrera	0.09285	0.09936	0.67546	0.13233	LB	MB_LB	Refined by Bayes
Necropolis de la Algorfa	0.31340	0.38615	0.28536	0.01509	EB_MB Classic	EB	Refined by Bayes
Ombria de L'Algaiat	NA	NA	NA	NA	NA	LB	Retained estimate
Pena de la Duena	0.06826	0.07330	0.32043	0.53801	LB_FB	LB	Refined by Bayes
Pena de Sax	0.06686	0.27969	0.28851	0.36493	MB_LB_FB	LB	Refined by Bayes
Pena Dorada	0.03187	0.24510	0.20226	0.52077	MB_LB_FB	LB	Refined by Bayes
Pena Negra I Overall	0.00883	0.02201	0.15801	0.81116	FB	FB	Match
Penon del Rey	0.07046	0.24069	0.47057	0.21828	MB_LB_FB	FB	Refined by Bayes
Penya de Sangomengo	0.02674	0.01617	0.23467	0.72243	LB_FB	EB_MB Classic	Refined by Bayes
Penya Foradada I	0.04625	0.69894	0.06223	0.19258	MB	EB_MB Classic	Refined by Bayes
Penyes Blanques	0.00000	0.00000	0.23171	0.76829	LB_FB	LB	Refined by Bayes

Site Name	Empirical Bayes Estimation by Chronological Period				Bayes Estimation	Estimated Chronological Attribution	Notes
	EB	MB	LB	FB			
Pic dels Corbs Fase III non-C14 estimate	0.02691	0.14937	0.18538	0.63834	FB	FB	Match
Pic dels Corbs Fase IV non-C14 estimate	0.02537	0.05761	0.14962	0.76740	FB	FB	Match
Pic dels Corbs Fase V non-C14 estimate	0.01096	0.04480	0.06662	0.87762	FB	FB	Match
Picayo II	0.02801	0.16931	0.15075	0.65193	MB_LB_FB	No info	Established by Bayes
Pico Nabo	0.03351	0.26557	0.15963	0.54129	MB_LB_FB	MB	Refined by Bayes
Poblado de Caparrota	0.02143	0.00000	0.20459	0.77398	LB_FB	MB	Refined by Bayes
Polovar	0.12469	0.26156	0.58801	0.02574	EB_MB_LB	EB and MB	Refined by Bayes
Pont de la Jaud	0.09585	0.26700	0.60424	0.03292	MB_LB	MB	Refined by Bayes
Pozo de la Alubia	0.02083	0.12842	0.19024	0.66052	MB_LB	MB	Refined by Bayes
Pozuelo	0.02939	0.23733	0.16269	0.57059	MB_LB	MB_LB	Match
Punta de las Aliagas	0.00000	0.00000	1.00000	0.00000	LB	LB	Match
Puntal de Cambra	0.01478	0.48662	0.14078	0.35782	MB_LB_FB	LB	Refined by Bayes
Puntal de l'Albaida	0.01731	0.08933	0.18884	0.70452	LB_FB	EB_MB Classic	Refined by Bayes
Puntal de la	0.08997	0.27194	0.61134	0.02676	MB_LB	EB_MB Classic	Refined by Bayes
Puntal del Buho	0.11540	0.03017	0.85291	0.00152	MB	EB_MB Classic	Refined by Bayes
Puntal dels Llops	0.01142	0.08690	0.41432	0.48736	LB_FB	LB	Refined by Bayes
San Anton	0.00375	0.01175	0.97887	0.00563	MB_LB	EB_MB Classic	Refined by Bayes
San Anton o Laderas del Castillo	0.44299	0.32109	0.19306	0.04286	EB_MB_LB	EB_MB Classic	Refined by Bayes
San Roche	0.07198	0.01427	0.17310	0.74064	LB_FB	MB	Refined by Bayes
Santa Barbera	0.28667	0.17330	0.54003	0.00000	EB_MB_LB	NA	Established by Bayes
Serra Grossa	0.99721	0.00012	0.00263	0.00003	EB	EB	Match
Serrella	0.09922	0.03767	0.27628	0.58683	EB	EB	Match
Sima de les Porrasses	0.14728	0.82441	0.02831	0.00000	EB_MB Classic	EB_MB Classic	Match
Sima Simarro	0.10356	0.06260	0.50610	0.32774	LB_FB	LB	Refined by Bayes
Tabaya Combined	0.09159	0.16798	0.68362	0.05681	MB_LB	EB_MB_LB	Refined by Bayes
Tabaya Early	0.00000	0.00000	1.00000	0.00000	LB	EB	Retained estimate (Late attribution is a misnomer)
Terlinques Combined	0.09492	0.29373	0.57955	0.03180	EB_MB Classic	LC_EB_MB	Match
Terlinques Fase I	0.09057	0.28626	0.43847	0.18471	EB_MB Classic	EB	Refined by Bayes
Terlinques Fase I-II Combined	0.00000	0.94729	0.05271	0.00000	MB	EB_MB Classic	Refined by Bayes
Terlinques Fase II	0.00000	1.00000	0.00000	0.00000	MB	EB_MB Classic	Refined by Bayes
Terlinques Fase II-III Combined	0.11785	0.79300	0.07492	0.01423	MB	MB	Match
Terlinques Fase III	0.19964	0.76835	0.02322	0.00880	MB	MB	Match
Tesoro de Villena	0.00000	0.00000	0.05603	0.94397	FB	LB_FB	Refined by Bayes
Teular de Sant Jaume 64	0.09718	0.26716	0.59922	0.03644	MB_LB	EB_MB Classic	Refined by Bayes

Site Name	Empirical Bayes Estimation by Chronological Period				Bayes Estimation	Estimated Chronological Attribution	Notes
	EB	MB	LB	FB			
Tossal de Cal Llop 1	0.00000	0.72474	0.23773	0.03754	MB	EB_MB Classic	Refined by Bayes
Tossal de San Miquel	0.02494	0.12127	0.18237	0.67142	MB_LB_FB	MB_LB_FB	Match
Tossal del Pou Clar	0.39788	0.12027	0.48185	0.00000	EB_MB Classic	EB_MB Classic	Match
Tossal Redo	0.99867	0.00017	0.00048	0.00069	EB	EB_MB Classic	Refined by Bayes
Tossalet de l'Aire	0.28667	0.17330	0.54003	0.00000	EB_MB Classic	EB_MB Classic	Match
Umbria Mala	0.03616	0.43676	0.21151	0.31558	MB_LB_FB	FB	Refined by Bayes
Color key:	Securely dated					Total attribution error	3.76%

APPENDIX J

RADIOCARBON DATES, CHRONOLOGICAL ATTRIBUTIONS, AND SITE LISTS

Radiocarbon Dates: Northern Region

Northern Region:			
Site Name	Bibliographic Reference	cal BC start	cal BC end
Castillarejo de los Moros	Bernabeu (unpublished)	1662	1580
Cueva del Murcielago Nivel IV	Palomar Macián 1995	1190	970
Cueva del Murcielago Nivel V	Palomar Macián 1995	1660	1480
La Lloma de Betxi Hab. III	de Pedro Michó 1998	2120	1900
La Lloma de Betxi Hab. III	de Pedro Michó 1998	1900	1740
La Lloma de Betxi Hab. III	de Pedro Michó 1998	2030	1770
La Lloma de Betxi Hab. III Combined	NA	2120	1740
La Lloma de Betxi Hab. I-II	de Pedro Michó 1998	2034	1743
La Lloma de Betxi Hab. I-II	de Pedro Michó 1998	2289	1936
La Lloma de Betxi Hab. I-II	de Pedro Michó 1998	2147	1873
La Lloma de Betxi Hab. I-II	de Pedro Michó 1998	1946	1682
La Lloma de Betxi Hab. I-II	de Pedro Michó 1998	1870	1660
La Lloma de Betxi Hab. I-II	de Pedro Michó 1998	1885	1670
La Lloma de Betxi Hab. I-II	de Pedro Michó 1998	2140	1910
La Lloma de Betxi Hab. I-II Combined	NA	2289	1660
La Lloma de Betxi Sector Este *	de Pedro Michó 1998	2140	1910
La Lloma de Betxi Sector Oeste	de Pedro Michó 1999	1760	1610
Les Raboses Combined	NA	1897	1347
Les Raboses Nivel II	Ripollés 2000	2034	1860
Les Raboses Nivel II	Ripollés 2000	1493	1347
Les Raboses Nivel III	Ripollés 2000	1897	1739
Pic dels Corbs Fase IA (non-C14 estimate)	Barrachina 2012	2400	1900
Pic dels Corbs Fase IB (non-C14 estimate)	Barrachina 2012	1900	1600
Pic dels Corbs Fase II	Barrachina 2012	1743	533
Pic dels Corbs Fase II (non-C14 estimate)	Barrachina 2012	1600	1400
Pic dels Corbs Fase III	Barrachina 2012	1518	1330
Pic dels Corbs Fase III	Barrachina 2012	1208	920
Pic dels Corbs Fase III	Barrachina 2012	1384	1129
Pic dels Corbs Fase III	Barrachina 2012	1600	1324
Pic dels Corbs Fase III (non-C14 estimate)	Barrachina 2012	1350	1050
Pic dels Corbs Fase IV (non-C14 estimate)	Barrachina 2012	1100	950
Pic dels Corbs Fase V (non-C14 estimate)	Barrachina 2012	1000	800
Pic dels Corbs Sector N-NW	Barrachina 2012	2012	1695
Puntal de Cambra	Bernabeu (unpublished)	1629	1545
Puntal dels Llops	de Pedro Michó 2001	1690	1500

* *Only used for Bayes Estimation, not in network analyses*

Radiocarbon Dates: Southern Region

Southern Region:			
Site Name	Bibliographic Reference	cal BC start	cal BC end
Altet d'Palau Ambito 2	de Pedro Michó & García Borja 2015	1440	1320
Altet d'Palau Combined	NA	1460	1310
Altet d'Palau Estancia 3	de Pedro Michó & García Borja 2015	1460	1310
Barranco Tuerto	Jover Maestre & López Padilla 2005	1903	1797
Cabezo de la Escoba Combined	NA	1900	1640
Cabezo de la Escoba incendio	Cabezas Romero 2015	1900	1770
Cabezo de la Escoba sondeo	Cabezas Romero 2015	2340	2200
Cabezo de la Escoba sondeo carena	Cabezas Romero 2015	1870	1640
Cabezo Pardo Fase I	López Padilla 2014	1936	1790
Cabezo Pardo Fase II	López Padilla 2014	1706	1671
Cabezo Pardo Fase III	López Padilla 2014	1631	1566
Cabezo Pardo Fase I-III	López Padilla 2014	1936	1566
Cabezo Pardo Fase II-III	López Padilla 2014	1706	1566
Cabezo Redondo Combined	NA	1756	1381
Cabezo Redondo Con H-2277	Jover Maestre & López Padilla 2016	1756	1381
Cabezo Redondo Sin-H2277	Jover Maestre & López Padilla 2016	1691	1391
Cati Forada	Walker 1981	2025	1641
Cerro de El Cuchillo Combined *	NA	1730	1370
Cerro de El Cuchillo Dept. 1 Nivel III *	Hernández Pérez et al. 1994	1730	1550
Cerro de El Cuchillo Dept. IV Fase III *	Hernández Pérez et al. 1994	1640	1460
Cerro de El Cuchillo Dept. V Nivel II *	Hernández Pérez et al. 1994	1550	1370
Cerro de El Cuchillo Dept. VI Nivel I *	Hernández Pérez et al. 1994	1871	1546
Cerro de El Cuchillo Dept. VIII Nivel III *	Hernández Pérez et al. 1994	1650	1470
Cerro de El Cuchillo Fase I *	Estimate Hernández Pérez et al. 1994	1730	1550
Cerro de El Cuchillo Fase II *	Estimate Hernández Pérez et al. 1994	1550	1640
Cerro de El Cuchillo Fase III *	Hernández Pérez et al. 1994	1640	1460
El Negret Combined	Barciela et al. 2012	1495	1113
El Negret UH1	Barciela et al. 2012	1268	1113
El Negret UH2	Barciela et al. 2012	1495	1326
Illeta del Banyets Cisternas	Estimate Soler Díaz 2006	1800	1504
Illeta del Banyets Tardio	Estimate Soler Díaz 2006	1610	1504
Illeta dels Banyets Cisterna 1	Soler Díaz 2006	2892	2014
Illeta dels Banyets Cisterna 1	Soler Díaz 2006	1610	1504

Radiocarbon Dates: Southern Region (continued)

Southern Region:			
Site Name	Bibliographic Reference	cal BC start	cal BC end
Illeta dels Banyets Terraplan perfil SW1 Nivel II	Soler Díaz 2006	1800	1620
Illeta dels Banyets Tumba III	Soler Díaz 2009	1883	1771
Illeta dels Banyets Tumba III	Soler Díaz 2006	1741	1633
Illeta dels Banyets Tumba IV	Soler Díaz 2009	1972	1782
Illeta dels Banyets Tumba IV	Soler Díaz 2009	1687	1560
Illeta dels Banyets Tumba V	Soler Díaz 2009	1880	1764
L'Arbocer	de Pedro Michó & García Borja 2015	1460	1310
L'Arbocer	de Pedro Michó & García Borja 2015	1440	1320
L'Arbocer Combined	NA	1460	1310
Lloma Redona	Gusi y Olària 1995	1897	1745
Pena Negra I	González Prats 1983; 1985	897	803
Pena Negra I	González Prats 1983; 1985	888	800
Pena Negra I	González Prats 1983; 1985	802	764
Pena Negra I	González Prats 1983; 1985	760	406
Pena Negra I Overall	González Prats 1983; 1985	850	740
Pic de les Moreres	González Prats 1983	2871	2472
Polovar	Jover y Martínez Monleón (unpublished)	1917	1777
Serra Grossa	Llobregat 1971	2461	2136
Tabaya C10 Tumba	Hernández Pérez 2009	1946	1881
Tabaya C11 Tumba	Hernández Pérez 2009	1878	1749
Tabaya C11 Tumba	Hernández Pérez 2009	1687	1560
Tabaya Combined	Hernández Pérez 2009	1946	1560
Terlinques Combined	NA	2151	1511
Terlinques Fase I	Jover Maestre & López Padilla 2016	2151	1986
Terlinques Fase II	Jover Maestre & López Padilla 2016	1946	1741
Terlinques Fase III	Jover Maestre & López Padilla 2016	1742	1511
Terlinques Fase I-II Combined	NA	2151	1741
Terlinques Fase II-III Combined	NA	1946	1511

* *Only used for Bayes Estimation, not in network analyses*

Site List: Northern Region

Chronology Key: EB = Early Bronze; EB_MB Classic = Early and Middle Bronze; MB = Middle Bronze; LB = Late Bronze; FB =Final Bronze; EB_MB_LB = Early, Middle, and Late Bronze; MB_LB = Middle and Late Bronze; LB_FB = Late and Final Bronze; MB_LB_FB = Middle, Late, and Final Bronze; LC = Late Chalcolithic (classed as Early Bronze)

Northern Region: Site Name	Site Name Abbreviation	Chronology	River Valley
Abrigo II de las Penas	AIdlP	MB_LB	Palancia-Valls
Albardeta	Al	MB	Palancia-Valls
Barranco de la Pena Roya	BdlPR	LB_FB	Palancia-Valls
Barranco del Cuervo	BdC	MB_LB	Palancia-Valls
Barranco Maso	BM	LB_FB	Palancia-Valls
Cabrera Baja	CB	MB_LB	Palancia-Valls
Castillo de Pina	CstlldPn	LB_FB	Palancia-Valls
Cerro de la Canada Larga	CdlCL	LB_FB	Palancia-Valls
Collado del Canar	CldC	MB_LB	Palancia-Valls
Corral de Morca	CrdM	MB_LB	Palancia-Valls
Cueva Cerdana	CC	MB_LB_FB	Palancia-Valls
Cueva de Alcabaira	CvdAl	LB_FB	Palancia-Valls
Cueva de la Peseta	CvdlPs	MB	Palancia-Valls
Cueva de las Balsillas	CvdlB	LB_FB	Palancia-Valls
Cueva de los Moros	CvdlsM	LB_FB	Palancia-Valls
Cueva del Cerro Las Simas	CdCLS	MB	Palancia-Valls
Cueva del Murcielago	CvdlMr	LB	Palancia-Valls
Cueva del Murcielago Nivel IV	CdMNI	FB	Palancia-Valls

Site List: Northern Region (continued)

Northern Region: Site Name	Site Name Abbreviation	Chronology	River Valley
Cueva del Pueblo Classic	CdPC	EB_MB Classic	Palancia-Valls
Cueva del Pueblo FB	CdPF	FB	Palancia-Valls
Cueva del Tio Paco FB	CdTPM	FB	Palancia-Valls
Cueva del Tio Paco MB	CdTPF	MB	Palancia-Valls
Cueva del Tio Ramon	CdTR	FB	Palancia-Valls
Cueva Grande de la Rocha	CGdlR	MB	Palancia-Valls
Cueva Moma	CM	MB_LB	Palancia-Valls
El Cabezo	ElCb	LB_FB	Palancia-Valls
El Castillarejo del Coronel	ECdC	MB	Palancia-Valls
El Martinete	ElMr	MB_LB	Palancia-Valls
El Picacho	ElPcc	MB_LB	Palancia-Valls
El Picayo	ElPcy	EB	Palancia-Valls
El Puntal	ElPnt	MB_LB	Palancia-Valls
El Sargal	ElSr	LB_FB	Palancia-Valls
Fuente de la Noguera	FdlN	MB	Palancia-Valls
Huerpita I y II	HIyI	MB_LB	Palancia-Valls
La Cueva del Abrigo I de Las Penas	LCdAIdLP	EB	Palancia-Valls
La Guaranila	LG	LB	Palancia-Valls
La Murta	LMr	LB_FB	Palancia-Valls
La Torrecilla II	LTI	MB_LB	Palancia-Valls

Site List: Northern Region (continued)

Northern Region: Site Name	Site Name Abbreviation	Chronology	River Valley
Les Raboses Combined	LRC	MB_LB	Palancia-Valls
Loma de Pante	LdP	LB	Palancia-Valls
Mas del Baile	MdB	MB_LB_FB	Palancia-Valls
Pena de la Duena	PdlD	LB_FB	Palancia-Valls
Pena Dorada	PD	MB_LB_FB	Palancia-Valls
Penyes Blanques	PB	LB_FB	Palancia-Valls
Pic dels Corbs Fase IA non-C14 estimate	PdCFIAne	MB	Palancia-Valls
Pic dels Corbs Fase IB non-C14 estimate	PdCFIBne	MB_LB	Palancia-Valls
Pic dels Corbs Fase II non-C14 estimate	PdCFIIn-e	LB_FB	Palancia-Valls
Pic dels Corbs Fase III non-C14 estimate	PdCFIIIne	FB	Palancia-Valls
Pic dels Corbs Fase IV non-C14 estimate	PdCFIVne	FB	Palancia-Valls
Pic dels Corbs Fase V non-C14 estimate	PdCFVne	FB	Palancia-Valls
Picayo II	PI	MB_LB_FB	Palancia-Valls
Pico Nabo	PN	MB_LB_FB	Palancia-Valls
Poblado de Caparrota	PbdC	LB_FB	Palancia-Valls
Pozo de la Alubia	PzdlA	MB_LB	Palancia-Valls
Pozuelo	Pz	MB_LB	Palancia-Valls
Punta de las Aliagas	PndlA	LB	Palancia-Valls
San Roche	SR	LB_FB	Palancia-Valls
Umbria Mala	UM	MB_LB_FB	Palancia-Valls
Alto de la Pena Cortada	AdlPC	LB	Turia
Casa del Camp	CsdC	LB	Turia

Site List: Northern Region (continued)

Northern Region: Site Name	Site Name Abbreviation	Chronology	River Valley
Cova del Cavall	CvdlCv	FB	Turia
Castillarejo de los Moros	CsdlM	MB_LB	Turia
Castillarejo de Penarroya	CstllrdP	MB	Turia
Cerro de los Bolos	CrdlB	FB	Turia
Cova de Rocafort	CdR	EB	Turia
El Castillarejo	ElCs	MB_LB_FB	Turia
El Gargao	ElGr	LB_FB	Turia
Els Germanells	ElsG	EB	Turia
Els Trencalls	ET	EB_MB Classic	Turia
Ermita de la Lloma de Montiel	EdlLdM	LB	Turia
La Atalayuela	LA	EB	Turia
La Lloma de Betxi Hab. I-II Combined	LLdBH.I-C	EB	Turia
La Lloma de Betxi Hab. III Combined	LLdBH.IIC	EB	Turia
La Lloma de Betxi Sector Oeste	LLdBSO	MB_LB	Turia
La Torreta	LTrrt	EB	Turia
Llometa del Tio Figuetes	LdTF	MB_LB_FB	Turia
Puntal de Cambra	PndC	MB_LB_FB	Turia
Puntal dels Llops	PdL	LB_FB	Turia
Tossal de San Miquel FB	TdSMM	FB	Turia
Tossal de San Miquel MB_LB	TdSMF	MB_LB	Turia

Site List: Southern Region

Chronology Key: EB = Early Bronze; EB_MB Classic = Early and Middle Bronze; MB = Middle Bronze; LB = Late Bronze; FB =Final Bronze; EB_MB_LB = Early, Middle, and Late Bronze; MB_LB = Middle and Late Bronze; LB_FB = Late and Final Bronze; MB_LB_FB = Middle, Late, and Final Bronze; LC = Late Chalcolithic (classed as Early Bronze)

Southern Region: Site Name	Site Name Abbreviation	Chronology	River Valley
Altet d'Palau Combined	AdC	MB_LB	Jucar
Arenal de la Costa	AdlC	EB	Jucar
Barranco de Fayona	BdF	FB	Segura
Barranco Tuerto	BT	EB	Vinalopo-Alicante
Cabezo de la Escoba Combined	CdlEC	EB_MB Classic	Vinalopo-Alicante
Cabezo de la Hiedra	CdlH	MB	Vinalopo-Alicante
Cabezo de las Particiones	CbdlP	LB_FB	Segura
Cabezo de Mariola	CbzdMr	LB	Vinalopo-Alicante
Cabezo de Navarro	CdN	EB_MB Classic	Jucar
Cabezo de Penalva	CbdP	MB	Vinalopo-Alicante
Cabezo de Sant Antoni	CdSA	MB	Vinalopo-Alicante
Cabezo de Serrelles	CbdS	MB_LB	Jucar
Cabezo de Valera	CdV	EB_MB Classic	Vinalopo-Alicante
Cabezo del Cantalar	CbdC	EB_MB Classic	Jucar
Cabezo del Molinico	CbzdlM	FB	Vinalopo-Alicante
Cabezo Pardo Fase I	CbPFI	EB_MB Classic	Segura
Cabezo Pardo Fase I-III	CPFI-	EB_MB_LB	Segura
Cabezo Pardo Fase II	CbPFII	MB_LB	Segura
Cabezo Pardo Fase II-III	CPFII-	MB_LB	Segura
Cabezo Pardo Fase III	CPFIII	MB_LB	Segura
Cabezo Redondo Combined	CRC	MB_LB	Vinalopo-Alicante
Cami de Catral	CmdC	FB	Vinalopo-Alicante
Caramoro I	CrI	MB	Vinalopo-Alicante

Site List: Southern Region (continued)

Southern Region: Site Name	Site Name Abbreviation	Chronology	River Valley
Caramoro II	CII	FB	Vinalopo-Alicante
Casa Paus	CP	EB	Vinalopo-Alicante
Cati Forada	CF	MB	Vinalopo-Alicante
Cerro de las Alabarizas	CdlA	MB	Vinalopo-Alicante
Cova de la Pedrera	CvdlPd	EB	Vinalopo-Alicante
Cova del Cantal	CvdlCn	EB	Vinalopo-Alicante
Cova dels Anells	CvdlA	EB	Vinalopo-Alicante
Cova dels Solsits	CvdS	EB	Vinalopo-Alicante
Coveta del Frare	CdF	MB	Jucar
Cueva de la Casa Colora	CdlCC	MB_LB	Vinalopo-Alicante
Cueva de las Delicias	CdlD	EB	Vinalopo-Alicante
Cueva de San Antonio de Padua	CdSAdP	EB	Segura
Cueva del Alto n1	CdAn	LB	Vinalopo-Alicante
Cueva del Molinico	CvdlMl	EB_MB Classic	Vinalopo-Alicante
Cueva Oriental de Salvatierra	COdS	EB	Vinalopo-Alicante
Cueva Oriental del Penon de la Zorra	COdPdlZ	EB	Jucar
El Azud	EA	EB	Vinalopo-Alicante
El Bancalico II	EBI	EB_MB Classic	Segura
El Bosch	EB	FB	Vinalopo-Alicante
El Cagallo del Gegant	ECdG	EB	Jucar
El Castellar Agost	ECA	LB_FB	Vinalopo-Alicante
El Castellet del Porquet	ECdP	LB	Jucar

Site List: Southern Region (continued)

Southern Region: Site Name	Site Name Abbreviation	Chronology	River Valley
El Fossino	EF	MB_LB	Jucar
El Mollo	ElMl	LB	Jucar
El Monastil	ElMns	LB_FB	Vinalopo-Alicante
El Montagut	ElMnt	EB_MB Classic	Vinalopo-Alicante
El Muron de la Horna	EMdlH	MB_LB_FB	Vinalopo-Alicante
El Negret Combined	ENC	LB	Vinalopo-Alicante
El Pinchillet	ElPnc	LB_FB	Vinalopo-Alicante
El Portixol FB	EPM	FB	Vinalopo-Alicante
El Portixol MB_LB	EPF	MB_LB	Vinalopo-Alicante
El Promontori	ElPr	EB	Vinalopo-Alicante
El Puntal de Bartolo	EPdB	EB	Vinalopo-Alicante
El Salido	ElSl	MB	Jucar
El Sambo	ElSm	MB_LB	Vinalopo-Alicante
Figuera Redona	FR	EB	Vinalopo-Alicante
Foia de La Perera	FdLP	EB_MB Classic	Vinalopo-Alicante
Fonteta del Sarso	FdS	EB	Vinalopo-Alicante
Frontera A	FA	EB	Vinalopo-Alicante
Frontera B	FB	MB	Vinalopo-Alicante
Hurchillo	Hr	MB_LB_FB	Segura
Illeta dels Banyets Cisternas	IdBC	LB_FB	Vinalopo-Alicante
Illeta dels Banyets Tardio	IdBT	LB	Vinalopo-Alicante

Site List: Southern Region (continued)

Southern Region: Site Name	Site Name Abbreviation	Chronology	River Valley
Illeta dels Banyets Terraplan perfil SW1 Nivel II	IdBTpSNI	MB	Vinalopo-Alicante
Illeta dels Banyets Tumba III	IdBTI	MB	Vinalopo-Alicante
L'Altet de la Moneda	LdlM	MB_LB	Vinalopo-Alicante
L'Arbocer Combined	L'C	LB	Jucar
L'Escalerola II	LI	LB	Jucar
La Alcudia Classic	LAC	EB_MB Classic	Vinalopo-Alicante
La Alcudia FB	LAF	FB	Vinalopo-Alicante
La Banyesa A	LBA	EB_MB Classic	Vinalopo-Alicante
La Buelta	LB	EB	Vinalopo-Alicante
La Cova de la Balconada	LCdlB	EB_MB Classic	Jucar
La Cova Sangomengo	LCS	EB	Jucar
La Esparraguera	LEs	LB	Vinalopo-Alicante
La Llometa	LL	MB_LB	Vinalopo-Alicante
La Moleta	LMl	EB_MB_LB	Vinalopo-Alicante
La Torre	LTorr	LB	Vinalopo-Alicante
La Torreta Vallada	LTV	EB	Jucar
Laderas del Castillo EB	LdCM	EB	Segura
Laderas del Castillo MB	LdCE	MB	Segura
Las Espenetas	LsEs	EB	Segura
Las Penicas	LP	EB_MB_LB_FB	Vinalopo-Alicante
Les Cabecoles	LsCb	EB_MB_LB	Jucar
Les Canyadetes	LsCn	LB	Jucar
Les Ermitetes	LsEr	MB	Vinalopo-Alicante

Site List: Southern Region (continued)

Southern Region: Site Name	Site Name Abbreviation	Chronology	River Valley
Lloma Redona	LR	MB_LB	Vinalopo-Alicante
Loma de Bigastro	LdB	LB_FB	Segura
Los Saladares	LS	FB	Segura
Mas de Felip	MdF	EB_MB_LB	Vinalopo-Alicante
Mollo de les Mentires	MdlM	MB_LB	Jucar
Morret del Moro	MdM	MB	Vinalopo-Alicante
Morro del Gorgorrobio	MdG	EB_MB Classic	Jucar
Muntanyeta de Cabrera	MdC	LB	Jucar
Necropolis de la Algorfa	NdlA	EB_MB Classic	Segura
Ombria de L'Algaiat	OdL	LB	Vinalopo-Alicante
Pena de Sax	PndSx	MB_LB_FB	Vinalopo-Alicante
Pena Negra I Overall	PNIO	FB	Segura
Penon del Rey	PdR	MB_LB_FB	Vinalopo-Alicante
Penya de Sangomengo	PnydS	LB_FB	Jucar
Penya Foradada I	PFI	MB	Jucar
Pic de les Moreres	PdlM	EB_MB Classic	Segura
Polovar EB	PE	EB	Vinalopo-Alicante
Polovar MB	PM	MB	Vinalopo-Alicante
Pont de la Jaud	PdlJ	MB_LB	Vinalopo-Alicante
Puntal de l'Albaida	Pdl	LB_FB	Segura
Puntal de la Rabossa	PdlR	MB_LB	Vinalopo-Alicante
Puntal del Buho	PdB	LB	Jucar
San Anton Classic	SAC	EB_MB Classic	Vinalopo-Alicante
San Anton EB	SAE	EB	Vinalopo-Alicante
San Anton o Laderas del Castillo Classic	SAoLdCC	EB_MB Classic	Jucar

Site List: Southern Region (continued)

Southern Region: Site Name	Site Name Abbreviation	Chronology	River Valley
San Anton o Laderas del Castillo EB	SAoLdCE	EB	Vinalopo-Alicante
Santa Barbera	SB	EB_MB_LB	Jucar
Serra Grossa	SG	EB	Vinalopo-Alicante
Serrella	Sr	EB	Segura
Sima de les Porrasses	SdlP	EB_MB Classic	Segura
Sima Simarro	SS	LB_FB	Segura
Tabaya Combined	TbC	MB_LB	Segura
Tabaya Early	TE	EB	Segura
Terlinques Combined	TrC	EB_MB Classic	Vinalopo-Alicante
Terlinques Fase I	TrFI	EB_MB Classic	Vinalopo-Alicante
Terlinques Fase I-II Combined	TFI-C	MB	Vinalopo-Alicante
Terlinques Fase II	TrFII	MB	Vinalopo-Alicante
Terlinques Fase II-III Combined	TFIIC	MB	Vinalopo-Alicante
Terlinques Fase III	TFIII	MB	Vinalopo-Alicante
Tesoro de Villena	TdV	FB	Vinalopo-Alicante
Teular de Sant Jaume 64	TdSJ6	MB_LB	Vinalopo-Alicante
Tossal de Cal Llop 1	TdCL1	MB	Vinalopo-Alicante
Tossal del Pou Clar	TdPC	EB_MB Classic	Vinalopo-Alicante
Tossal Redo	TR	EB	Vinalopo-Alicante
Tossalet de l'Aire	Tdl	EB_MB Classic	Jucar

APPENDIX K

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