OBSIDIAN CIRCULATION NETWORKS IN SOUTHWEST ASIA AND ANATOLIA

OBSIDIAN CIRCULATION NETWORKS IN SOUTHWEST ASIA AND ANATOLIA (12,000 – 5700 B.P.): A COMPARATIVE APPROACH

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ABSTRACT

This Master's thesis documents and interrogates networks of regional interaction in southwest Asia and Anatolia during the Neolithic and Chalcolithic periods (12,000 - 5700 B.P.) by comparing the variable use of obsidian raw material variants at 151 sites. This represents an effort to bring together all of the obsidian sourcing data produced for this broad archaeological setting, and evaluate it from a heterarchical approach that highlights the distributed nature of regional interaction. Heterarchical perspectives are applied here through the use of network analysis in order to highlight clusters of sites that are more connected to each other than they are to others in the system, and to determine the roles of each site in the system's overall structure. As such, order is highlighted as a result of the organization of data-driven ties among sites, which are unrestricted by presumptions relating to geographical position or of pre-defined rank. The results are compared with more established models of regional interaction in the settings of interest, and heterarchical perspectives through network analysis are shown to complement common understandings of broad-scale connectivity at various points in time.

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LIST OF ABBREVIATIONS AND SYMBOLS

ASPRO – Atlas des Sites du Proche Orient

BC / BCE – Before Christ / Before Common Era

BP – Before Present

BR – Brainerd-Robinson

DObsiSS – Database of Obsidian Circulation Studies

ICP – Inductively Coupled Plasma

ICP-MS – Inductively Coupled Plasma Mass Spectrometry

INAA – Instrumental Neutron Activation Analysis

MOM – Maison de l'Orient et de la Méditerranée

PIXE – Particle Induced X-Ray Emission

PPN – Pre-Pottery Neolithic

PPNA – Pre-Pottery Neolithic A

PPNB – Pre-Pottery Neolithic B

PPNC – Pre-Pottery Neolithic C

SEM – Scanning Electron Microscopy

XRF – X-ray Fluorescence

DECLARATION OF ACADEMIC ACHIEVEMENT

This is a declaration that the content of the research in this thesis has been completed by Zachary Batist, recognizing the important contributions of Dr. Tristan Carter, Dr. Andy Roddick, Dr. Clemens Reichel and Dr. Mark Golitko.

1 – INTRODUCTION

When examined at broad spatial and temporal scales, the interactions between archaeological populations are often examined in terms of the spatial and temporal extent of finds deemed representative of particular cultures or of significant socio-cultural developments. However this approach, which I refer to as top-down or culture-historical in nature, categorizes sites in a way that makes it easy to ignore variability among them or the ways by which they may actually have been related to one another without first drawing from pre-emptive assumptions of their relatedness. One archaeological feature that has commonly been used as an index of broad-scale interaction is the prehistoric consumption of obsidian. In southwest Asia and Anatolia, this volcanic glass of excellent tool-making properties is only found naturally in the regions of central and eastern Anatolia, and Armenia, yet was circulated over great distances from the Epi-Palaeolithic onwards. Archaeologists have recurrently employed distribution maps of these materials as a means of depicting interaction zones at regional and supra-regional scales (e.g. Roaf 1990:34) (Figure 1.1), however this approach, which I refer to as top-down or culture-historical in nature, make it easy to ignore variability among populations or the mechanisms by which obsidian was exchanged.

In recent years there have been calls for recognition of such variability, as expressed through the different ways in which obsidian was used, through more direct comparison among sites in different parts of southwest Asia and Anatolia (Asouti 2006; Carter et al. 2013; Watkins 2008). In this thesis I compare the proportions of obsidian derived from different raw material sources and represent these relationships as networks, which were then analyzed in order to identify groups of sites that shared common habits

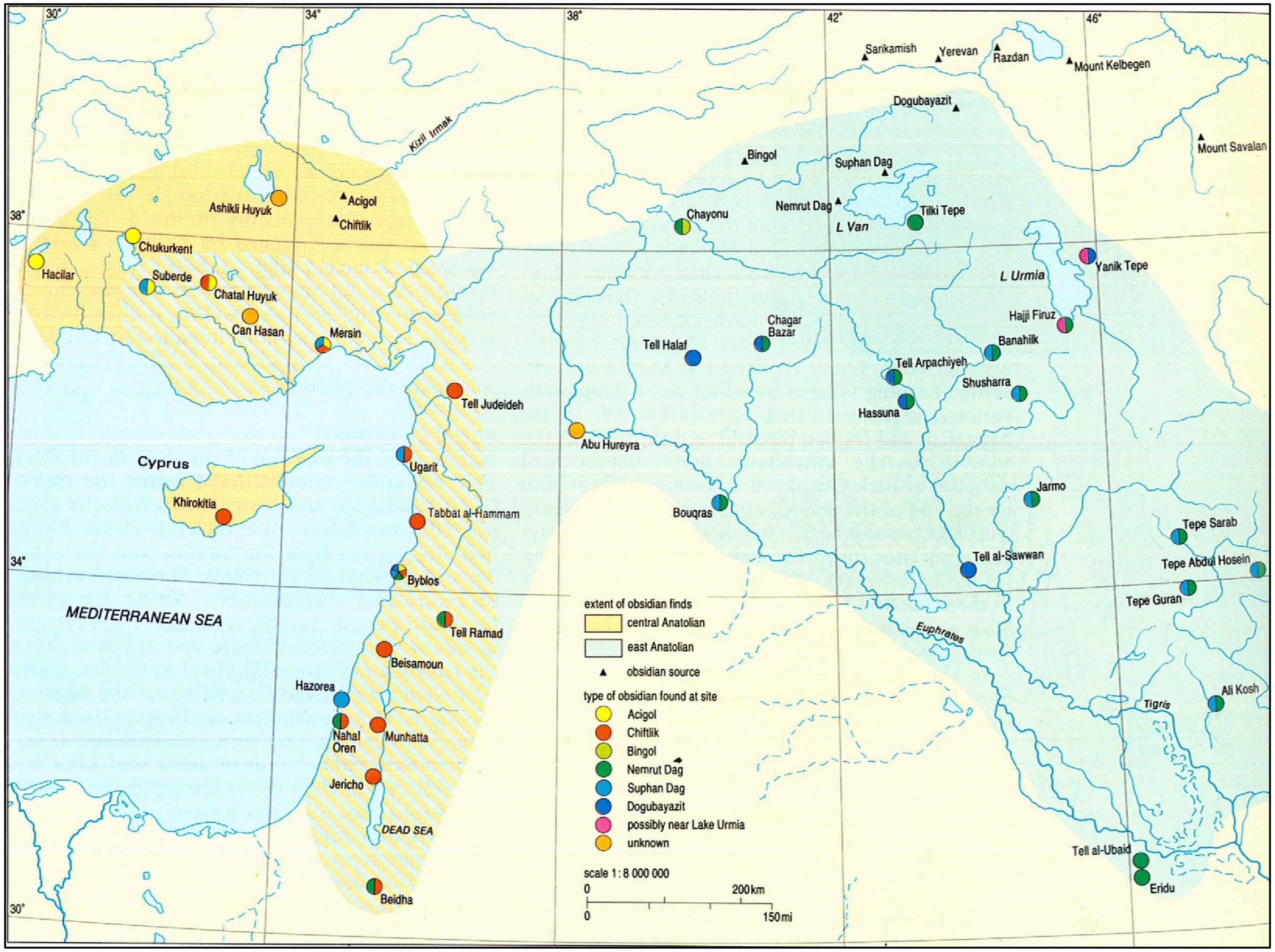

Figure 1.1 Map of obsidian distribution zones (from Roaf 1990:34).

of obsidian procurement. These emergent clusters are more effective representations of broad-scale groupings than top-down models, since they are detected through evaluation of series of synchronic heterarchical relationships among sites (Crumley 2005:47; Irwin-Williams 1977; Knappett 2011; Renfrew 1986).

This approach might be contrasted with top-down models, which classify sites according to pre-defined criteria that are used to imply their association, without drawing direct comparisons between them. Heterarchical approaches recognize each entity's significance in relation to others in the system as derived from the distributions of unrestricted ties among them (Crumley 1995). While archaeologists use top-down approaches to categorize populations into homogenous categories, those employing heterarchical models seek to highlight the heterogeneity that is actually present between sites at a regional scale (Broodbank 2000; Fuller et al. 2012; Malkin 2011; Nissen 2001; Stein 1999, 2002; Stein and Rothman 1994). This thesis takes on a heterarchical perspective by comparing roughly contemporaneous sites with regards to obsidian distribution patterns and representing these relationships as networks, and subsequently analyzing them to highlight order that emerges from these interconnections. More specifically, groups of sites that shared more interconnections among themselves than they did with others in the system were highlighted, and various measures of connectivity pertaining to each site and to the system as a whole were determined. This methodology was employed since it enables the roles of each site to be ascertained as a result of their ties with others, which are unrestricted and data-driven. At the same time, this approach enables us to overcome the simplistic notion that sites could be encompassed within arbitrarily defined distribution zones.

This thesis is thus an attempt to produce a more nuanced understanding of how obsidian was circulated in southwest Asia and Anatolia over seven periods during the

Neolithic and Chalcolithic periods (12,000 – 5700 B.P.). While many scholars are content to use the results of obsidian sourcing studies to mark the extent of the materials' distribution or to imply that the inhabitants of a site participated in such an extensive exchange system, the structure of such a system or the particular roles of each site are rarely addressed (see Freund 2013 for a more detailed overview on this issue). Moreover, while these concerns may be implied by geographical position, the procurement and circulation of obsidian did not always follow optimal behaviour as predicted through geo-spatial observations (Coward 2013; Ortega et al. 2013). However the relationships evaluated in this thesis reflect socio-economic patterns relating to the circulation of obsidian without accounting for geographical position or other presumptions of rank. Thus, these observed patterns might indicate whether certain materials were restricted or preferred for particular functions based upon culture-specific ideals, or they may pertain to broader mechanisms of regional interaction that may or may not have been in place. In order to determine their significance, the results of network analysis were interpreted in light of more established views of supra-regional interaction in each setting. While the results do highlight pertinent socio-economic trends that archaeologists who are focused on these specific settings might appreciate, the way in which this thesis re-assesses the distribution of obsidian might be considered its most important contribution.

2 – THE NEOLITHIC AND CHALCOLITHIC PERIODS IN SOUTHWEST ASIA AND ANATOLIA

2.1 On the definition of cultural boundaries

This thesis is primarily concerned with the interrogation and documentation of long-term interactions in southwest Asia and Anatolia from the Neolithic to Chalcolithic periods. While further details concerning the parameters and structure of my dataset are outlined in Chapter 5, a brief overview of the periods concerned is outlined here.

The region of southwest Asia and Anatolia is widely considered to have been the setting for the earliest global instances of humans' adoption of sedentary lifestyles, the domestication of plants and animals, and the development of complex socio-political organization (Kuijt and Goring-Morris 2002). These changes in residency and subsistence patterns were long viewed as the hallmarks of the Neolithic period (new stone age) occurring from approximately 12,000 B.P., a 'revolutionary' moment in human socio-economic development according to Gordon Childe (1951). For Childe, these developments were the result of climatic change in the context of a rich environment that hosted an array of wild plants and animals whose domesticated versions would come to form the subsistence basis of Eurasian farming societies. The pace, nature and reason for these changes has been hotly debated, with many now believing that Childe's revolution might perhaps be better viewed as a long-term process over the Late Pleistocene to Early Holocene. Indeed, the suite of allegedly contemporaneous changes Childe (1951:75-80) referred to as the 'Neolithic package' are now seen to be spread out over some 7000 years, from the initial use of ground stone tools and the appearance of sedentary village life in the Epi-Palaeolithic (Natufian), to the subsequent domestication of cereals in the Pre-Pottery Neolithic A, followed by animal domesticates in the Pre-Pottery Neolithic B, and finally the appearance of ceramic vessels in the Pottery Neolithic (in total c. 14,000 –

7000 B.P.) (Gebel 1994, 2004; Goring-Morris and Belfer Cohen 2011; Kuijt and Goring-Morris 2002). Nonetheless, it remains that the Neolithic represents a crucial period for socio-economic development in the region, with settled village life leading to larger populations and by extent greater political complexity (Watkins 2010), together with an increased significance accorded to material culture and its circulation (Hodder 2004). It is this issue of objects and materials circulating over increasing distances, and their role in linking communities (arguably underpinning the initiation and maintenance of the social relations that bound these cultures together), that forms one of the key topics of this thesis.

The next major change is witnessed around 7500 – 7000 B.P. in the Levant,[1] when we view the first recurrent production of metal artefacts, mainly in the form of un-alloyed copper, a technological innovation that is used to define the period as the Chalcolithic period, or 'copper age' (Garfinkel et al 2014; Moorey 1988). The emergence of a metallurgical tradition led to further socio-economic developments, not least the creation of new prestige media for exchange, consumption and display (Golden 2009; Rowan and Golden 2009). These innovations arguably further led to a reconfiguration of exchange networks, as the desire for raw materials such as copper and for other crafted goods, led to relations being initiated with the inhabitants of new regions (e.g. metal source areas) and the intensification of existing connections.

While each of these developments was completely novel in their own right, they should not be interpreted as arising in a vacuum. Many archaeologists refer to the series

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[1] The Levant refers to the Mediterranean coastal region whose extent roughly runs from north-western Syria at its northern-most end, towards the southern parts of Israel and Jordan at its southern-most end.

of interwoven developments that occurred throughout the Neolithic as processes of Neolithization, a term that generally brings to mind long-term processes occurring in parallel (Gebel 1994; Goring-Morris and Belfer-Cohen 2011). Although the progressions that occurred during later Chalcolithic period are not usually included in such discussions, here they are generally treated in a similar way due to the current focus on long-term and broad-scale processes. These particular periods were chosen for evaluation since they fall within the boundaries of the chronology adopted for this thesis, and because they are settings wherein archaeologists already focus their attention with regards to sourcing obsidian and tracking its circulation.

It is also important to note that the aforementioned major developments that mark the Neolithic and Chalcolithic periods have occurred at different times across the broad region considered here, i.e. the domestication of cereals occurs earlier in the Levant than it does in central Anatolia, whereby the earliest Neolithic periods of these regions date to the 9th and 8th millennia respectively. I thus employ an absolute chronological scheme to structure this thesis as a means of simplifying comparisons across the regions under consideration. The supra-regional chronological scheme that is employed is a slightly modified version of that defined in the *Atlas des sites du Proche Orient* (ASPRO) and published by the *Maison de l'Orient et de la Méditerranée*, (Table 2.1) (Hours et al 1994). Within the periods defined by this scheme I detail regional 'cultural' distinctions that have usually been defined according to the appearance of diagnostic features in the archaeological record.

This cultural scheme (or 'culture history'), which is presented in more detail in the following section, is merely a brief descriptive account of the regional distribution of common features that are considered to represent independent cultures, homeostatic units that are relatively consistent internally, relative to other collective ways of life (other,

Period	**ASPRO**	**B.P.**	**Northern Mesopotamia**	**Southern Mesopotamia**	**Anatolia / Levant**	**Levant / Upper Euphrates**	**Khuzestan**
1	1	12000 - 10300	Zarzi	Zarzi	Late Natufian / PPNA	Mesolithic 2	
2	2	10300 - 9600	Zawi Chemi / PPNB	Zawi Chemi	Early/Middle PPNB	Neolithic 1	Bus Mordeh / Ali Kosh
	3	9600 - 8600	Zawi Chemi / PPNB	Zawi Chemi	Late/Final PPNB	Neolithic 1 / Neolithic 2	
3	4	8600 - 8000	Proto-Hassuna / Sotto	Ubaid 0	PPNC / Early PN	Neolithic 2	Mohammed Jaffar
4	5	8000 - 7600	Hassuna / Samarra / Halaf	Ubaid 1	Amuq A/B	Neolithic 3	Sabz / Choga Mami Transitional
	6	7600 - 7000	Halaf / Halaf-Ubaid Transition	Ubaid 2	Amuq B/C/D / Yarmoukian		
5	7	7000 - 6500	Ubaid 3 (Northern Ubaid)	Ubaid 3	Amuq E / Wadi Rabbah	Neolithic 4	Khazineh / Mehmeh
6	8	6500 - 6100	Late Chalcolithic 1/2	Ubaid 4	Amuq E	Neolithic 4	Bayat
7	9	6100 - 5700	Late Chalcolithic 3/4	Uruk	Amuq F/G	Neolithic 4	

Table 2.1 – The chronological-regional-terminological framework adopted for this thesis.

neighbouring ‘cultures’). This scheme provides us with a top-down view of prehistoric societies, in the sense that the categorical units dictate the ways that archaeologists view the individual entities that they are comprised of, and can easily be represented cartographically as a series of dots representing archaeological sites, and surrounded by borders delineating cultural boundaries. This mode of thought seems to be influenced by the work of Montelius (1903) and Childe (1935:198-199), who recognized that material culture reflected collective ways of life, and that peoples who produced and used similar kinds of artefacts and architecture would have had more in common that those whose material culture was radically different. However, this view is problematic since it treats both the material manifestations of human actions and the people who made them as static entities or snapshots representing human activity at a given point in time and space, whereas artefacts are actually the result of dynamic human processes (Kroeber 1952; Stark 1998). Moreover, ethnographic studies have shown that there is rarely a straightforward correlation between an ethnic group (the concept often implicit in the notion of culture history), and a particular form of material culture, burial practice, or subsistence basis (Jones 1997; Shennan 1989).

An alternative approach focuses on how social structure guides behaviours or practices, which may be imprinted in the result of materialistic endeavours (Dietler and Herbich 1998; Druc 2013; Struever and Houart 1972). Moreover, this approach allows for archaeologists to move between various spatial scales. For example, one’s most intense relationships, with family members for instance, may have a much greater effect on one’s personal identity than links he or she shares with people outside this primary group or with others indirectly connected through these secondary acquaintances. However, ideas may eventually permeate throughout a geographically dispersed extended social network through inter-marriage, the establishment of long-term trade partnerships, or other binding socio-economic relations (Gamble 1998; Gosselain 2008: 71-72). The artefacts and architecture produced by members of this broader social network may be recognized as a roughly similar form of material culture shared by interconnected agents. As such, patterns resulting from the distribution of material culture across the landscape are better viewed as a series of relationships among individuals rather than as scatters of artefacts taken to indirectly represent people. This thesis adopts such a relational view through the use of network analysis in an effort to overcome overtly top-down models that seem to be concerned with the categorization of material culture according to rather arbitrary and strict guidelines. While a truly bottom-up perspective, which mirrors top-down approaches, would account for the actions and interactions of agentic individuals, such a detailed model may be optimally applied in cases wherein the data exhibits finer resolution (cf. Gosselain 2008; Mills et al. 2013). In contexts such as that examined in this thesis, this is not entirely feasible.

In order to determine how temporal scale should be adequately addressed it may be sensible to drawn from the Annales School of historical thought, an approach that explicitly evaluates and attempts to recognize the interplay between temporal scales, in order to consider what kinds of questions can be asked of the data at hand (Smith 1992). Braudel (1972) outlined four rhythms of temporal change, organized as an embedded hierarchy pertaining to scale. 'Events' concern individual actions that generally occur on the scale of the human lifetime (Braudel 1972: 21). Examples might include battles, treaties, or other actions taken by decisive individuals. 'Intermediate-term conjunctures' correspond with trends and drawn-out activities such as wars, price cycles or rates of industrialization (Braudel 1972:899). Similarly, 'long-term conjunctions' refer to larger demographic movements or the shifting dimensions of states and empires (Braudel 1972: 899). Braudel (1972: 20) refers to these latter two rhythms as the realm of "social history”. The ‘*longue durée*’ refers to the slow and continuous relationship between humans and their environments (Braudel 1972: 20). These rhythms of temporal change are illustrated in Figure 2.1 as a series of waves of different frequencies (Roddick 2014, personal communication).

The Annales School is a helpful construct for archaeologists because it is a flexible framework that may be used to reference how time is being considered, and what kinds of processes are being evaluated (Knapp 1992:13-14). Much of the material from Neolithic and Chalcolithic contexts in southwest Asia and Anatolia tend be associated with broad temporal periods due to chronological limitations. However, the archaeological record is actually representative of shorter-term processes, read by archaeologists as a palimpsest of human activity, whose specific and varied authors cannot be untangled. Although the actions and activities of individuals are not the primary focus of this thesis, I do not ignore them either; through a more holistic approach to examining the ways in which obsidian artefacts were transformed and transported, individualistic aspects are raised throughout the discussion of results.

While the culture history of southwest Asia and Anatolia and the temporal framework employed for this thesis may be presented in somewhat rigid ways, the transformations that occurred throughout the Neolithic and Chalcolithic periods should be considered to have been more fluid in nature. From top-down perspectives cultural boundaries are constructed based upon the distribution of recognizable attributes within space and time, however by thinking about the processes that underlie such static manifestations, a more realistic way of understanding and delimiting cultural variability may be realized.

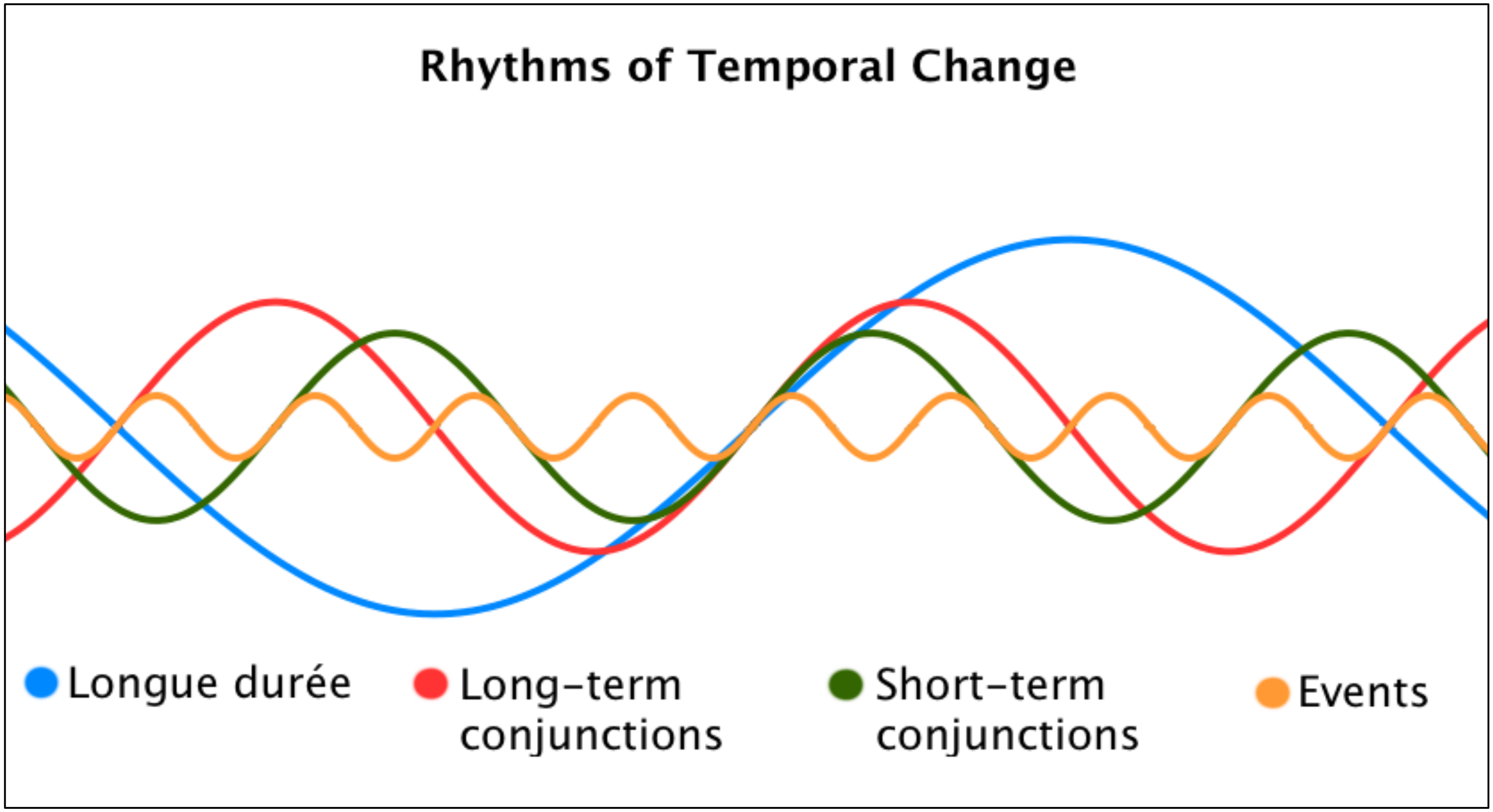


Figure 2.1 Braudel's rhythms of temporal change. Derived from Roddick 2014, personal communication.

2.2 The chrono-cultural framework of the thesis

2.2.1 Overview

In this section I provide an overview of the temporal-spatial contexts within which this thesis is set. The features and developments that characterize each period are outlined, and common threads of discussion concerning regional interaction are emphasized. This summary it meant to familiarize the reader with this project's setting and to act as a point of reference for drawing comparisons against the results of the analyses conducted for this thesis.

2.2.2 Period 1 (12,000 – 10,300 B.P.)

The Neolithic period of southwest Asia and Anatolia is divided into a number of phases, with one major division established between the earlier communities that lacked potting traditions, i.e. an Aceramic Neolithic (also referred to as the Pre-Pottery Neolithic), and subsequent Pottery Neolithic phases. In the southern Levant archaeologists further subdivide the former period into Pre-Pottery Neolithic A and B (PPNA and PPNB), based on a scheme first suggested by Kenyon (1960) on the basis of the stratigraphic sequence at Jericho. This scheme has been adopted by many (but not all [cf. Moore 2000]) in the northern Levant, Middle Euphrates and south-eastern Anatolia. As shall be seen below, these terms have ultimately become synonymous with cultural expression as much as a temporal phase, defined not only on the basis of their position within a temporal scheme, but also through their common archaeological traditions. As such, maps have been generated to document the spatial extents of the PPNA and PPNB 'worlds' (cf. Bar-Yosef 2001; Kuijt and Goring-Morris 2002). However the use of this temporal-cultural terminology to characterize sites in certain regions has been contested by those who believe that it does not do justice to the distinct regional traditions of the northern Levant / Mesopotamia, and central Anatolia (Moore et al 2000; Özbarasan and Buitenhus 2002).

It should also be noted that the term PPNC, to denote a final aceramic Neolithic phase, is employed in some areas of the southern Levant; it does not have such widespread use however as PPNA and PPNB, due to an increased regionalism towards the end of the 8th millennium BC (Rollefson 1989).

Returning to the specificities of Period 1, we are here dealing with the archaeology of the latest Epi-Palaeolithic and PPNA periods. The former is constituted by the so-called Natufian culture of the Levant. These 'people' are known to have lived sedentary lifestyles; indeed the first settled villages of the larger region (if not globally), as documented through the construction of subterranean roundhouses and evidence of year-round occupation (Bar-Yosef and Belfer-Cohen 1989; Kuijt et al 2009). Their subsistence, however, remained based on the exploitation of a broad spectrum of wild animals and plants.

The most important development that occurred during the subsequent PPNA, which is the main focus of Period 1, was the development of agriculture, specifically that of cereal cultivation (Bar-Yosef 1989:61). Additionally, archaeological finds imbued with symbolism and spiritual connotations, along with the evidence of maritime activity, suggest that complex forms of socio-political organization were further developed (Cauvin 2000; Farr 2006; Knapp 2010).

The PPNA has been classified by Bar-Yosef (1989) on the basis of a range of shared features amongst the (primarily) Levantine sites of the period, namely: round subterranean architecture, blade-based lithic technologies (including sickle blades), a common subsistence basis of cereals and hunting, plus elaborate burial practices, including special treatment of human skulls (a practice first seen in the Natufian). These

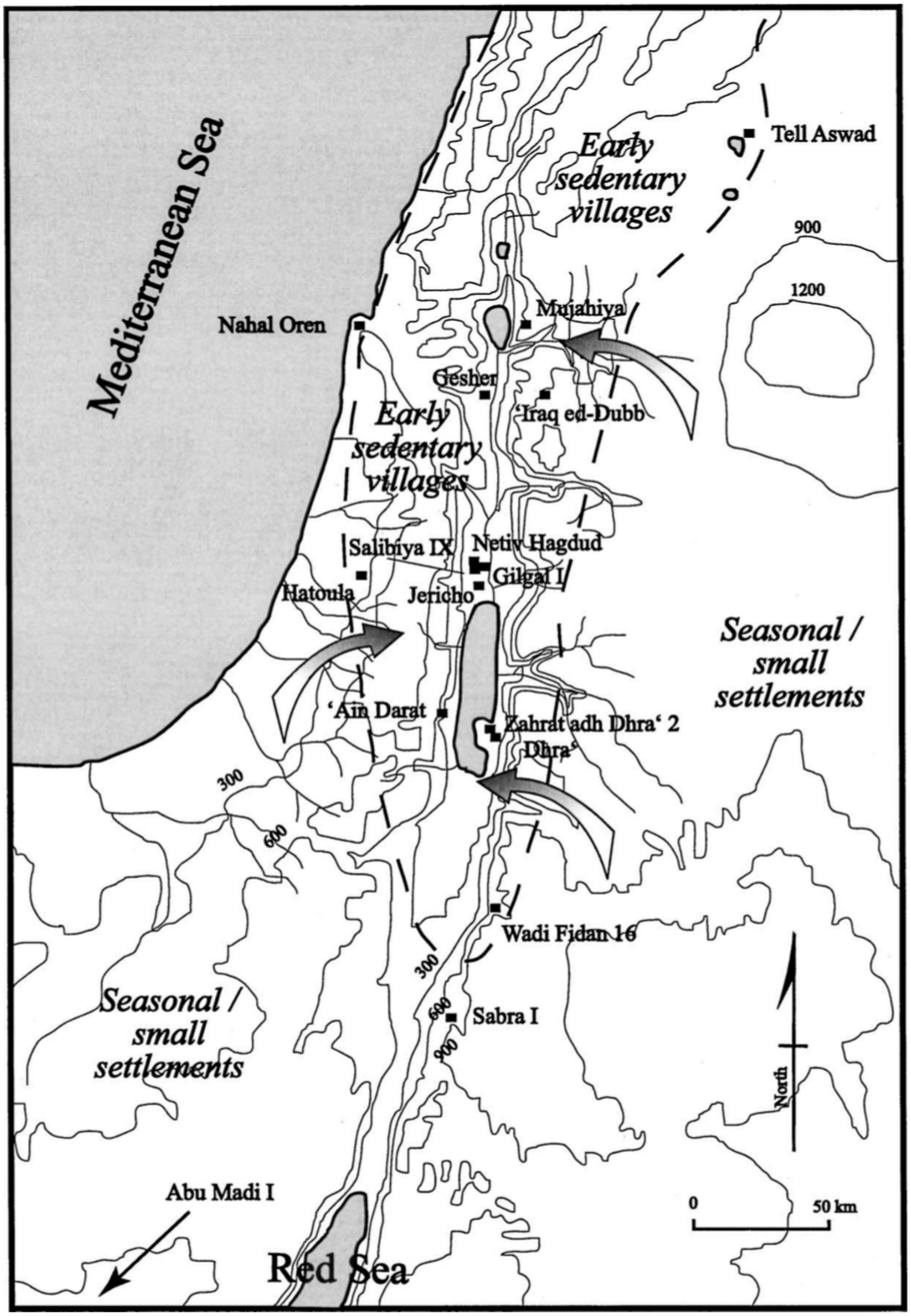


Figure 2.2 – The geographical extent of the PPNA cultural entity (from Kuijt and Goring-Morris 2002).

features have been uncovered at sites throughout the Levant, prompting Kuijt and Goring-Morris (2002:369-372) to outline the boundaries of this cultural entity (Figure 2.2). More recently, work on the nearby island of Cyprus has discovered contemporary sites whose dwellings and material culture show broad similarities to the Levant, leading to the use of the PPNA temporal-cultural terminology here as well (Knapp 2010). In their map and brief section devoted to evaluation of the geographical extent of PPNA attributes, Kuijt and Goring-Morris (2002) did not evaluate variability among sites exhibiting these features, although they did recognize the need to acknowledge heterogeneity within this cultural complex.

As alluded to earlier, the mechanisms that might have led to the adoption of such common traditions of living, tool making and subsistence, may have included the establishment of inter-community relations articulated through the gifting and exchange of meaningful goods such as obsidian. These relations might be conceptualised in terms of trade partnerships or other binding socio-economic relationships such as inter-marriage or the cooperative exchange of resources. Finds of obsidian and greenstone in the Levant are key indicators that long-distance exchange mechanisms were in place, and various efforts, including this thesis, have been made to better understand regional interactions using this material (Carter et al. 2013; Cauvin and Chataigner 1998; Delerue 2007; Frahm 2010, *inter alia*). Moreover, the major PPNA sites of Wadi Faynan 16 in southern Jordan and Göbekli Tepe in southern Turkey have been proposed as central gathering places where the inhabitants of surrounding regions would set up camp, engage in ritualistic activity, or exchange physical objects and ideas (Finlayson and Mithen 2007; Renfrew 2013; Schmidt 2000).

2.2.3 Period 2 (10,300 – 8600 B.P.)

Period 2, which is largely aligned with the PPNB, was a period of major population growth and an increased number of settlements. Demographic increase is viewed by many as the combined product of settled life (which is linked to diminished infant mortality), and cereal cultivation, to which we can now add animal domestication that appears for the first time in the PPNB (Bocquet-Appel and Bar-Yosef 2008; Horwitz et al 1999). This period witnesses the development of a number of so-called 'mega-sites', i.e. regional centres with thousands of inhabitants (Bocquet-Appel and Bar-Yosef 2008). The increased volume and distance of obsidian circulation at this time also suggests that systems of regional interaction were further intensified.

One result of these developments was the perpetuation of what Gamble (1998) referred to as the 'release from proximity', the construction of a social landscape beyond the scope of one's closest relations. While Gamble (1998) was more concerned with the initial formation of such extended social systems during the Palaeolithic period, the inhabitants of the PPNB mega-sites were the first people to recurrently take part in these larger-scale systems of interaction, This would have introduced novel ways of thinking about ones situation in the broader social landscape, and prompted more meaningful imprinting of social relationships on to objects and architecture (Byrd 1994; Dunbar 2008; Gamble 1998; Hodder 2004).

As in the PPNA, the PPNB 'world' is defined by a shared set of material culture and practices (including rectangular houses, large projectiles, agro-pastoral regimes, *inter alia*) which can be mapped throughout the Levant, Cyprus, south-eastern Anatolia, northern Mesopotamia, and along the flanks of the Zagros Mountains. This area has been referred to as the 'PPNB interaction sphere' (Figure 2.3) (Bar-Yosef and Belfer Cohen 1989; Cauvin 2000). It has been suggested that this culture originated in the upper

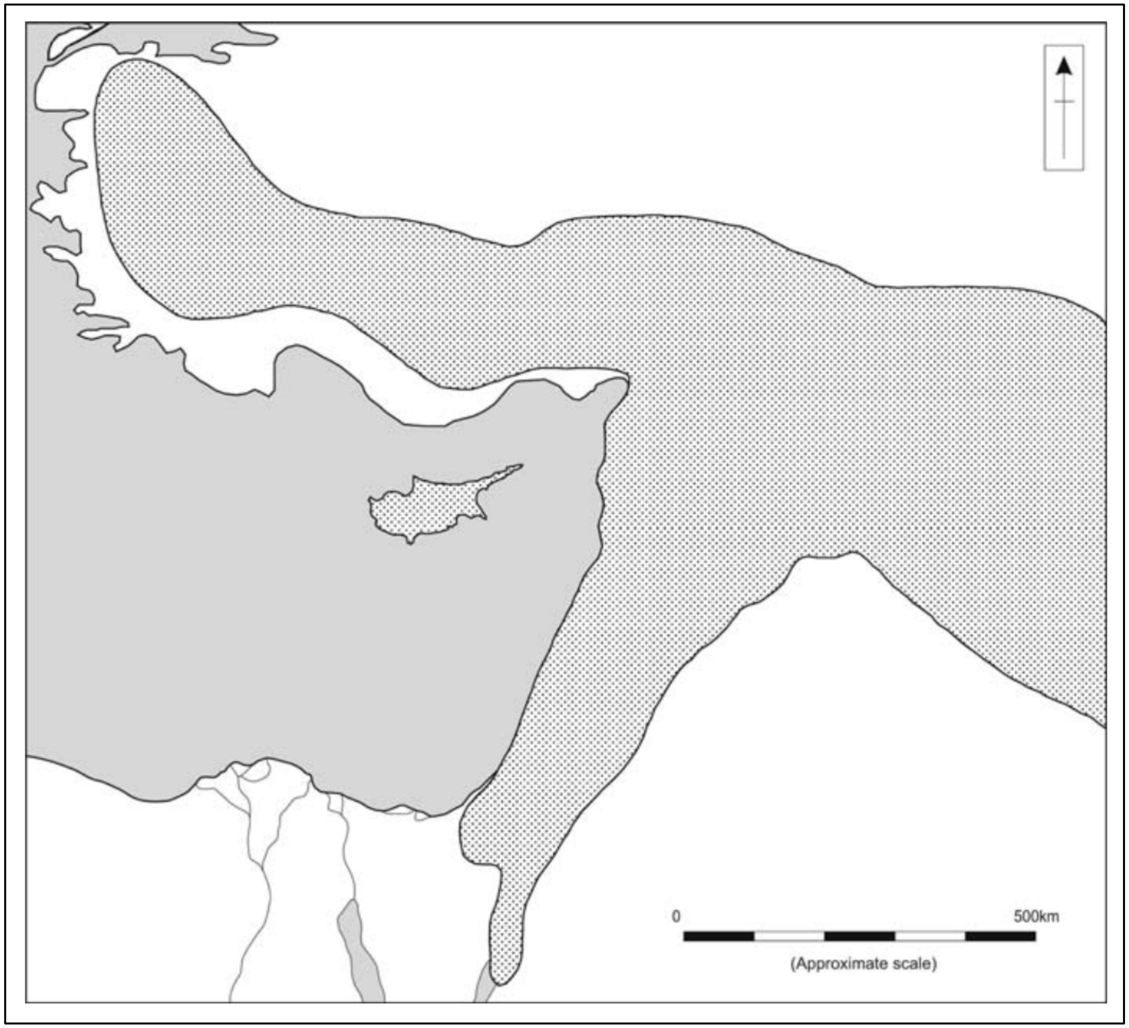


Figure 2.3 – The spatial extent of the PPNB interaction sphere (from Bar-Yosef 2001, reproduced in Asouti 2006).

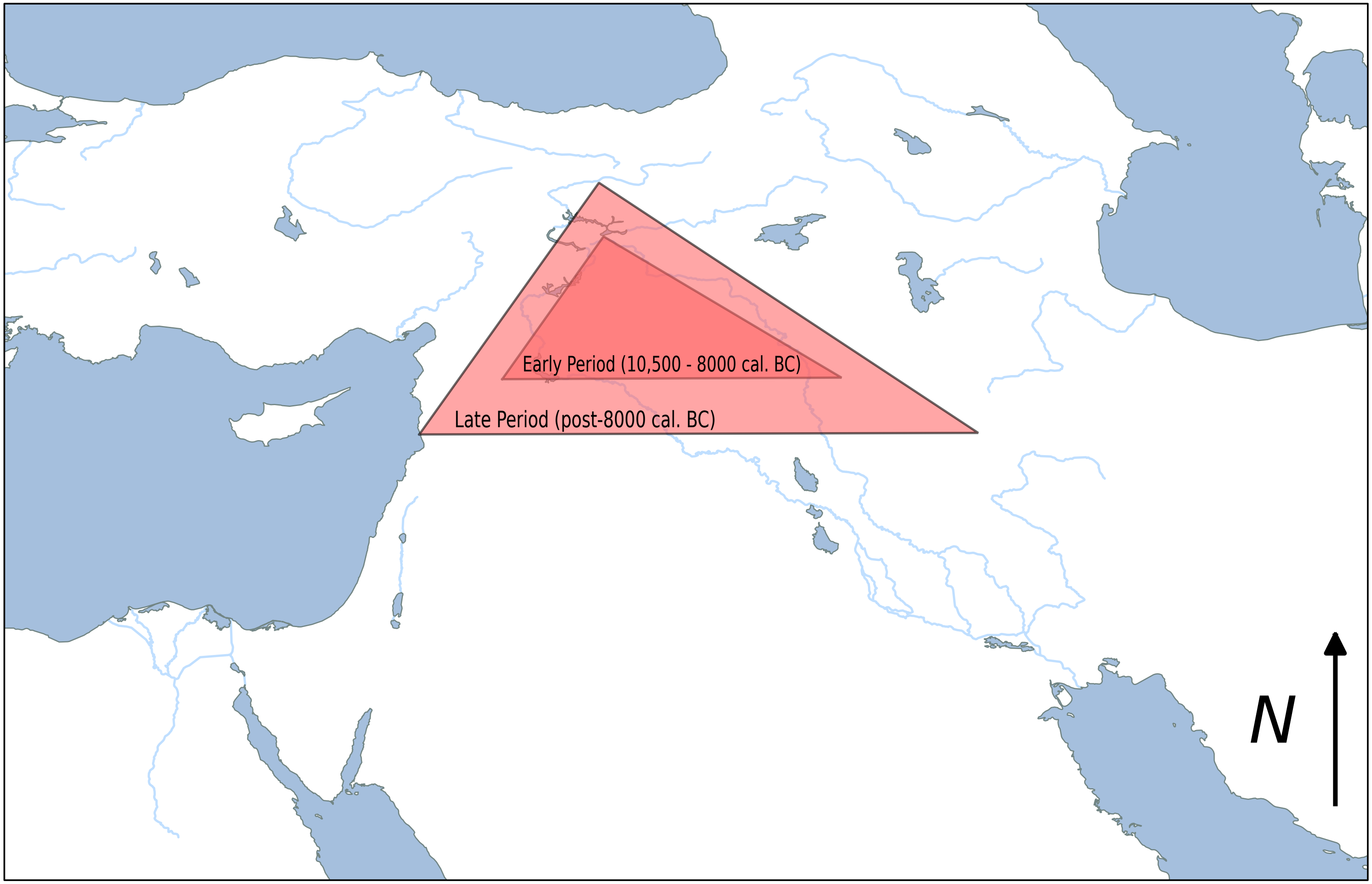


Figure 2.4 – Kozlowski and Aurenche's 'golden triangle' (from Kozlowksi and Aurenche 2005).

Euphrates basin, as evident by a gradual increase in the proportion of pressure-flaked tools and groundstone artefacts (which have come to be diagnostic of this interaction sphere) in this region early on, with similar trends documented elsewhere dated slightly later (Shea 2013:278). Moreover, Kozlowski and Aurenche (2005) identified geographically-dispersed subgroups of the PPNB culture, made apparent by examining the distributions of different kinds of arrowheads, which appear in greater frequency throughout the Levant at this time. However this approach is patently reductionist, since the authors suggest that single types of artefacts can represent cultural group. Moreover, Kozlowski and Aurenche (2005) support the position that the major developments that occurred throughout the Aceramic Neolithic originated along the upper Euphrates in a zone that they refer to as the 'golden triangle', however they do not sufficient explain *how* these developments became adopted in neighbouring regions (Figure 2.4).

Interestingly, much of the discussion concerning the classification of sites within cultural categories, and the recent challenges posed by proponents of alternative models that emphasize the fluidity of cultural processes – as discussed in the previous section – arose out of how the PPNB interaction sphere was defined and characterized (cf. Asouti 2006; Watkins 2008). The case for a common thread between sites in the Levant, Cyprus, the Fertile Crescent and much of southern Anatolia is indeed quite convincing, however its focus on geographical distribution without discussing the mechanisms by which such features were distributed is a hindrance.

In fact, archaeological discussion focused on the PPNB is primarily centred on the regions of the Levant, northern Syria and western Anatolia. Although aceramic sites in the eastern portion of the study area are mostly uncovered either in central Anatolia or along the base of the Zagros Mountains, they tend to be more dispersed at this time, making it difficult to document broader trends in the archaeological record. Nevertheless these sites represent the earliest indications of semi-sedentary habitation of these areas that would later grow into much larger regional centres (Aurenche 1987:85-86).

2.2.4 Period 3 (8600 – 8000 B.P.)

Period 3 corresponds with a phase spanning the tail end of the PPNB in the Levant and the beginning of the Pottery Neolithic towards the east (via the PPNC in those regions where the term is used [Rollefson 1989]). It is generally understood that this phase oversaw large population displacements, largely due to the shift to more nomadic pastoral regimes, changes that may have been related to climate change (Köhler-Rollefson 1988; Rollefson and Köhler-Rollefson 1993; Russel 2010; van der Plicht et al 2011). Another significant innovation of the period is the alleged first use of seal stamps, which were used to impress proprietary imagery upon protected goods, that, when broken, indicate that the contents were tampered with or accessed without authorization. The use of seal stamps indicates that notions of private ownership, perhaps relating to the storage of grain, were being developed, a practice that would have presumably led to some form of social stratification (Akkermans and Duistermaat 2004).

Garfinkel (2011) also noted that obsidian was circulated in reduced volumes, and suggested that this is reflective of the heterogeneity of recognizable cultures in the Levant at this time. His proposition that the presence of obsidian – or lack thereof – may be an indicator of the degree of cultural contact highlights the need to examine interactions among populations. However Garfinkel (2011) did not actually look at this variability as expressed through obsidian (i.e. raw material variability, or how it was worked), which may help to better understand the nature of these interconnections.

2.2.5 Period 4 (8000 – 7000 B.P.)

Period 4 corresponds with a large portion of the Pottery Neolithic, which is ordered temporally and spatially according to the distribution of various ceramic styles. The Samarra, Hassuna and Halaf pottery traditions, which feature very complex painted geometric, anthropomorphic and zoomorphic designs, existed roughly concurrently throughout the Levant and northern Mesopotamia, however the Halaf style had the widest geographical distribution and extended later into time. These distinctive ceramic traditions have been conflated into culture types.

Many view the Halafian culture as the product of chiefly societies due to evidence of craft specialization, distinctions in domestic architecture, intensified long-distance exchange and new emphases on personal adornment (Akkermans 2000; Campbell 2000; Carter et al. 2003; Frangipane 2007). Frangipane (2007) has more succinctly suggested that the rapid extension of Halaf material culture at this time should not be represented as the widening of a seemingly homogenized cultural unit, but instead as the extension of a series of actions and interactions among dispersed populations, which were primarily cooperative efforts to optimize agricultural and pastoral output. This notion that the Halaf was a non-centralized society is supported by the earlier work of LeBlanc and Watson (1973) who quantitatively compared decorative motifs on painted Halaf pottery from assemblages pertaining to various locales within the zone of Halaf influence, and found that immense variability did exist. Moreover, the authors found that distance between sites strongly correlated with the degree of stylistic differences, which reinforces the conception of the Halaf as a spatially distributed array of material culture representing peoples exhibiting their own idiosyncrasies. In light of evidence hinting at the beginnings of hierarchical social structures (such as seal stones and public architecture), and the relative lack of diversity of material culture during directly previous times, the trade in

Halaf pottery is interpreted as a form of communication among elite members of neighbouring communities (Akkermans 2000:43; Le Blanc and Watson 1973).

Additionally, decorative items made from obsidian, such as beads and pendants, have been more commonly uncovered in Halaf contexts (Belcher 2011; Campbell 2000:21-22; Campbell and Healey 2013; Healey 2007). Their aesthetic properties and high costs of production further illustrate the desire and capability of certain individuals to distinguish themselves among their peers (Healey 2007:183; Healey and Campbell 2014). Moreover, the ability to procure the raw materials necessary for the production of these adornments would have influenced ones ability to produce these items. Thus, position within a more widespread system of regional interaction and exchange would have been crucial for amassing positive recognition. Based upon these observations, the Halaf is seen to represent a radical break from previous ways of life, wherein the regional system of interaction may be characterized as commensal in nature, although not without the potential for social strata to emerge.

The Ubaid culture also developed into a regional phenomenon around this time in southern Mesopotamia. It is most commonly associated with a style of pottery whose decorative designs feature geometric patterns that encircle typically closed neck vessels. These patterns have led certain archaeologists to believe that Ubaid pottery may have been a variant of northern styles, with motifs adapted by the local culture and applied through the additional use of the slow-wheel (or *tournette*) in the decorative process (Nissen 2001:167-169). However the exact nature of the relationship between northern and southern communities, as read through ceramic traditions, remains hotly debated, and is elaborated upon in greater detail in the next section pertaining to Period 5.

2.2.6 Period 5 (7000 – 6500 B.P.)

During Period 5 the Ubaid pottery tradition became widely adopted towards the north, however the mechanisms of its introduction remain ardently debated (Akkermans and Schwartz 2003:157-159; Stein 2010). The changing distributions of different pottery traditions at this time suggest that there was a dynamic and reciprocal cultural exchange occurring between northern and southern populations (Karsgaard 2010), however the dramatic change in settlement pattern between the Halaf and Ubaid in northern Mesopotamia also suggests that larger population movements were occurring, and some scholars (Breniquet 1996; Forest 1996) have interpreted these demographic shifts as reactions to more forceful conflicts or intense competition.

Through evaluation of the social implications of ceramic production and use, Karsgaard (2010) highlighted certain differences regarding socio-political behaviours pertaining to the Halaf and Ubaid cultures. Specifically, he contrasted the more simplistic and closed-neck Ubaid designs that started to appear in northern Mesopotamia, with the hand-painted and rather individualistic open vessels that characterized the Samarra, Hassuna and Halaf pottery traditions. To synthesize, Karsgaard (2010) concluded that the introduction of Ubaid material culture in the north would have enabled more commensal relationships among individuals through sharing of food or drink derived from the same container, and signalled participation in communal activities through the use of similarly decorated vessels (Karsgaard 2010).

This can also be viewed as the first major period of metals' use in the Levant and Anatolia (native copper artefacts were manufactured in tiny numbers from the PPNA [Molist et al. 2009]). Copper artefacts have been found in hoards or burial contexts, and have prompted debate concerning the nature of socio-political organization in these settings as well (Golden 2009; Moorey 1988; Rowan and Golden 2009:66-69).

Metalworking seems to have been unevenly distributed, with metal artefacts being found in huge quantities in certain locales, but with nearly none in others (Rowan and Golden 2009:66-67). This poses concerns about the role of the metal industry in the potential formation of hierarchical social structures. Settlement patterns are quite distributed, and intense exchange between sites at an intra-regional scale is notable; specifically, such exchange seems to have occurred with the aim of acquiring resources such as basalt and bitumen, materials that are only available in highly localized areas in the Levant (basalt from the Golan region, and bitumen from the Dead Sea), and that have been found in archaeological contexts indicative of ritual activities (Rowan and Golden 2009:65-67). Moreover, exotic goods such as turquoise and gold were sought after from the Sinai Peninsula and either Nubia or the Ural Mountains respectively, and have been uncovered in small quantities at very few sites (Rowan and Golden 2009:54, 68). Obsidian derived from Anatolia is rather uncommon in the Levant relative to prior periods, which suggests that access or desire for these materials was diminished (Rowan and Golden 2009:62; Yellin et al. 1996). These trends insinuate that the system of supra-regional interaction in the Levant was being reconfigured to further incorporate ties towards the southwest (Yellin et al. 1996:367).

The notion that metallurgy was a primary contributor the development of chiefdom-like societies has recently been downplayed in light of these observations. Instead, models of commensal competition with respect to the management and distribution of local commodities, wherein some individuals have benefitted more than others, are generally accepted. Social distinction may have been amplified by access to exotic goods. Moreover, the enactment of ritual or religious behaviour that occurred in dedicated settings may also have played a substantial role in the differentiation of elite individuals (Rowan and Ilan 2007).

2.2.7 Period 6 (6500 – 6100 B.P.)

During Period 6 the Ubaid culture underwent transformations in two different ways. In northern Mesopotamia, where there are more signs of metalworking having been practiced, settlements patterns point towards the dispersal of communities, which became more locally autonomous and socially stratified. While associations with the Ubaid have diminished, as recognized through the gradual disappearance of Ubaid-style pottery, a few sites exhibit clear continuity from the prior period (Stein 2009, 2012:131). Meanwhile towards the south, massive population growth occurred due to the sudden availability of key agricultural land along the major rivers. Nissen (2001:171) suggested that the heightened roles of complex administrations and temples might have been resolutions to the inevitable conflicts and social problems that arose due to the population increase and demographic shifts.

2.2.8 Period 7 (6100 – 5700 B.P.)

The massive population increase in southern Mesopotamia, which gave rise to the Uruk period city-states during Period 7, was spurned by agricultural surpluses, which many argue led to the development of writing and texts as a mechanism to manage the receipt, storage and redistribution of these commodities (Nissen 1993). This period also sees the appearance of significant Uruk cultural influence in northern Mesopotamia, south-eastern Anatolia and the Iranian Highlands, which Algaze (1993) famously interpreted as the result of expansionist practices. These alleged 'Uruk colonies' were supposedly established as gateway communities with the aim of channelling metals and other non-local goods back to the city-states of resource-poor southern Mesopotamia. Although it has since been argued convincingly that these 'colonies' were largely independent and cooperative entities that exhibited continuity from previous local habitations, the overt attendance of southern representatives in the north clearly represents a reconfiguration of regional interaction that may have underscored a form of economic dominance (Algaze 1993; Henrickson 1994; Stein 1999). Although later interactions between northern and southern Mesopotamia, which may perhaps be better understood through written or glyptic evidence, are also quite captivating, ultimately such topics extend beyond the chronological scope of this thesis.

2.2.9 Final remarks

This overview of the prehistory of southwest Asia and Anatolia is quite brief, but hopefully familiarizes the reader with the archaeological setting and contextualizes the analyses conducted for this thesis. Emphasis was placed on interconnectivity at a regional scale and the delimitation of cultural boundaries, since these are topics that this thesis is particular geared to address. This summary thus acts as a reference, whereby the findings obtained through network analysis may be compared with the more established understandings of regional interaction presented here. However before such comparisons are made, it is necessary to consider how examination of obsidian circulation may be useful for critically engaging with these debates and cultural constructs, and how network analysis may be used as a methodology to reach such an end. These considerations will be explored throughout the next two chapters of this thesis.

3 – OBSIDIAN AND ITS ARCHAEOLOGICAL IMPLICATIONS

3.1 Prehistoric use

Due to its homogeneity (as a glass it is isotropic), obsidian is the easiest and most controllable of all raw materials with a conchoidal fracture habit to flake, or knap (Crabtree 1977:17-19; Whittaker 2010:69). Moreover, when freshly flaked, obsidian's edges are razor sharp, though being a glass it is also very brittle. Thus throughout prehistory obsidian has been a choice raw material for the manufacture of fine cutting tools, rather than heavy duty implements such as axes (aside from the Lower-Middle Palaeolithic, see Carter 2014). Lithic artefacts are made by fracturing part of the material from a larger piece. The latter piece is called the core, and the components removed from it are called flakes, with 'blades' being pieces that were deliberately flaked to be elongated in form, at least twice as long as they were wide (Shea 2013:32). Detailed study of associated production debris may allow an archaeologist to recognise waste material distinctive of particular knapping traditions, even if the end-products themselves are missing. Due to obsidian's versatility as a knapped material, a wide variety of lithic artefacts can be produced. Morphological diversity is recognized by archaeologists as a typological sequence. Additionally, the mode or technology of manufacture can be deduced by examining the scarring patterns or surfaces of cores and flakes. Lithic analysis is an archaeological specialty in its own right, and in the interest of brevity a definitive overview is not included here (see Odell 2004; Shea 2013, *inter alia*). In the region under consideration there can be significant temporal and regional variability in the types of tools that were being made, and the specific manners in which they were produced. These distinctions in morphology and manufacture (typology and technology) can sometimes have distinct temporal and spatial boundaries, whereby certain tool-types or manufacturing processes are used by archaeologists as chronological indices (i.e.

helping to date the site), or for claimed reflections of cultural behaviour (Shea 2013:39-46). For example, the distinctive 'opposed platform' blade technology, whose end-products were recurrently shaped into large projectiles, was once seen as a hallmark of the PPNB period/culture (Bar-Yosef 2001).

From the later Neolithic onwards we also see obsidian being occasionally employed to make beads, pendants, mirrors and decorative vessels (Astruc et al. 2011). This thesis concentrates on chipped/flaked stone tools and their associated manufacturing debris (cores, flakes inter alia), focusing on the social processes surrounding raw material procurement and the circulation of end-products (cf. Rosen 1996).

3.2 Obsidian as an archaeological material

3.2.1 Geology and the physical / chemical properties of obsidian

Obsidian is a naturally occurring volcanic glass that forms from the rapid cooling process of silica-rich magma, which causes it to vitrify rather than crystallize into a rock (Pollard and Heron 2008:77). Obsidian is found naturally at highly localized rhyolitic lava flows, with sources scattered at various locations across the globe. In southwest Asia and Anatolia the primary obsidian sources of archaeological significance are located in central and eastern Turkey (Cappadocia and the Lake Van regions respectively), plus Armenia/Transcaucasia (see Figure 5.1).

Obsidian is vitreous and often has a translucent appearance. It is typically dark grey or black in colour (making visual discrimination of different source products difficult, if not impossible), though some raw materials may range from dark brown to green due to their elemental make-up. It is obsidian's chemical composition that makes the material so valuable for the study of prehistoric interaction. Obsidian is primarily made of Silica (65-75% SiO_2), the remainder is comprised of major and trace elements of varying concentrations based on its source, i.e. each volcanic flow has a unique chemical signature, or 'fingerprint' (Pollard and Heron 2008:77).

3.2.2 Chemical characterization methods

Over the past 50 years multidisciplinary teams of archaeologists, geologists and geographers have been working to locate, map, and characterize these volcanic outcrops, developing various methods – primarily geochemical – to discriminate the volcano's products from all others (see Carter in press for a detailed overview of the development of obsidian characterization methods).

Today the most common means of sourcing the raw material used to make an obsidian tool is through reference to its elemental composition. The methodological basis of this approach is that the product of each volcano is unique at the trace elemental level, whereby the analyst aims to characterise the elemental fingerprint of the archaeological obsidian, which is then matched to the chemical signature of a unique source (Pollard and Heron 2008). Over time many instrumental methods have been employed to achieve this aim, their use coming with varying degrees of benefits and costs. These include Instrumental Neutron Activation Analysis (INAA), Inductively Coupled Plasma (ICP), Particle Induced X-Ray Emission (PIXE) and X-Ray Fluorescence (XRF). Each of these techniques offer precise measurements of chemical concentrations, the first three providing the greatest potential range of elements to be analysed (Pollard and Heron 2008:83-85). That said, INAA and ICP-MS are both destructive techniques and expensive, both of which may limit their application for reasons of cultural sensitivity, bureaucracy and finance (Laser Ablation-ICP-MS however involves only a micro-destructive process, leaving crater pits up to 100 μm in diameter (Carter et al. 2006; Gratuze et al. 2001).

When analyzing artefacts generally it is always preferable to use methods that ensure its preservation in accordance with ethical standards, and so it can be incorporated in further research later on. For these reasons one may prefer to use non-destructive techniques such as PIXE or XRF to characterize obsidian artefacts. New portable XRF techniques also offer the ability to analyze artefacts or geological samples in the field or in museums, or where it may not be possible to move artefacts to a lab-based technique (Frahm et al. 2013; et al. 2014; Poupeau et al. 2010). In certain contexts it is possible to use Scanning Electron Microscopy (SEM) techniques in a non-destructive manner to discriminate obsidian sources on the basis of their *major* elemental concentrations. For example SEM can distinguish a number – but not all - of the major Anatolian source products (Orange et al. 2013; Poupeau et al. 2010).

On the basis of these characterisation studies, archaeologists are able to source the raw materials used to make the obsidian tools found at their sites, through matching the chemical composition of the artefact with the elemental profiles of a specific geological source (Tykot 2003:63). Obsidian artefacts are often found at locations very far from the sources of raw material, and by properly determining which ones were exploited by the inhabitants of distant sites archaeologists can investigate the extent of early regional interaction and reconstruct patterns of obsidian use that may reflect social processes (Pollard and Heron 2008:87-91; Renfrew and Bahn 2008:376-377).

3.2.3 Major obsidian sources of southwest Asia and Anatolia

For the prehistoric populations of southwest Asia and Anatolia, the most important obsidian sources for making tools were located in four main regions: in south-central Turkey (Cappadocia), in eastern Turkey (the Lake Van region), in northeast Turkey, and in Armenia. Numerous sources exist in each of these regions, some of which have very complex obsidian flows exhibiting diverse geochemical properties (see Poidevin 1998 for a detailed overview).

As is apparent in the results of this thesis, for much of the time-span under consideration (the Neolithic and Chalcolithic Periods, c. 12,000 – 5700 BP) the obsidian of three main volcanic complexes represents the main raw materials exploited by distant populations, namely Göllü Dağ in southern Cappadocia, plus Bingöl and Nemrut Dağ in southeastern Anatolia (the sources labelled 2, 6 and 8 in Figure 5.1, respectively). From the later 8th millennium BC onwards other sources are used more frequently, including Nenezi Dağ and Acıgöl (Cappadocia), Meydan Dağ on the north shore of Lake Van, and the location-unknown 'Source 3d' products (Chataigner 1998: 316-319), amongst others.

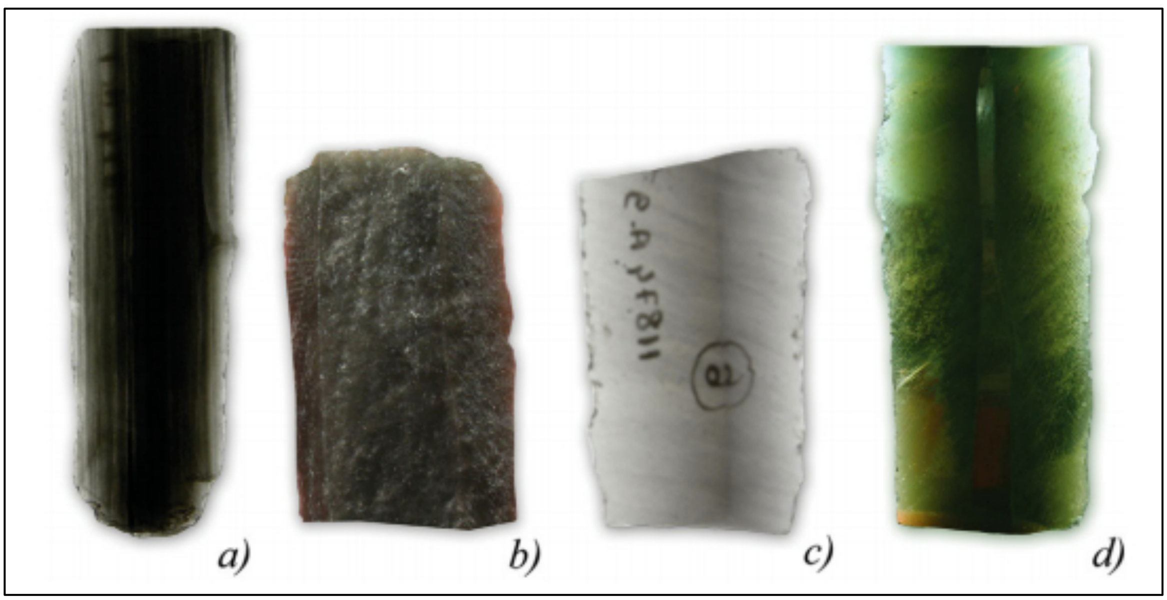


Figure 3.1 – Obsidian blades made from material derived from various sources: a-b) Nenezi Dağ; c) Göllü Dağ East; and d) Bingöl A / Nemrut Dağ (from Carter et al. 2008).

3.3 Analysis of lithic assemblages

An aggregation of lithic artefacts deriving from a specific context is called an assemblage. Assemblages are assessed by examining their configurations, which is expressed in terms of the proportions of artefacts exhibiting certain properties. When examining each artefact, information can be gained regarding four vectors of information: raw material, technology, morphology and function (Odell 2004:89, Figure 4.1). Individual artefacts can be fully assessed by assigning values to each of these classes of information, and in a similar vein, the diversity of the entire assemblage can be determined by counting and comparing the number of instances where the values are apparent. The compositions of lithic assemblages are usually tabulated or recorded in the form of ratios comparing one value to another.

Documenting entire lithic assemblages can also help archaeologists determine what activities were occurring at the site (Odell 2004:91-103). For instance, if only finished tools are uncovered then the site could be characterized by a certain activity (e.g. an assemblage dominated by projectiles might be interpreted as a hunting stand), and further, it can be argued that the people there were reliant on others for originally procuring the raw material and working it into tools. Clearly this information can be very useful for assessing the nature of a site in terms of its connectivity and potential role in relation to others (the power dynamics of supplied and supplier for example).

Obsidian is not the only material used for the production of chipped stone artefacts. Tools made from other lithic resources such as chert, radiolarite, chalcedony and quartzite may also make up a portion of lithic assemblages (as indeed they were in the area under consideration), which may have been selected due to their availability or their physical properties (Odell 2004:193-202). These alternative raw materials will not be discussed further in this thesis, except when referencing a site's complete stone tool assemblage and the relative proportion of obsidian artefacts to those made from other lithic resources.

Archaeologists have also examined lithic assemblages as an alleged means of assessing cultural distinctions. The recognition of contemporary sites with closely comparable lithic assemblages (in terms of tool types and raw materials) has been viewed by many to reflect a shared cultural tradition, potentially a manifestation of a common people (cf. Arnold 1988; Kozlowski and Aurenche 2005). However rather than focusing on raw material proportions or arrowhead types, evaluation of the specific ways in which objects were made (raw material choices / technical traditions), are now argued by many to be more informative of the occurrence of specific practices (Carter et al. 2013; Dobres and Hoffman 1994:213; Druc 2013). By noting variability along the trajectories of tool manufacture (*les chaînes d'opératoires*) at multiple sites and considering alternative production scenarios, markers of technological style, and other archaeological evidence that reflect group processes, one would be able to distinguish between the ways that communities treat materials and modify them according to local custom (Carter et al. 2013; Dietler and Herbich 1998:246-247).

3.4 Obsidian as a signifier of long-distance interaction

Alongside the advent of geochemical sourcing studies in the 1960s, was an interest in tracing the circulation of obsidian. While excavators may note the presence of obsidian at sites quite far from the volcanic sources, and interpret this as an indication that the inhabitants participated in exchange mechanisms that enabled the material to traverse such far distances, this does not touch on the specific processes by which it may have arrived at the context of deposition (Freund 2013:4-5). Even when obsidian artefacts are successfully paired with volcanic sources through geo-chemical analysis, the matter of determining the socio-economic mechanisms by which it was distributed consists of its own aims and challenges (Carter 2014, in press; Freund 2013; Torrence 1986).

3.5 Obsidian circulation studies

3.5.1 Lessons learned from an early obsidian circulation study

Obsidian is considered to be an excellent archaeological material for reconstructing patterns of regional interaction during prehistory. The material's durability ensures that it survives in the archaeological record, and the fact that it can be sourced in a relatively straightforward manner contributes immensely to archaeological understandings of early cultural contact and regional interaction. The principle aim of Cann and Renfrew (1964), who initiated this field of study, was to enable archaeologists to leverage this new form of data in order to reconstruct the mechanisms by which obsidian was carried across the landscape, along with ideas and other materials as well (Cann and Renfrew 1964:111-112; Pollard and Heron 2008:86).

After elementally characterizing geological samples collected from known obsidian sources throughout the Mediterranean, and matching their chemical signatures with those determined for archaeological obsidian as well, the originators of this methodology were able to source dozens of obsidian artefacts from prehistoric sites (Epi-Palaeolithic – Late Bronze Age) throughout the Aegean (Renfrew et al. 1965), Anatolia, and southwest Asia (Renfrew et al. 1966, 1968). The percentage of artefacts made from obsidian derived from a specific source was then determined for each assemblage, and the results were compared with measurements of distance from the source to the site (Figures 3.2 and 3.3). Renfrew (1968:326-330) noted that as the distance from the volcanic sources increased, the proportion of obsidian present decreased, what he referred to as a 'law of monotonic decrement'. After plotting this distance-decay relationship on a Cartesian plane, Renfrew speculated that the variable rates of decay might be indicative of economic systems that oversaw the materials' distribution across long distances. For instance, at a certain point the relative proportion of tools made of obsidian (in relation to those made of other raw materials) decreases significantly, which Renfrew interpreted as a delimitation between what he called the 'supply zone' – the area where it was worthwhile for populations to procure obsidian directly from the source – and the 'contact zone' – the area further afield where obsidian procurement was dependent on exchange (Renfrew et al. 1968:327-330; Renfrew 1969:157). In the contact zone, Renfrew suggested that this fall-off curve might be explained by a 'down-the-line' exchange mechanism, wherein sites would keep some material and pass some of it along to neighbours further from the obsidian source. Renfrew also speculated that the variable rates of decay might be indicative of different economic systems corresponding with the various types of socio-political organization outlined by Service (i.e. band, tribe, chiefdom, or state) (1962, 1975).

Torrence (1986:14) notes that this study is considered to be "extremely important for the history of research on prehistoric exchange because it was the first time an archaeologist had described the link between an anthropological model of primitive exchange … and the material consequences of it, which were potentially recoverable archaeologically". However there have also been concerns about the validity of proposing socio-economic models to explain the observed trends. Hodder and Orton (1976:138) suggested that the curve produced from Renfrew's observations could also have resulted from random-walk processes, raising concerns about the potential for equifinality when exploring artefact distribution in this way. More recently Ortega (et al. 2013) programmed a simulation based upon the mathematics that underlie the down-the-line model, and after running it, concluded that this exchange mechanism does not adequately

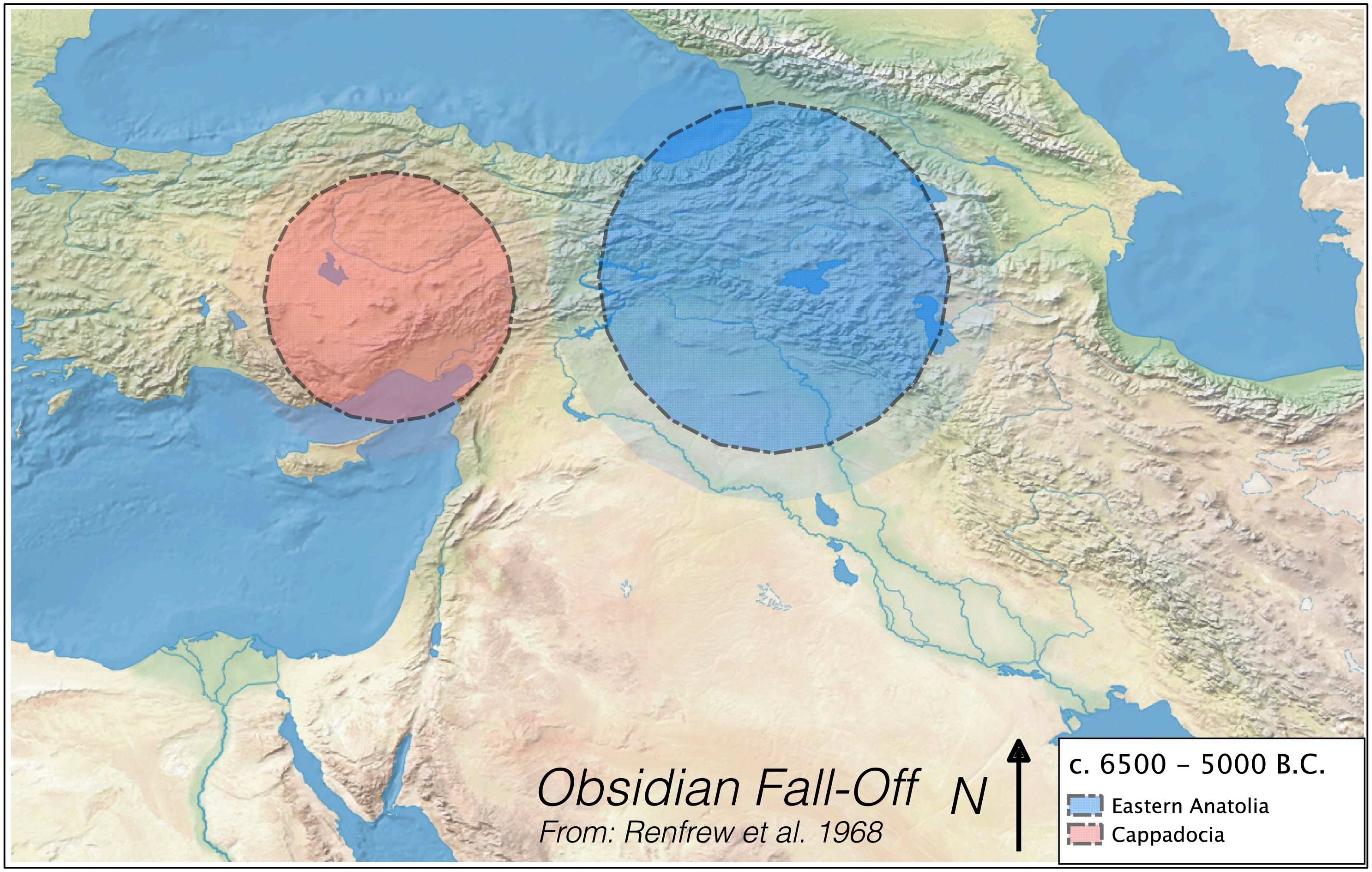


Figure 3.2 – Obsidian fall-off, reproduced using data from Renfrew (et al. 1968).

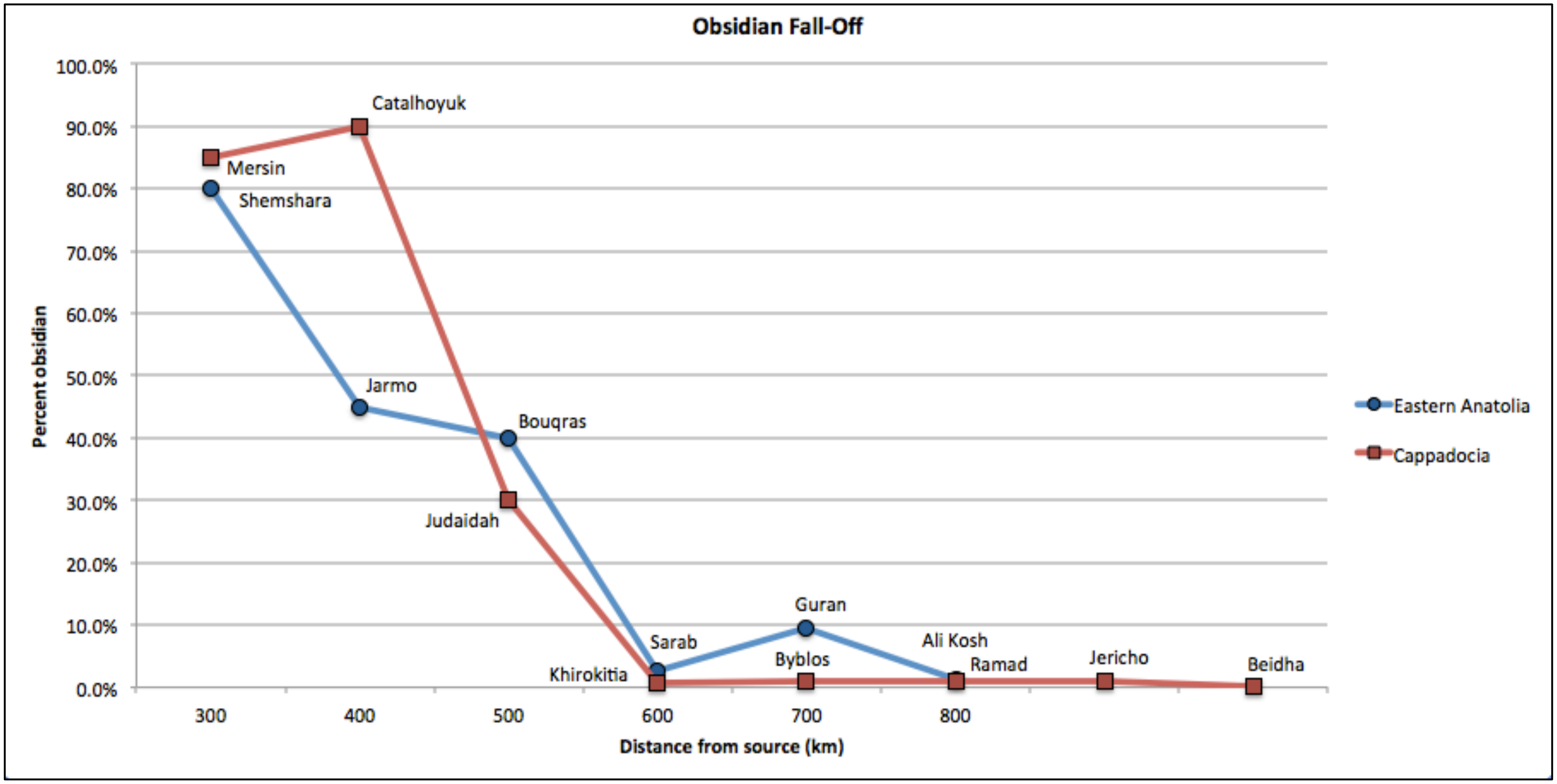


Figure 3.3 – Obsidian fall-off curve, reproduced using data from Renfrew (et al. 1968).

account for the discovery of obsidian artefacts at distances very far from the materials' source.

Despite these concerns, Renfrew's initial conceptualizations cleared the way for new avenues of thinking about obsidian circulation. Not only did people start to see the value of using obsidian as a proxy for tracing prehistoric exchange, but constructive criticism also emerged pointing out various factors that should be explored in more detail (Torrence 1986:16-21). One such variable is concerned with topographic and localized environmental variation. Renfrew's early examination of obsidian circulation was based upon the relationship between a site's proximity from the geological sources of obsidian and the intensity of material uncovered there. Ericson (1977:110-111) characterized this analysis as two-dimensional since the displacements were traced as-the-crow-flies – ignoring many crucial environmental, cultural and technological variables that may either extend or reduce the effective distances that would be perceived by a walker on the ground. By incorporating certain geographical variables (such as elevation data, aridity, or coastal and riverine channels) and by accounting for technologies developed to make transportation more efficient (such as pack animals, paddled craft and ultimately sailing vessels), the potential routes by which obsidian may have been most easily circulated by humans would undoubtedly be altered. This notion follows suggestions made by Wright (1969:73), who pointed out that weight may be a better indicator of trade volume than artefact counts. The ability to domesticate donkeys as pack animals, a technology that was originally developed in northeast Africa earlier on, arrived in the Levant at around 5000 B.P. and coincides with the tail end of the Chalcolithic Period (Kimura et al. 2013:86). This may have extended the range by which obsidian and other materials could be exchanged over terrestrial routes. Additionally, transportation along navigable riverine channels would emphasize downstream travel and perhaps influence the distribution of obsidian and other materials. Given that people were living on Cyprus from at least the 11th millennium B.C., which indicates that simple boats were in use from Period 1 onwards, vessels could have been used to carry obsidian more efficiently to other locations along the Mediterranean coast (not least in the Levantine littoral) as well (Simmons 2014).

Concerning the impact of topographical variation and other environmental factors, computational methods for geo-spatial analysis are useful tools. However they are not very efficient for large-scale spatial expanses, given technological and budgetary constraints. Recent efforts to align obsidian circulation patterns with digital elevation models over smaller areas have been fruitful, setting great backdrops for further analysis (Barge and Chataigner 2003; Chataigner and Barge 2008; Chataigner and Gratuze 2014b).

There have also been concerns regarding the influence of human decision-making on the circulation and distribution of obsidian. Ammerman (1979) noted that on the coast of Neolithic Calabria, where the arrival of obsidian from the island sources of the western Mediterranean would most definitely have been conducted via maritime transport mechanisms, the material is found more frequently at some sites rather than at others. Because maritime transportation would have enabled obsidian to circulate with greater ease, Ammerman suggested that the decision-making processes that led to this patterning must also be considered when constructing models of prehistoric exchange. Adopted from the field of human geography and drawing on analogies to Newtonian physics (Yeates 1974), gravity models have since been developed and applied by archaeologists in efforts to account for the potential attraction that a site may have (see Evans et al. 2012; Rihll and Wilson 1987 for more detailed overviews). They are well suited for examining certain forms of regional interaction, and can also be used as null models to compare with others, or with the archaeological evidence at hand (Johnson 1977:481, 490). However these models, which are very reductionist in nature, still do not account for entirely social factors that may influence the decision to acquire a certain variety of obsidian over another, irrespective of distances involved or the values of other variables accounted for.

Since Renfrew's early characterization studies, a wealth of obsidian sourcing data has been produced from sites throughout the region. However the fact that this information has not been systematically collated until now has effected how it has been queried. On an independent basis, obsidian sourcing data can relate the artefact's context of deposition with the source of the object's raw material, usually described in terms of linear distance between these two points. Such a simplistic assessment does not attempt to explain the processes by which the material found its way to its resting place, and certainly does not account for potential geographical influences like those described above. The information gleaned through site-specific sourcing studies can be made more constructive by comparing the results and interpreting them within a broader context. Unfortunately much of the obsidian sourcing data has not been discussed in this way (Freund 2013:783). It seems that many archaeologists sourcing obsidian were less interested in investigating broader socio-economic systems, and were content with simply presenting site-specific narratives, or documenting the presence of 'exotica' (cf. Le Bourdonnec et al. 2011; Pollard and Heron 2008:87-91). However by thinking of obsidian sourcing data as a medium for comparison, it can hold much more meaning.

3.5.2 Broader contextualization of obsidian circulation

In their seminal study, Cann and Renfrew (1964:119-120) identified various interaction zones, or areas where products of a particular source have been found in high concentrations. While this was done to broadly identify general geographical trends, Torrence (1986:11, *emphasis original*) eloquently notes that "the zones simply define the universe of study; the research goal is to reconstruct the exchange mechanisms which distributed the obsidian *within* each zone of interaction." Despite this intent the conceptualization of these artificial boundaries has increasingly been incorporated into larger discussions regarding Neolithization, usually in a generalized manner (Asouti 2006; Watkins 2008). The growth of extensive trade 'networks', which are almost never explicitly defined or reconstructed, are said to have facilitated the development and spread of successive waves of shared material culture and the dissemination of new ideas. However critics have pointed out that this mode of thought is problematic since it adheres to unspecified diffusionist protocols of acculturation, and is oriented towards the description and confirmation of observed generalized trends (Asouti 2006; Jennings 2006; Stein 2002; Watkins 2008). While obsidian circulation has been raised as a signifier of such cultural contact, simply relying on classificatory frameworks that territorialize the concentrated use of raw materials or tool types is not recommended (Asouti 2006:104; Carter et al. 2013:565-568). Examining the different forms in which raw materials circulated and the distinct ways that obsidian was consumed allows for cultural variability to be better understood (Carter et al. 2013).

Recently efforts to consider obsidian circulation in such a social framework have been made. From this perspective, multiple aspects of obsidian artefacts are integrated in order to gain a more holistic understanding of social processes (see Cauvin 1991; Gero 1989). Rather than thinking only about where the material came from, one may further enquire about the ways that this particular material was worked, shaped, used and discarded by drawing on the artefact's typological and technological facets as well (Carter et al. 2013:565-568). This enables archaeologists to detect more nuanced behaviour (such as the kinds of reduction occurring on site, or whether obsidian artefacts were largely imported as finished products), which may be compared among sites in a larger regional context.

Cauvin and Chataigner (1998) have initiated movement in this direction by incorporating geographical factors alongside the analysis of lithic variability in their characterizations of "communities of attitude towards obsidian" (337, trans. from French). While their observations are rather brief and non-formalized, they are nonetheless valid. It is also important to note that this research represents the first large-scale study of obsidian circulation in southwest Asia and Anatolia since Renfrew's pioneering work. Since then, a 'new wave' of obsidian circulation studies has emerged that focuses on the social processes that underlie the use of this material, and a return to thinking about obsidian as a means to understand a greater end (Freund 2013; Pollard and Heron 2008:91-93).

In a more detailed synthesis building on Cauvin and Chataigner's work, Delerue (2007) provided an extremely detailed account of the patterns of obsidian use in Anatolia and the Near East from the Upper Palaeolithic to Late Neolithic. While Delerue's attempts to formalize the social approach are commendable, in certain respects this resulted in over-complication. For instance, the maps that were produced to illustrate the many facets of obsidian use are strewn with arrows and dots representing the movement of raw materials, the technological sequence present at each site, and the degree of certainty for each analysis (Figure 3.4). While Delerue's impressive synthesis is rich in data, it is also reasonable to argue that it misses the forest for the trees.

Also noteworthy is the work of Carter (et al. 2006; et al. 2011; et al. 2013), who has investigated the ways that obsidian is procured and transformed in order to characterize broader socio-economic systems. At Çatalhöyük, Carter (et al. 2006:905-907) have emphasised the need to integrate raw material and techno-typological considerations

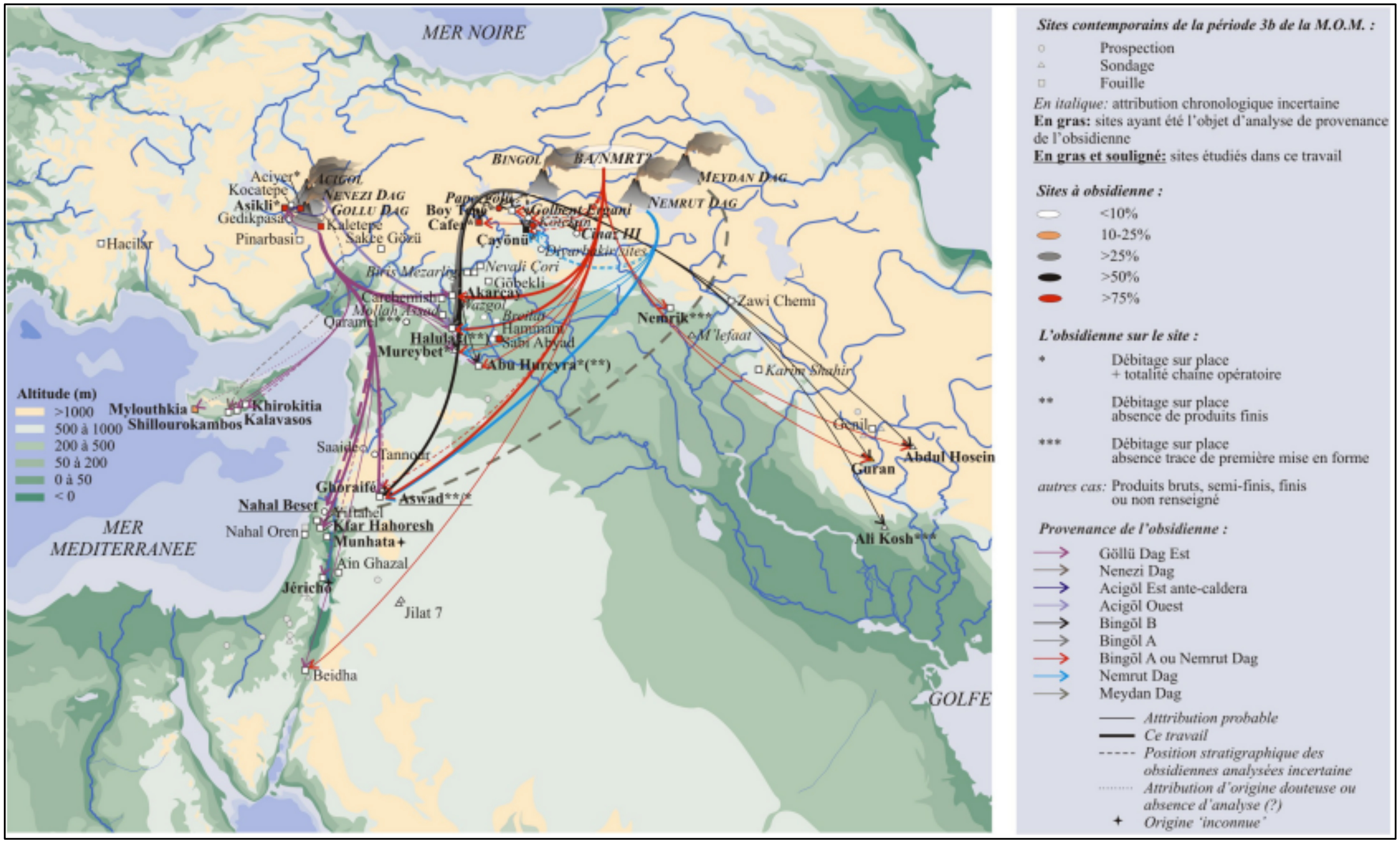


Figure 3.4 – Detailed account of obsidian circulation during the PPNB (from Delerue 2007).

when seeking to 'characterise' an obsidian artefact. Such an approach, along with the analysis of large data-sets from well-dated contexts throughout the site's occupation, has revealed a complex history of raw material consumption, with numerous parallel traditions at any one time, and major shifts in the relative significance of specific source materials during the Neolithic. Such rich data, for which no analogous data-set currently exists from the region, arguably demonstrates the extra value one can gain from a more integrated form of characterisation study. Alas such multi-attribute data – source, technology, typology, context, use-history – is simply not available for most of the obsidian sourcing studies that form the basis of this thesis, whereby my analyses are largely restricted to raw materials alone.

Carter (et al. 2013) recognized that certain lithic industries were being adopted with strong associations to an obsidian source not commonly exploited in prior levels. The authors aligned this observation within wider recognition of changes at the site and in the region as a whole, which draw on alternative forms of archaeological data. Similarly, after analyzing obsidian from Öküzini Cave, Carter (et al. 2011) was able to infer about the inhabitants'participation in larger-scale exchange systems. And more recently, Carter (et al. 2013) explicitly attempted to characterize communities of practice with regards to obsidian at Körtik Tepe and its surrounding vicinity by drawing on direct comparisons with the typological and technological aspects of obsidian assemblages in conjunction with raw material choices. Through these studies, Carter contextualized obsidian use within site-specific and regional systems, and used it to characterize change over time.

Carter's contextual approach is interesting because it situates the analysis within a certain narrative, and enables commentary on wider developments concerning it. For instance, his evaluation of changing obsidian use at Çatalhöyük may be viewed as one component contributing to the documentation of a shifting role of the site in larger regional circles (Carter et al. 2006:907; Thissen 2002:18). At Öküzini, Carter (et al. 2011:142-144) leveraged the data he attained through sourcing obsidian in order to contribute to a broader discussion concerning cultural insularity in the site's regional context. Furthermore, Carter (et al. 2013) was able to distinguish between distinct habits of production in the area surrounding Körtik Tepe, and align his findings with geographical factors and topographical phenomena. While this stream of thought has yielded interesting conclusions, more formalized computational analyses that balance emphasis on the data from other archaeological sites, which have been somewhat marginalized as 'other' in respect to the one in focus, may yield results that would be more suitable for larger-scale analysis.

One promising tool that has been used constructively to investigate the circulation of obsidian is Geographical Information Systems (GIS). GIS offers the capability to explore how large-scale patterns of obsidian distribution may relate to other geographical or cultural variables. For the Late Horizon Period of California, Ericson (1977) examined the distribution of obsidian artefacts in relation to the availability of alternative resources, documented transportation routes, and contemporary language families. Ericson conducted this study partly in response to Renfrew's examination of obsidian fall-off curves, with the aim of finding out whether these layers of information would have influenced any deviation from the standard linear model.

Geo-spatial methods have also been applied in a more analytical way in order to examine more closely the potential impacts of the environment on the distribution of obsidian. While this work tends to be quite computationally inefficient for large-scale spatial expanses given technological and budgetary constraints, recent efforts to align obsidian circulation patterns with digital elevation models over small areas have been fruitful (Barge and Chataigner 2003; Chataigner and Barge 2008; Chataigner and Gratuze

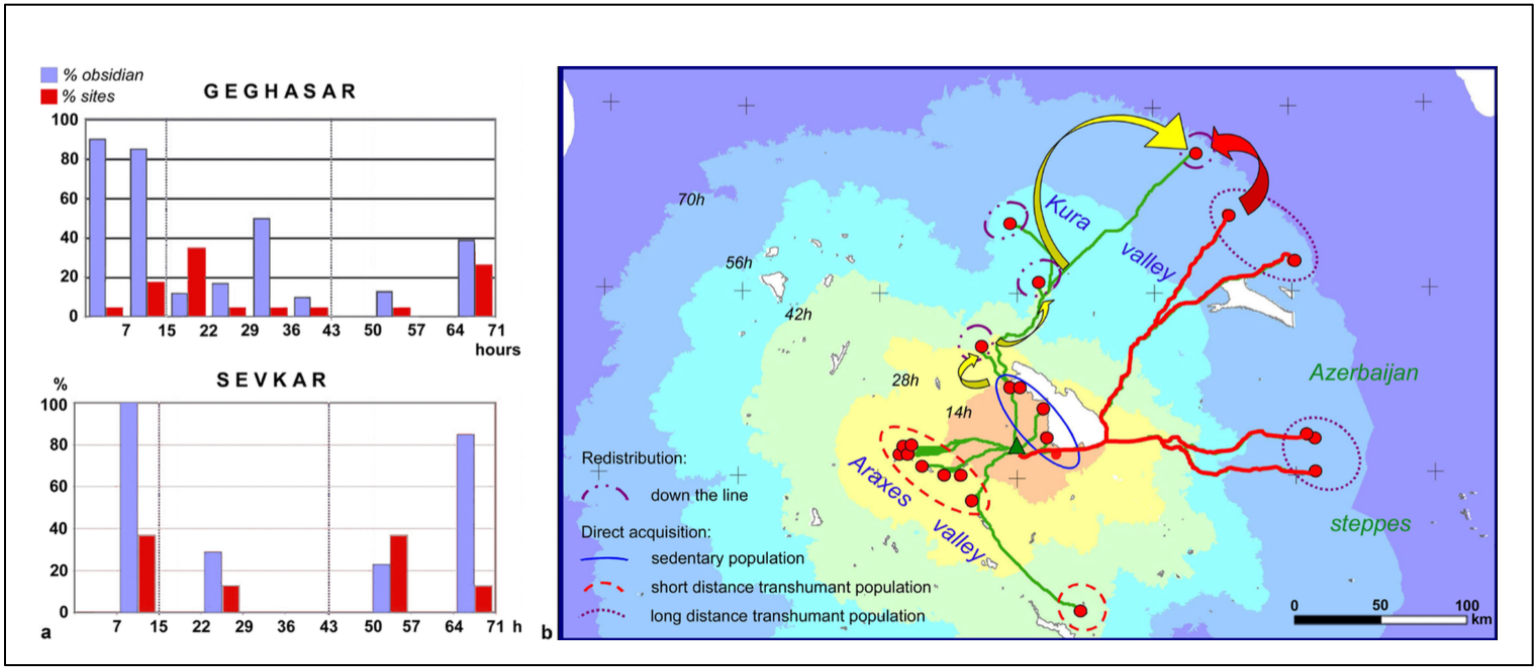


Figure 3.5 – Map depicting the amount of time needed to walk from Armenian obsidian sources to various archaeological sites in the vicinity, with the percentage of obsidian from each source overlaid graphed on the left (from Chataigner and Barge 2008).

2014a, 2014b). One great example is a study by Barge and Chataigner (2003), who evaluated the impacts of different variables on travel costs in the rugged landscape of the southern Caucasus region and eastern Turkey (Figure 3.5). After determining that elevation had the largest effect, the authors calculated the amount of time and effort needed to travel to or from the volcanic sources, and identified optimal routes that would have mitigated the difficulty posed by topographic constraints. Geo-spatial analysis has a lot of potential for the study of obsidian circulation and the development of models that attempt to explain artefact distribution patterns.

Clearly, the contextualization of obsidian distribution patterns within a social framework has contributed immensely to broader archaeological topics. The study of obsidian circulation has opened up a novel recognition of variability within broad, generalized groupings. By rendering obsidian sourcing data comparable and integrating it with other aspects of lithic artefact analysis, a great deal can be said with regards to the shared practices between and within groups of people. Ultimately this would allow archaeologists to further refine attitudes towards obsidian identified at various sites, and enquire as to how such distinctions may have come about in the first place. Network analysis can be a very useful tool for this research since it provides a formalized framework in which to conduct a comparative study. However archaeologists must recognize what benefits network analysis offers, what parameters need to be set for its proper use, and how to step back to discuss the relevance of results attained using this methodology.

4 – NETWORKS AS REPRESENTATIONS OF HETERARCHICAL RELATIONAL STRUCTURES

4.1 Fundamentals of network analysis

This thesis takes on a heterarchical approach to examine the circulation of archaeological obsidian in order to present a novel perspective on supra-regional interaction in the study region, and to further deconstruct cultural historical perspectives when reconstructing past socio-economic relations. To enable this work network analysis is employed as a methodology. In undertaking this approach is important to consider how such a method differs from more established ways of understanding the distribution of obsidian in the study region, and to evaluate how network analysis has been adopted for archaeological research elsewhere.

A *network* is an aggregation of dyadic relationships, or a series of ordered pairs conceptualized as *nodes* and *edges*. Nodes are entities that can potentially be linked by an edge representing a relationship that may exist between them (Figure 4.1). While sets of nodes and edges are often visualized as webs of entangled dots and lines formally known as *graphs*, network data is also represented as *matrices* or *edgelists* of ordered pairs.

Networks can be used to represent any kind of linked data. Nodes are basal units that may combine to form emergent systems that are constructed through the distribution of relationships between them. Realistically speaking many variables likely contribute to the emergence of human systems, so network analysis should be more aptly recognized as a tool used to examine specific kinds of relationships whose meaning can be inferred through theoretical considerations and enlightened interpretation guided by disciplinary standards. However there are some methodological considerations that have to be addressed as well. Every node must have the same potential ability to connect to any other node via an edge, and edges must represent the same kind of relationship. This methodological constraint allows for a specific kind of connection to be focused on, and all interpretations must account for this narrow field of vision (although see chapters 16 and 17 in Hanneman and Riddle 2005 for information concerning multi-plex and multi-model networks, which offer alternative possibilities not suited for this thesis). The intensity of relationships, as well as their directionality, may vary, however these parameters must remain consistent throughout the network (Figure 4.2). The quantified value of an edge's intensity is its *weight*, and when all are uniform they are said to be *binary* (either present or absent). A non-reciprocal, or directed relationship is known as an *arc*, as opposed to symmetrical edges that are undirected. Due to the nature of the relationships examined in this thesis (only reciprocal coefficients of similarity may be determined; see Chapter 5 for more details), only undirected edges are considered.

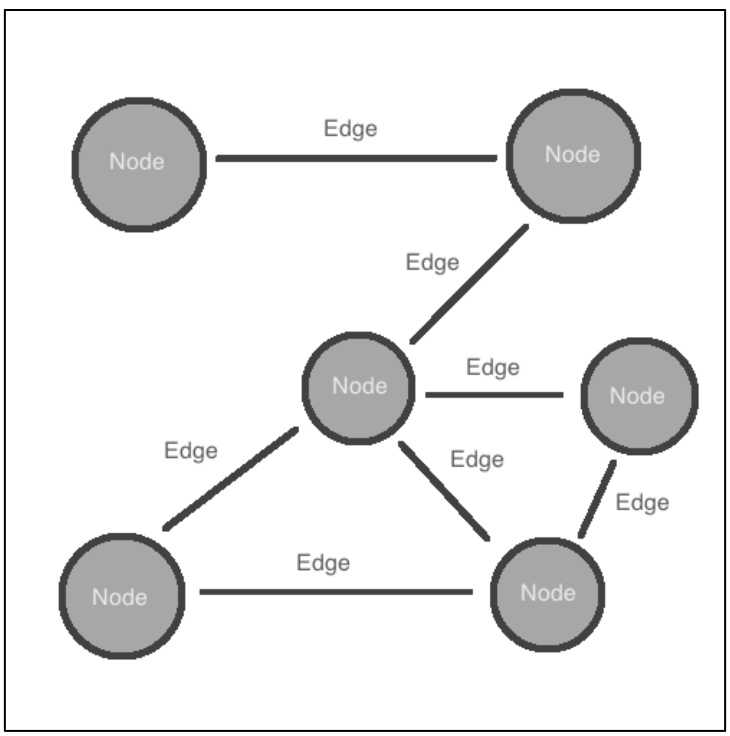


Figure 4.1 – A network is an aggregation of dyadic relationships, organized as a series of nodes connected by edges.

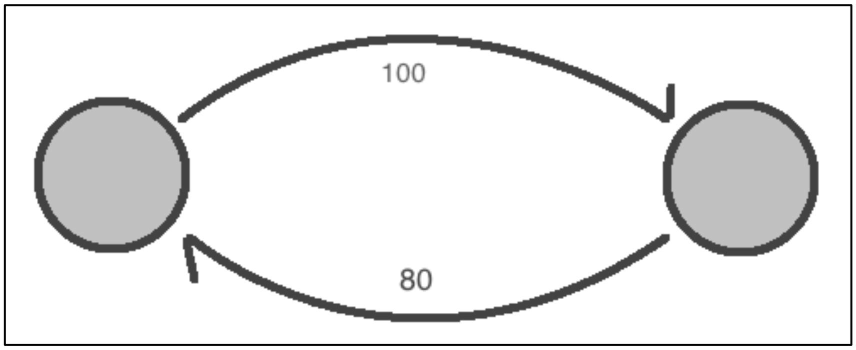


Figure 4.2 – Directions and weights can be specified for edges.

Once a network is constructed it can be analyzed through the implementation of analytical *algorithms*. Algorithms conduct a series of mathematical calculations designed to output a value that reflects a desired *metric*. A diverse range of analytical methods exists for the evaluation of network data, and the analyst must determine which ones will yield meaningful results. However it is important to remember that network analysis as a methodology is not characterized as a collection of tools, but is rather unified by the nature of networks as a data type (Brandes et al. 2013; Brughmans 2014:21).

The output results reflect the network's structure regardless of the meaning underlying the data used to construct it, and must be interpreted in light of any limitations or constraints inherent within the dataset. Thus *filtering* the network, which is the process of systematically reducing the amount of nodes or edges according to set criteria, results in different values being output after running analytical algorithms. More specific details concerning the algorithms employed are provided in the methods section of this thesis.

<u>4.2 Heterarchical implications of archaeological network analysis</u>

Several archaeological studies have already been conducted using this methodology. Some networks are derived from prosopographical sources (cf. Graham 2006, 2014; Graham and Ruffini 2007) or geographical data such as proximity or effective distance (cf. Broodbank 2000; Davis 1982; Hage and Harary 1991, 1996; Irwin-

Williams 1977; Knappett et al. 2008, 2011; Terrell 1976). The most common approach, however, is to define edges based on the similarity of assemblages or co-occurrence of certain finds thought to be representatives of shared social processes or acting as manifestations of institutions worthy of note (cf. Batist 2011; Brughmans 2010; Freund and Batist 2014; Mills et al. 2013; Munson and Macri 2009; Sindbæk 2007a, 2007b). After constructing networks and conducting analysis, these scholars compare their findings with alternative models (cf. Coward 2013; Terrell 2010), or the analyst draws attention toward other relevant aspects of each site being compared that may contribute to the argument being made (cf. Golitko et al. 2012; Mizoguchi 2009).

Networks are essentially simplified representations of interconnected entities, linked through criteria defined by the analyst, that have the potential to be ranked and organized according to the distribution of relationships among them. Crumley (2005) has acknowledged that networks may be useful for representing heterarchical relational structures, and has posited that heterarchy should be considered dialectically opposed to the notion of hierarchy, which contends that relationships may be restricted among certain entities due to pre-existing differential ranks between them (Crumley 1995:2, 2005:41-45). In other words, hierarchical structures incorporate rankings as fundamental attributes pertaining to each entity being compared, whereas heterarchical models assume that all entities are fundamentally on equal footing and ascribe rank as dependent upon the relations that may exist between them (Crumley 2005:41-45). As such, archaeologists have explored heterarchical relationships to overcome overtly top-down understandings of social or regional systems of interaction (cf. Malkin 2011; Renfrew and Cherry 1986; Scarborough et al. 2003; Stein and Rothman 1994).

For example, Stein (1999, 2002) reacted to the application of World Systems Theory as a way of understanding the Uruk expansion in 4th millenium B.C. Mesopotamia (cf. Algaze 1993) by seeking to understand how relationships between northern and southern sites may have been practically manifested, rather than assume a given hierarchy between a dominant southern core and a passive northern periphery. Although this work mainly consisted of a re-evaluation of the archaeological record from an alternative standpoint, it is clear that Stein recognized the value of examining his setting of interest as a decentralized and heterarchically-organized system of interaction in order to better understand emergent phenomena at a broader scale (Jennings 2006).

Network analysis lends itself as an extremely flexible methodology for formalizing such comparative studies in a quantitative manner; however without grounding ones work within proper theoretical and contextual frameworks the results may potentially be considered devoid of valuable meaning (Barton 2013; McGlade 2003). One must ensure that the underlying data being examined, which represent the entities being compared and the kind of relationship that may connect them, would aggregate in a way that informs archaeologists of certain phenomena through the application of specified algorithms (such considerations pertaining to this thesis specifically are provided in Chapter 5). In other words, it is important to consider how the heterarchical relational structure imparted by network analysis may be leveraged in order to shed light on emergent phenomena arising from the uneven distribution of relationships among archaeological sites.

4.3 Network analysis for the study of obsidian circulation

Obsidian circulation has been the primary focus of some prior applications of network analysis. Freund and Batist (2014), Golitko (et al. 2012), Golitko and Feinman (2014) and Phillips (2011) have applied this methodology to determine how raw material was distributed, and to evaluate these patterns as indicators of changing socio-economic organization and exchange.

In order for obsidian sourcing data to be constructively analyzed in this way, it must be thought of as a medium for comparison. Golitko (et al. 2012) compared the proportions of artefacts made from material derived from specific obsidian sources in Mesoamerica, applying the Brainerd-Robinson formula to attain coefficients of similarity for each pair of sites (Brainerd 1951; Robinson 1951; Cowgill 1990). These index values were then used to form the basis for connections in a network. After filtering the network to include only stronger connections, Golitko applied a community detection algorithm to identify groups of sites where raw materials were present in similar proportions. The changing extent of these modules across the four chronological periods examined represented shifting patterns of raw material use. Golitko found that *Ixtepeque* obsidian from Guatemala, which was largely distributed eastwards at inland sites earlier on, began making its way to distant coastal sites with greater frequency than material from other sources. This was considered to be indicative of a shift from inland to coastal exchange mechanisms, a phenomenon that is significant due to the general observation that inland sites declined sooner prior to the Spanish incursion (Golitko 2012:517-518).

Other analyses examining the distribution of material culture, including this thesis, use a fairly similar overall methodology as the one implemented by Golitko (et al. 2012). However they do exhibit some degree of variability guided by the questions being addressed. For instance, edges were not binarized for this thesis since it was deemed important to consider the variable strengths of ties among sites. Moreover, the algorithms used for analysis were configured to account for these weighted edges.

For instance, in southwest Asia and Anatolia, which is the research context for this thesis, the interplay between observed relationships and various geographical factors is worth exploring in greater detail. Network analysis only considers the inputted relationships between entities, and the results are agnostic of geographical variables or alternative features that may also be relevant to the topic being investigated. In order to address this concern Coward (2013) conducted a very thorough statistical analysis, comparing networks constructed from artefact distribution patterns (including obsidian) from the Epi-Palaeolithic and Early Neolithic in the Near East with those derived from models based upon measurements of direct and effective distance. The final results showed that "within each timeslice network, geographical distance, and the cost of travel between sites in fact had very little impact on the similarity of their material culture inventories" (Coward 2013:268-269). From an environmentally-led approach these results may seem counter-intuitive at first, but Coward points out that this warrants further investigation into new variables to integrate into future models (Coward 2013:269-271). Ultimately, the results of this study can be interpreted to suggest that social factors may have played a bigger role in early regional interaction than previously thought. Refining the parameters for measuring effective distance is thus only one side of the coin when it comes to reconstructing potential exchange mechanisms and socio-economic processes during prehistory.

Ortega (et al. 2013) has also worked to refine models of obsidian exchange in this broad regional context. Ortega identified the mathematical underpinnings of the down-the-line model proposed by Renfrew (1969) to explain the movement of obsidian, and after breaking it down into rule-based components, designed an agent-based simulation around variables assigned to each site that would influence their decisions to pass material along. By tweaking each variable and noting the degree to which the resulting outcome would change, the authors were able to determine what factors had greater impacts on the system. Ortega thus proposed that rather than thinking of obsidian circulation in terms of a linear model, it would be beneficial to instead conceive of it as a distributed complex system, which may be evaluated as a network, wherein each site acts independently and synchronically.

Additionally, Carter (et al. 2006) noted differences in the use of raw material variants at Çatalhöyük, and examined these developments in light of other changes observed at the site, and with regards to broader regional developments as well. Carter emphasized his view that information derived from sourcing studies should be more effectively paired with other vectors of information (such as typology, mode of manufacture, use-wear, etc) in order to more fully understand past peoples' attitudes towards obsidian. By tracing the distribution of these holistically-evaluated trends, which may be interpreted as representative of different learned skillsets for tool manufacture, selective preferences for various kinds of products, or restricted access to raw materials, socio-economic communities may be distinguished. Similarly to Ortega (et al. 2013), Carter (et al. 2006, 2013) did not formally evaluate networks of interaction, however these studies did make comparisons in very explicit ways while considering the archaeological record as resulting from activity that occurred in a non-centralized and mosaic-like fashion.

Coward (2013), Ortega (et al. 2013) and Carter (et al. 2006, 2013) each considered different factors in order to better understand the distribution of obsidian, and, either implicitly or explicitly, a heterarchical approach was taken in each of these cases. Their respective focuses on geographical limitations, decision-making processes, and broader socio-economic contexts in such a way prompt others to reflect on the roles of these variables in shaping contemporary understandings of cultural boundaries. While these elements are not directly considered in this thesis, the results presented in Chapter 7 represent overall obsidian distribution patterns that arose from a culmination of these aforementioned variables. The results of this thesis are merely reflections obsidian circulation patterns and do not fully characterize cultural boundaries, however they are posed as alternative yet complementary representations of differential attitudes towards obsidian that are constructed through a comparative approach, as opposed to top-down delimitations of cultural patterning that have been emphasized in the past.

5 – DATA

5.1 Network data – defining nodes and edges

Network analysis is a flexible methodology that can be used to explore virtually any kind of relational data, and has thus been adopted by practitioners of a wide variety of scientific and social scientific disciplines alike. It is centred on the evaluation of a certain data type – aggregations of relationships between pairs of entities, each conceptualized as two nodes connected by an edge. Nodes and edges can represent virtually any kind of linked data, such as synaptic connections between neurons (Greicius et al. 2003), flights patterns among major airports (Brueckner 2002; Guimerà et al. 2005), or the cross-appointment of executives on corporate boards of directors (Davis et al. 2003; Koenig and Gogel 1981). Many formal techniques are used to analyze networks, but it is the data type that unifies the methodology (Brandes et al. 2013; Brughmans 2014:21).

When constructing networks, one must predict whether the underlying data would aggregate to form meaningful and realistic results through the application of certain analytical techniques. Analytical algorithms simply highlight order in a network, but one must know what kinds of patterns would actually be significant with respect to the foundational information that nodes and edges represent, the goals of the research project, and the disciplinary framework that guide interpretation. For example, when tracking flight patterns an analyst may concentrate his or her efforts on the identification of airports that are major hubs on multi-leg journeys. On the other hand, someone else examining neural networks may be more interested in detecting clusters of highly connected nerves or analyzing the efficiency of a signal's transmission throughout different sections of the brain. In any case, network analysis requires that all nodes be comparable, having the same potential to connect with any other node. Additionally edges should represent basal connections that contribute to the formation of larger systems, and must be quantifiable either in a binary format or as a value of variable weight.

For archaeologists investigating regional interaction using network analysis, nodes often represent archaeological sites and edges embody either the potential similarity of artefact assemblages, the co-occurrence of certain features or finds, or geographical distance between sites. Because interaction and exchange can only have occurred among the inhabitants of contemporaneous sites, networks are constructed pertaining to individual 'time slices', including data from the chronological period under consideration. A diachronic sequence of such networks is generated that allows the analysts to note changes over time. With a chronological framework of great temporal resolution one may observe changes to a very high degree of specificity, as for example with the recent study of demographic changes in the southwestern United States wherein the analysts were able to generate networks for every 50 years (Mills et al. 2013).

Similarly, edges should represent meaningful connections that inform that analyst about the issue being explored. Typically edges are drawn if nodes are related in some way or share similar properties, which may be significant in a social or cultural sense. For example, in Viking Age Scandinavian contexts Sindbaek (2007a) compared 31 kinds of commonly found artefacts with relatively specific provenance and found that despite their common occurrence, in aggregate their proportions matched alternative interpretations of cultural divisions. Additionally, if it is assumed that sites located very near each other would interact more than those at greater distances, then the edge weights between all pairs could be expressed as the inverse of the distance between them. However if all nodes are linked to all other nodes, the result is a *complete network* exhibiting 100% connectivity. Although complete networks are not inherently devoid of meaning, the uneven distribution of edges is what gives a network unique and realistic structure. To ameliorate this, the network can be filtered so only edges with weight above a certain threshold value are considered. This cut-off value may influence the *density* of a network, which represents the number of actual connections relative to the number of edges that would exist in a complete network consisting of the same number of nodes. The threshold value can be determined in many ways (cf. Cochrane and Lipo 2010:3890; Mills et al. 2013:5786; Phillips 2011:170-173), however it is often decided upon arbitrarily (Peeples and Roberts 2013). This decision is very important since it shapes how complete a network will be, and thus influences analysis in certain respects, however ultimately it lies on the analysts' own judgement. If determined arbitrarily, as was done in this thesis, the cut-off value may serve to represent constraints imposed by limited transport technology or variable willingness to travel extremely far distances, factors that limit the possibility of a network to be completely connected (Broodbank 2000:336-349; Irwin-Williams 1983; Knappett et al. 2008; Terrell 1976).

For the work presented in this thesis, nodes represent broadly contemporaneous archaeological sites connected by edges that embody quantified indices of obsidian assemblage similarity, primarily with reference to raw material composition (based on archaeometric sourcing data). The parameters that guide the construction of networks are outlined below.

5.2 Chronological framework

In this thesis, each site, as represented by a node, is attributed to one of seven chronological periods, spanning the temporal range of 12,000 – 5700 B.P. (Table 2.1). This periodization is adapted from a scheme originally developed by Hours (et al. 1994) for the Atlas des Sites du Proche Orient (ASPRO) published by the Maison de l'Orient et de la Méditerranée (MOM). These chronological divisions were defined on the basis of alleged major technological or socio-cultural milestones (e.g. the beginnings of agricultural subsistence strategies, metal production or various pottery traditions). However the boundaries between chronological units should not be treated as absolute divisions; instead they should be considered as 'fuzzy' borders that are loosely shaped by changes in the archaeological record.

It is also important to note that archaeologists working in various regions make use of different chronological schemes to document excavated materials and structures, and stitching them together is considerably challenging. For example, the term 'Pre-Pottery Neolithic' (PPN), with its sub-divisions A and B (PPNA / PNNB) was first defined with reference to the stratigraphic sequence at Jericho in the southern Levant, pertaining to periods of the settlement where the community exploited domestic cereals (and thus a farming / Neolithic way of life), but lacked ceramic vessels. While this terminology was subsequently adopted by many of those working on broadly contemporary sites in the northern Levant, northern Mesopotamia and southeast Anatolia (cf. Boese 1995; Braidwood 1982; Ibáñez 2008), others – such as the excavator of Abu Hureyra (Middle Euphrates) – have chosen not to apply the PPN scheme as they believe the term only really pertains to the archaeology o the southern Levant and to employ it in other regions only serves to mask important local differences in cultural tradition (Moore et al. 2000; see also Özbarasan and Buitenhus 2002 for a related critique concerning the application of the PPN terminology to Central Anatolia). The local sequences for each site were closely consulted in order to identify the chronological period to which the pertinent data belongs, however in cases where a stratigraphic unit overlaps two periods, any data relating to this context is assigned to the period that it spans most. Moreover, if obsidian uncovered at contexts pertaining to distinct chronological periods has been sourced, the data is assigned to its respective chronological dataset. Despite the challenges that are faced, broad scale evaluations of material culture distribution patterns have proven to be extremely valuable (cf. Knapp 1986; Nissen 2001, *inter alia*).

Certain periods from the ASPRO chronology were merged together due to constraints faced throughout the data collection process. Due to a lack of precision regarding the specific chronological contexts of sourced obsidian pertaining to PPNB and earlier Pottery Neolithic phases, their material was lumped into broader temporal spans. This means that Periods 2 and 3 of the ASPRO chronology were merged, as well as Periods 5 and 6. Additionally, despite the small size of the individual datasets pertaining to certain other chronological units, they were not merged in an effort to maintain adequate chronological resolution. As such, certain datasets are larger than others, which influences what can potentially be gained through analysis and subsequent interpretation of results.

5.3 Geographical extent

Obsidian sourcing data has been collected for sites located in southwest Asia plus central and eastern Anatolia. This includes the area within the modern borders of Cyprus, Iran, Iraq, Israel, Jordan, Lebanon, Palestine, Syria and Turkey. In terms of physical geography this expanse ranges from the Mediterranean coast of the Levant to the west, east to the Persian Gulf, and north to the Anatolian coast of the Black Sea. The regions of western Anatolia and Transcaucasia were excluded in order to maintain focus on raw material preferences in the Fertile Crescent and surrounding areas, and contribute to discussions concerning Neolithization and socio-economic changes that occurred throughout this archaeological setting. Obsidian sourcing data has been produced for sites in these outlying regions, however this work brings forth alternative questions that go beyond the scope of this thesis. As shall become clearer, the communities under consideration were primarily consuming obsidian from the major source regions of central and eastern Anatolia.

Within the area that is investigated for thus thesis, obsidian sourcing data has been compiled pertaining to 151 sites using information from published journal articles, excavation reports, conference papers and other scholarly records. These obsidian sourcing studies, which generally operated independently of each other and of this thesis, were cumulatively responsible for the analysis of c. 4127 artefacts in all. The sites where material has been sourced amount to between 40% to 70% of all archaeological locations where obsidian has been uncovered, however this is only a rough overall estimate, and of course the frequency of material uncovered varies over time. The relatively small number of artefacts analysed at most sites is arguably due to the fact that early characterisation studies tended to involve destructive and relatively time-consuming techniques (e.g. OES and NAA), whereby a mix of bureaucratic and financial considerations may have restricted a project's sample size. Political conflicts are other factors that may have potentially limited or skewed the availability of obsidian sourcing data, since most analyses were conducted by American, British, French and German scholars. The recent advent of portable and cost-effective XRF instruments is now serving to change the situation drastically, which enable archaeologists to chemically characterize raw materials in the field and in museums, reducing these barriers and even allowing for the analysis of many more samples than would typically be examined (Forster and Grave 2012; Frahm et al. 2014). As such, the volume of obsidian sourcing data is expected to grow considerably.

Additionally, certain chronological periods are generally more extensively researched than others in various regions, which influences the geographical distribution of data for various periods. While the reasons for such uneven attention may be inherently

Period	Date range (B.P.)	Number of Sites	Total Samples Analyzed	Mean Total Samples Analyzed	Number of Sources	Mean Sources	Median Sources	Mode Sources	Max Sources
1	12,000 - 10,300	10	264	26.4	5	1.8	1.5	1	3
2	10,300 - 8600	41	1811	44.1	7	2.1	2	1	5
3	8600 - 8000	25	542	21.6	7	2.0	2	2	4
4	8000 - 7000	38	1060	27.8	13	2.6	2	2	5
5	7000 - 6500	15	74	4.9	7	2.0	2	2	3
6	6500 - 6100	8	80	10.0	6	2.6	3	3	3
7	6100 - 5700	14	296	21.1	10	2.5	2	2	4

Table 5.1 – Statistics concerning the datasets for each period.

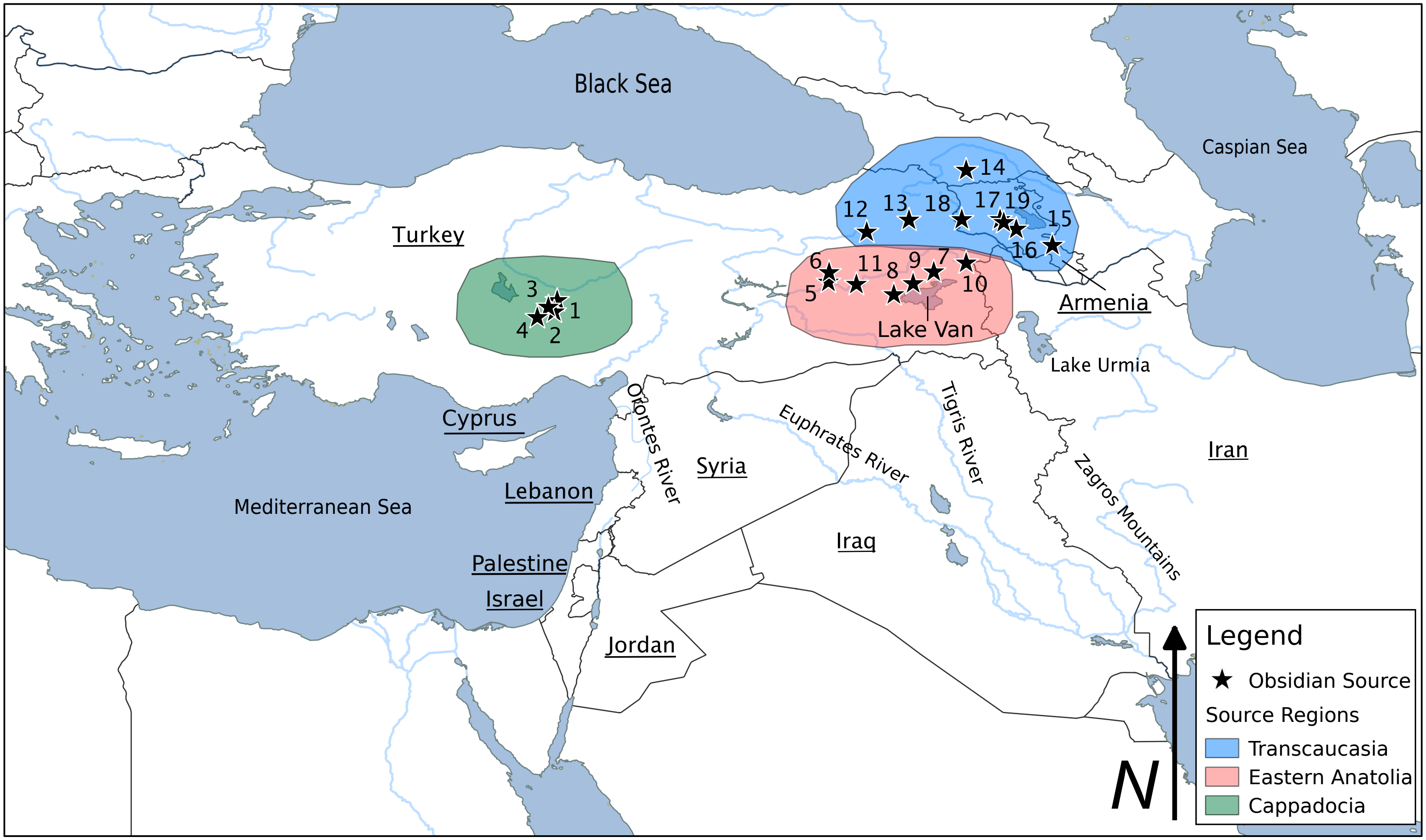


Figure 5.1 – The geographical extent of this thesis and common toponyms mentioned throughout the text. Obsidian sources: 1 – Acıgöl; 2 – Göllü Dağ; 3 - Nenezi Dağ; 4 – Hasan Dağ; 5 – Bingöl A; 6 – Bingöl B; 7 – Meydan Dağ; 8 – Nemrut Dağ; 9 – Süphan Dağ; 10 – Tendürek Dağ; 11 – Muş; 12 – Pasinler; 13 – Sarikamis; 14 – Kojun Dağ; 15 – Sjunik; 16 – Gegham; 17 – Gutansar; 18 – Arteni; 19 – Hatis.

caused by archaeological factors (such as lack of settlements uncovered that would yield more substantial archaeological remains), the overall research interests of primary investigators also plays a role in the analyses performed upon archaeological material found on site and the questions that these examinations are meant to address.

5.4 Obsidian sourcing data

5.4.1 Calculating coefficients of similarity

The edges of the networks constructed for this thesis represent quantified indices of similarity between all pairs of archaeological sites, in terms of the proportions of the different raw materials that comprise their obsidian assemblages. For every pair of sites, the proportions of material determined to be present through sourcing studies are compared using the Brainerd-Robinson formula (Brainerd 1951; Robinson 1951):

$$\boxed{\mathrm{S} = 200 - \sum_{\{k=1\}}^{\mathrm{p}} \left|\mathrm{P}_{\mathrm{i}_\mathrm{k}} - \mathrm{P}_{\mathrm{j}_\mathrm{k}}\right|}$$

Figure 5.2 – For all variables (k), P is the total percentage in assemblages i and j. This provides a scale of similarity from 0-200 where 200 is perfect similarity and 0 is no similarity (from Peeples 2011).

Designed to formally draw associations between pottery assemblages (but applicable for many other kinds of data as well), this equation calculates coefficients of similarity by comparing the proportions of items listed under various classes or categories (Cowgill 1990). Brainerd-Robinson coefficients can then be aggregated to form the basis for a network with weighted edges, representing similar use of various raw materials. Thus two sites with the same range of raw materials in similar ratios will possess a stronger connection in the network, than two sites that have a different array of raw materials, or the same obsidians but in radically different proportions.

A filter is also imposed so only coefficients of similarity above 100 (50% similar or more) are considered. This mid-range threshold value was selected in order to maintain a broad recognition of variable raw material use, while also pruning the weaker edges so as to emphasize the unique network structures shaped through assemblage similarity. Moreover the remaining edges are not binarized, which also serves to preserve the variability inherent in the calculated indices of similarity.

Additionally, only sites with more than one sourced obsidian artefact are included. The presence of only a single sample precludes any possibility of variability, which is defined by the mixture of multiple components. One may also express concern over the comparison of incongruently sized samples; however since the Brained-Robinson formula is based upon the comparison of proportions this method remains practical.

5.4.2 Defining obsidian sources

The Brainerd-Robinson formula operates by comparing tallies of the number of artefacts made from obsidian derived from chemically characterized and segregated natural sources. Each source is considered to be a class under which counted material can be recorded. It is extremely important to consider the level of specificity of the classes being compared. For example, the results of comparing tallies of apples, oranges, peaches and bananas would differ than the outcome of comparing oranges, peaches, bananas, and three subsets of apples – green, red and yellow – all on the same plane. Moreover, the results would be skewed if bananas were compared with all round fruit, which includes all varieties of apples, oranges and peaches. This latter error would be made more extreme if bananas were compared with all round fruit excluding peaches, even though peaches are round fruits and should be listed as such.

In terms of obsidian, the definitions of volcanic sources assigned by various laboratories are often incongruent, which poses similar concerns. Ultimately the designations made by Poidevin (1998; also see Cauvin and Chataigner 1998, Figure 2) were adopted for this thesis (see Table 5.2). Obsidian sources are sometimes collectively referred to according to the region where they are located, which are illustrated in Figure 5.1.

Certain sources are included that have complex lava flows, and thus contain multiple smaller outcrops with geochemically distinct material. Many studies do not recognize the distinctiveness of individual sub-sources, so source attribution was only recorded to the level of specificity of the parent group. For example, the many lava flows at Göllü Dağ, Acıgöl and Gegham are grouped respectively.

Moreover, certain sources are very difficult to distinguish from one another on a geochemical basis and are therefore lumped into the same class. In some cases archaeologists have eventually discovered how to segregate between them, but if the vast majority of material has not yet been differentiated then they remain lumped in this dataset. For instance, the peralkaline (distinctively green) products of Nemrut Dağ and Bingöl A sources both share very similar chemical properties despite being 150km distant from one another, whereby it has not been until relatively recently that have they been conclusively distinguished (Frahm 2012; Orange et al. 2013; though see Cauvin et al. 1986). Prior to this, characterization studies commonly referred to an artefact's raw material as coming from Nemrut Dağ / Bingöl A (cf. Chataigner 1998:279-280). Because most source attributions matching their merged geochemical signatures group them together, even the results of the newer analyses are listed under their umbrella class designated for this thesis. However this is deemed acceptable in broader discussions since both Nemrut Dağ and Bingöl A are located roughly within the same source area of the Lake Van region of eastern Anatolia. On the other hand, the 1e-f geochemical group originally characterized by Renfrew (et al. 1966) is thought to consist of many independent sources that have later been more specifically defined (e.g. Kars, Erevan and Acıgöl (Chataigner 1998:279-280)). While some of the original source attributions have been re-evaluated in light of the more recent distinctions, much of the archaeological material matching the 1e-f group cannot be properly re-assigned. Therefore this remaining information is listed under a class pertaining to unknown or problematic sourcing results.

Another interesting problem is the '3d' geochemical group, also originally identified by Renfrew (et al. 1966) and characterized by high concentrations of Rubidium (Rb). Obsidian with this chemical composition is relatively commonly uncovered during the later Neolithic towards the eastern extent of the region covered in this thesis. While the exact whereabouts of this obsidian source remain unknown, it is still considered independent and is thought to be located somewhere in Transcaucasia (Chataigner 1998:320-321).

5.4.3 Problematic data

Sourcing attributions acquired through visual examination are excluded from the dataset that was compiled for this thesis. In some cases a small sample of obsidian was geochemically characterized, and then all material in the assemblage sharing its colour or physical features would be ascribed to the same source (cf. Renfrew 1977; Kayacan and Özbasaran 2007; *inter alia*). Although a test comparison of predicted source attributions based on visual examination and the results of geochemical analysis had high success

Laboratory	Acıgöl -West	Acıgöl -East	Nenezi Dağ	Göllü Dağ West	Göllü Dağ East	Bingöl B	Bingöl A	Nemrut Dağ	Meydan Dağ	Suphan Dağ	References
Cambridge	4f	1e-f	1e-f	1e-f	2b	1g	4c	4c	3a	3c	Renfrew et al. 1966, 1968
Michigan		1e-f, loc. 1-3	1e-f	1e-f	2b, loc. 6	1g	4c	4c, Nemrut B	3a		Wright 1969
Bradford		B5			B1	B2	G2	G1	B4		McDaniels et al. 1980
Jerusalem	KRUD	HTMS	NNZD		GLD			NMRD1, NMRD2	ZNKT		Yellin & Perlman 1981
NIST	Koru	Hotmis I-III			Göllü	Group D		Nemrut I-IV	Group E		Blackman 1984
Strasbourg	Acıgöl				Kömürcü	Bingöl B	Bingöl A				Cauvin et al. 1986, 1991
Orléans		Group 7	Group 5		Group 3	Groups 2, 4	Group 1b	Group 1a		Group 6	Gratuze et al. 1993

Table 5.2 – Comparison of commonly designated geochemical groups (from Cauvin and Chataigner 1998, Figure 2).

rates (Orange 2012), data generated through visual examination was excluded in order to base the analysis conducted for this thesis on the most accurate information possible.

5.5 DObsiSS: The Database of Obsidian Sourcing Studies

While the obsidian sourcing data that has been compiled for this thesis has always been available in some way or another, much of it is only found in journals aimed towards specialized researchers, detailed in regional-journal field reports, or kept as supplementary material in databases held by archaeometric laboratories. Aside from the issue of data accessibility, much of it is not presentable in ways that enable it to be easily compared or thoroughly analyzed. Many reports lack detail when summarizing the results of sourcing studies, and many generalizations need to be unravelled following chains of citations to previous work performed by more specialized archaeologists. This dataset is thus the result of an effort to make this immense accumulation of information useful for larger-scale contextualized studies, and to enable its integration with other analyses centered on alternative forms of material culture. The Database of Obsidian Sourcing Studies (DObsiSS) is available online[2] for anyone who is interested in using it in any capacity. Bringing all of this information together and making it openly accessible enables archaeologists or any other interested parties to tap into this great wealth of data that has been steadily growing for over 50 years (Freund 2013). In particular, this dataset should be a valuable resource for archaeologists focusing on lithic analysis who are now turning to contextualize their work within broader regional frameworks.

DObsiSS is the most complete compilation of obsidian sourcing data pertaining to southwest Asia and Anatolia during the Neolithic. However it is important to keep in

[2] DObsiSS can be accessed online by visiting https://zackbatist.github.io/DObsiSS

mind that it is limited by the information that is generated on an independent basis. While virtually all verifiable obsidian sourcing data is included pertaining to the region covered in this thesis, more information is continuously being produced. Only 151 records are incorporated in this study, however DObsiSS can very easily expand to include any other data from contexts beyond the scope of this thesis.

6 – METHODS

6.1 Constructing networks

The first stage of the methodology is the construction of networks. After organizing the data along the parameters outlined in the previous chapter the sourcing data is separated from all other information regarding the archaeological contexts of the finds. For each period, only obsidian sources that have been identified at least once are considered for comparison. An overview of the number of sources used during each period is available in Table 5.1. The context-specific information (which includes geographical coordinates, the country and region in which they are located, and the number of artefacts analyzed) is collated into an attributes table.

The proportions of obsidian sources used at each site are then compared using the Brainerd-Robinson formula. A script that automates its repetitive calculation was used to process the data more efficiently. This script was acquired from Matthew Peeples (2011), who wrote it to be used as part of the R statistical analysis suite.

In previous archaeological studies that have relied on coefficients of similarity to construct networks, links representing weaker indices of similarity were filtered out and 'binarized' (cf. Golitko et al. 2012; Mills et al. 2013; Phillips 2011). This means that connections with weight (or coefficient of similarity) below a certain threshold value are removed or given a value of 0, and all remaining edges are then assigned the same weight value of 1 (Peeples and Roberts 2013). Thus only stronger connections are included in the network, and variation among them is no longer considered. For the work in this thesis a threshold value of 50% was chosen so that a wider range of raw material variability could be considered, while also maintaining focus on stronger ties. However the remaining edge weights are not binarized, consisting with the aim to recognize variability instead of nullifying it.

6.2 Analysis

6.2.1 On the implementation of analytical algorithms

Analytical algorithms simply detect patterns in the network without considering what data was used to construct it. Whether or not the results are meaningful is up to archaeologists to decide through subsequent evaluation while keeping in mind what is being represented. The results should then be integrated into broader discussions surrounding the topics at hand – in this case lithics variability, overall trends evident in other aspects of the archaeological record, or related geographical assessments. The processes that underlie the applied algorithms are outlined below, along with the potential significance of their outputs in terms of the aims of this thesis. All analyses and conversions were conducted using the igraph software package, which is a component of the R statistical programming suite (Csardi and Nepusz 2006; R Core Team 2014).

6.2.2 Centrality

The uneven distribution of edges among all nodes results in certain nodes being more connected than others, as opposed to complete networks wherein all nodes are connected to all others with every possible connection being actualized. Nodes with varying connectivity hold different roles tying the overall network together. A node's position in terms of the connections associated with it is measured as *centrality*. Centrality can be defined in many ways, however this thesis only considers three variants: *degree*, *betweenness* and *eigenvector*.

Degree centrality is a measure of how many edges are associated with a node. For directed networks whose arcs imply non-reciprocal relationships between nodes, this metric can be split as in-degree and out-degree (no directed networks are analyzed in this thesis). An *isolate* is a node that is not connected to any other, and has a degree of 0.

Betweenness centrality is the measure of how often a node is situated along the shortest path between all other pairs of nodes in the network (Brandes 2001). Eigenvector centrality is a measure of how well connected a node is to other highly connected nodes, as calculated through other measures of centrality (betweenness in particular) (Bonacich 1987).

Considering that edges represent variable uses of geochemically distinct obsidian, nodes with high betweenness centrality have a high degree of mixture among variants. For example, if two sites have high concentrations of different raw materials and are therefore unconnected, and both variants of obsidian have been identified at a third site, this latter node would have connections with each of the others and would be positioned between them along their shortest path. In many sociological, biological or technological applications of network analysis, betweenness centrality is interpreted as an indicator of an individual's potential to impact a larger group, or as a bottleneck for the flow of information. Although this can be a tremendously useful and versatile metric, one must be wary to interpret it properly with regards to the data being represented in network format. While it is great to be able to identify sites with high degrees of raw material variability in relation to others, it may be inappropriate to associate this reading with notions of power or influence. Instead a reasonable argument may be that a site with high betweenness centrality may have participated in multiple exchange systems that oversaw the movement of different kinds of obsidian. Eigenvector centrality is used to identify nodes that are well connected to others that are themselves highly central. In the context of this thesis, this metric may be useful for identifying more nuanced variability as an extension of betweenness measures.

6.2.3 Community detection

Groups of nodes that are more highly connected to each other than they are to others in the network are called *clusters*, *modules* or *communities*. A node that is a part of a cluster is said to be a *member* of it. Many algorithms have been devised to detect clusters, but only one is used in this thesis.

The *edge-betweenness method*, also known as the *Girvan-Newman method for community detection* after its original designers, gradually removes edges from the network exhibiting the highest betweenness centrality. Similarly to betweenness concerning nodes, *edge-betweenness* is calculated by determining how often an edge is situated along the shortest paths between all pairs of nodes. As a result the network fragments since these highly central edges form indirect links between otherwise completely unconnected sections (Newman and Girvan 2004). Each of these groups thus conforms to the definition of a module given above. Clusters can be broken down into smaller sections as central edges are successively removed, the order of which is visualized as a dendrogram that also highlights the hierarchical nature of this particular community detection algorithm.

Although the terminology may be slightly misleading from an anthropological perspective, community detection methods are not employed to detect the ranges or borders of human groups, however they can still offer significant insight. The edge-betweenness method detects groups of sites that have similar proportions of raw material by splitting the network along edges that bridge a gap between sections with little or no direct connections. While this results in the identification of sites with highly similar proportions of raw material, one must consider how the obsidian was transformed and used in order to truly identify cultural similarities or differences.

6.2.4 Clustering coefficients and measurements of density

The local clustering coefficient, also referred to as *transitivity,* is a measurement of mutual connectivity among the neighbours of a node (Barratt et al. 2004). A node's neighbours are other nodes that are directly linked to it by an edge. As such, a node's local clustering coefficient is the quotient of the number of actualized edges between its neighbours divided by the total number of possible connections between them. While high local clustering coefficients may indicate uniform use of raw materials in the vicinity of a node, its own conformity can be determined by counting the *number of triangles* that it is member of.

6.3 Visualization

All graphs in thesis are visualized using the Force Atlas layout, a spring-embedded layout algorithm that dynamically disperses nodes and edges as of they were components in a physical or electronic system (Jacomy et al. 2014). Besides the layout algorithm itself, all other visualization tasks were done using the Gephi software package (Bastian et al. 2009). Moreover the networks were converted into GIS readable files using the *Gephi Export to SHP Plugin* designed and programmed by Roman Seidl (2012). These files enabled the results of analysis to subsequently be mapped using Quantum GIS. Additionally, the dendrograms representing the community structure breakdowns were created using igraph.

7 – RESULTS & DISCUSSION

7.1 Overview

This chapter outlines the results attained through analysis of networks representing differential raw material exploitation strategies, and evaluates other aspects of obsidian artefacts (such as typology and technology) to form a more holistic understanding of the socio-economic processes that underlies the material's distribution. A narrative is constructed in order to highlight changes over time and to situate the findings within the broader body of research concerning regional interaction in each setting.

While much of the reasoning behind this discussion has a basis in aspects of geography, space is not considered to have strictly dictated the attitudes of a population. Rather, a site's position in the network or its membership to a cluster is a product of its relationships to others, as manifested through their obsidian assemblages. Geographical factors are accounted for as inevitable forces that would have to be dealt with in order to facilitate any kind of interaction between archaeological communities, however their roles are not emphasized to a strong degree (Coward 2013).

Admittedly this thesis lacks focus on intra-site distribution of obsidian, which could be evaluated to better understand the roles of specific agents in initiating and maintaining long-distance relationships. While such work would be very interesting to do (cf. Frahm and Feinberg 2013; Maholy-Nagy 1976), the supporting information that would be required to take on this angle (such as specific provenance of finds, along with all typological, technological, and raw material analyses, which are already too-commonly disjointed) is not commonly published for Near Eastern sites. Certain analyses of this kind have been conducted (cf. Carter et al. 2006; Frahm 2010) but their detailed inclusion in this discussion was not a priority.

7.2 Period 1

The network representing similarity of raw material use for Period 1 consists of 10 nodes and 24 edges between them. After applying the Girvan-Newman method for community detection, three modules become apparent. The largest is a tightly connected cluster of nodes representing sites in the Levant and the region along the middle Euphrates. The obsidian present at these sites is largely derived from Göllü Dağ in Cappadocia, however some eastern material is also present is small quantities. Abu Hureyra (*1_1*) and Körtik Tepe (*1_8*), both of which have much more diverse obsidian assemblages, form their own module. To the East, Chia Sabz (*1_4*) is represented by an isolated node, whose edges with others are weighted below the similarity threshold.

Although the dataset pertaining to this period is rather small (n=10), certain patterns are highlighted through network analysis that generally match observations made elsewhere. Kozlowski and Aurenche (2005) have undertaken an extremely detailed review of the overall archaeological record to document the spatial distribution of various artefact classes. In their Early Period, which they consider spans from 10,500 – 8000 B.C. (Kozlowski and Aurenche 2005:15) and which roughly corresponds with the chronological unit presently being discussed, the authors define borders demarcating the spatial extent of prehistoric peoples in the Near East through a detailed assessment of the distribution of material culture. While the spatial patterning of many kinds of artefacts complemented each other well, this study equates the material record with the people who produced it. In this sense, Kozlowski and Aurenche do not explicitly account for the processes by which the objects they compare were produced, which are believed to be a better way of identifying cultural boundaries (Druc 2013). However this work is useful as a reference to compare the results gathered here with the collective distribution patterns of various alternative archaeological materials.

The primary border that Kozlowski and Aurenche define is situated just east of the Balikh River, delimiting the eastern and western 'wings' of the Fertile Crescent. The borderland, which encompasses the area surrounding this hypothetical boundary, is recognized as a threshold where material culture pertaining to each wing would 'spill over' into the other. A secondary border is also placed at the southern end of the Orontes River, distinguishing between sites in the central Levant and those situated along the middle Euphrates. While not a lot of obsidian sourcing data has been generated pertaining to sites on the eastern wing of the Fertile Crescent for this period, making it difficult to draw comparisons between each side, one large module is detected that is comprised of nearly all sites in the Levant and northern Syria. The secondary distinction within this module made by Kozlowski and Aurenche, which is supported by divisions proposed by Shea (2013:274-278) through comparison of overall lithic typologies (no distinction between obsidian and chert was made), is not confirmed through analyses performed here. This makes it clear that comparison of raw materials alone is not adequate for defining archaeological communities.

Despite this drawback, the homogenization of Levantine sites into a single tightly connected module does signify the standard use of Cappadocian obsidian in the region. However some variability does exist with regard to the volume of raw material uncovered and characterized. While some obsidian from eastern sources is found at sites belonging to this module, its presence is limited only to Tell Aswad (*1_2*) (9%) in the central Levant and Cheikh Hassan (*1_3*) (37%) along the middle Euphrates, both of which exhibit high betweenness centrality. The presence of eastern raw material in the Levant (limited to only a single sourced obsidian artefact from Tell Aswad, in fact) is significant because it suggests that there was contact, albeit to a limited degree, with people who did have access to eastern obsidian. While no details concerning the morphology or technology of

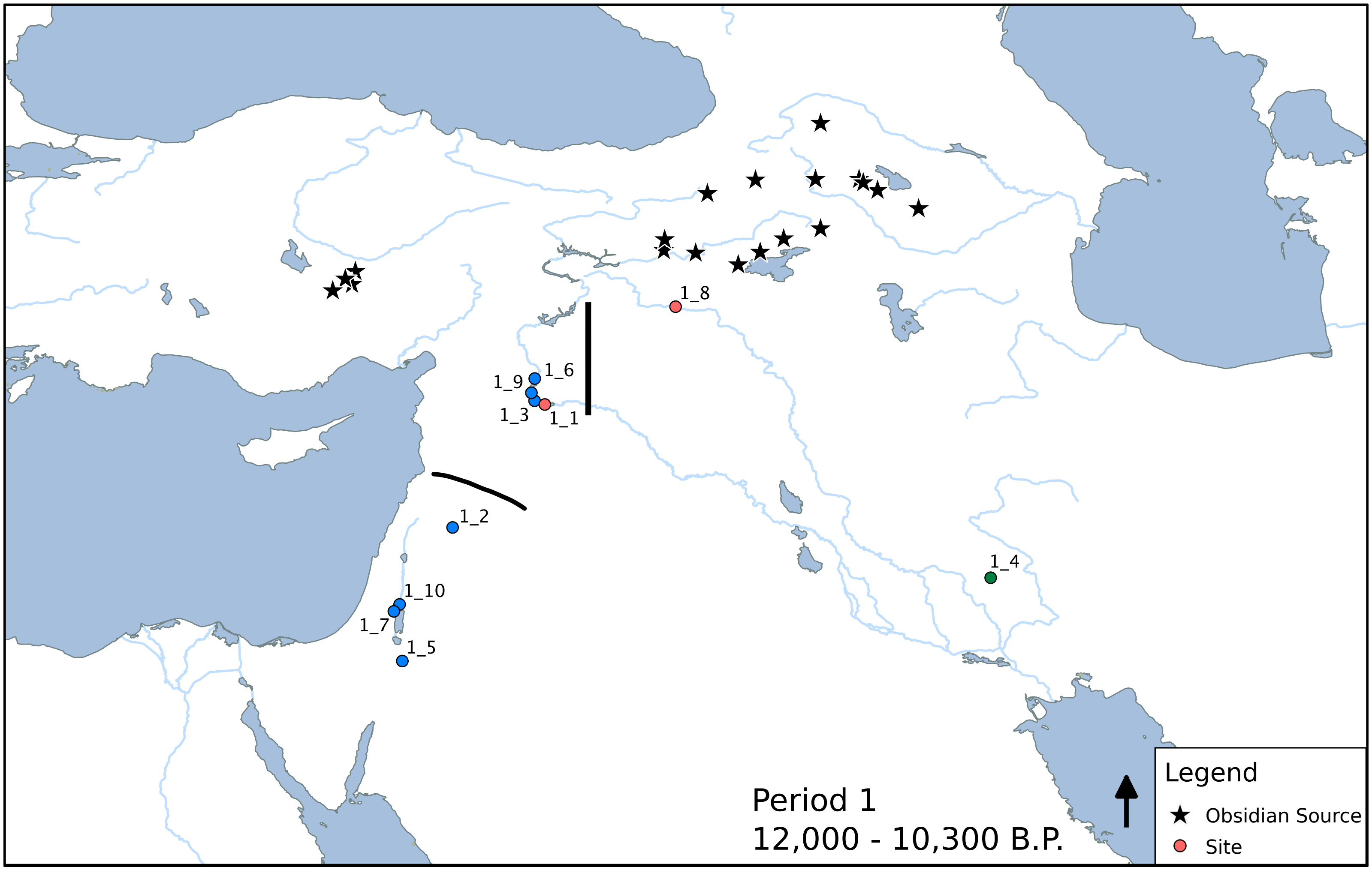


Figure 7.1 – The modules detected using the Girvan-Newman algorithm in relation to the borders designated by Kozlowski and Aurenche (2005).

manufacture of this specific piece are published, the overall lithic assemblage pertaining to the context in which it was found is often compared with that of the middle Euphrates region (Cauvin 1974:431-435; Moore 1982:7; Shea 2013:276-277).

An interesting exception to the homogenization of the Levant and middle Euphrates is a second module comprised of Abu Hureyra (*1_1*) and Körtik Tepe (*1_8*). Carter (et al. 2013; in press) has extensively examined the obsidian assemblages at these two sites (each analysis was conducted independently), considering technological and typological variation in addition to raw materials analysis. In Carter's (et al. 2013) evaluation of the obsidian from Körtik Tepe the authors identified a local tradition of manufacture, whereby eastern Anatolian obsidian was exclusively used to make microblades. They compared this tendency with observations of very different practices at sites along the middle Euphrates, whereby the same eastern Anatolian materials were transformed nearly exclusively using pressure-flaked blade technology. Carter (et al. 2013) interpreted this discrepancy as two contrasting attitudes towards obsidian that were culturally derived. This evaluation, which emphasized practice over presence, provides a more realistic delimitation of cultural identities (Druc 2013). The connection between Abu Hureyra and Körtik Tepe observed through the analysis presented here is based upon evaluation of raw materials alone without considering how it was transformed, and perhaps through consultation with Carter's still-unpublished work pertaining to Abu Hureyra, or through collection of more data pertaining to sites east of the Euphrates River, more extensive explanation for this strong link may be derived.

In a more general sense, there are too few sites towards the east of the study region to draw any definitive interpretations from. However it is interesting to note that obsidian – in this case from Nemrut Dağ / Bingöl B, over 800 km away (great circle distance, 'as the crow flies') – does traverse a great distance to reach East Chia Sabz (*1_4*) at this time.

At this site, Darabi and Glascock (2013:3806-3807) found tools, debris and cores, which indicates that obsidian artefacts were manufactured locally using imported and unworked raw materials. This material manifestation of resource procurement strategies contrasts sharply with that of the Levant, which is of a comparable distance from the Cappadocian sources; there are no such instances of unworked raw materials or debris present during Period 1 in the Levant that would signify local manufacture of obsidian tools.

Despite challenges posed by the datasets small size and spatial distribution, the results pertaining to Period 1 complement current understandings of obsidian circulation. While the extent of the cluster representing sites that primarily used Cappadocian obsidian could easily have been delimited from a top-down perspective, the methodology applied here enabled more detailed examination of the degree of heterogeneity within this group. Additionally, through examination of the second cluster it is apparent that it is necessary to account for multiple facets of obsidian artefacts in order to arrive at more well-rounded conclusions.

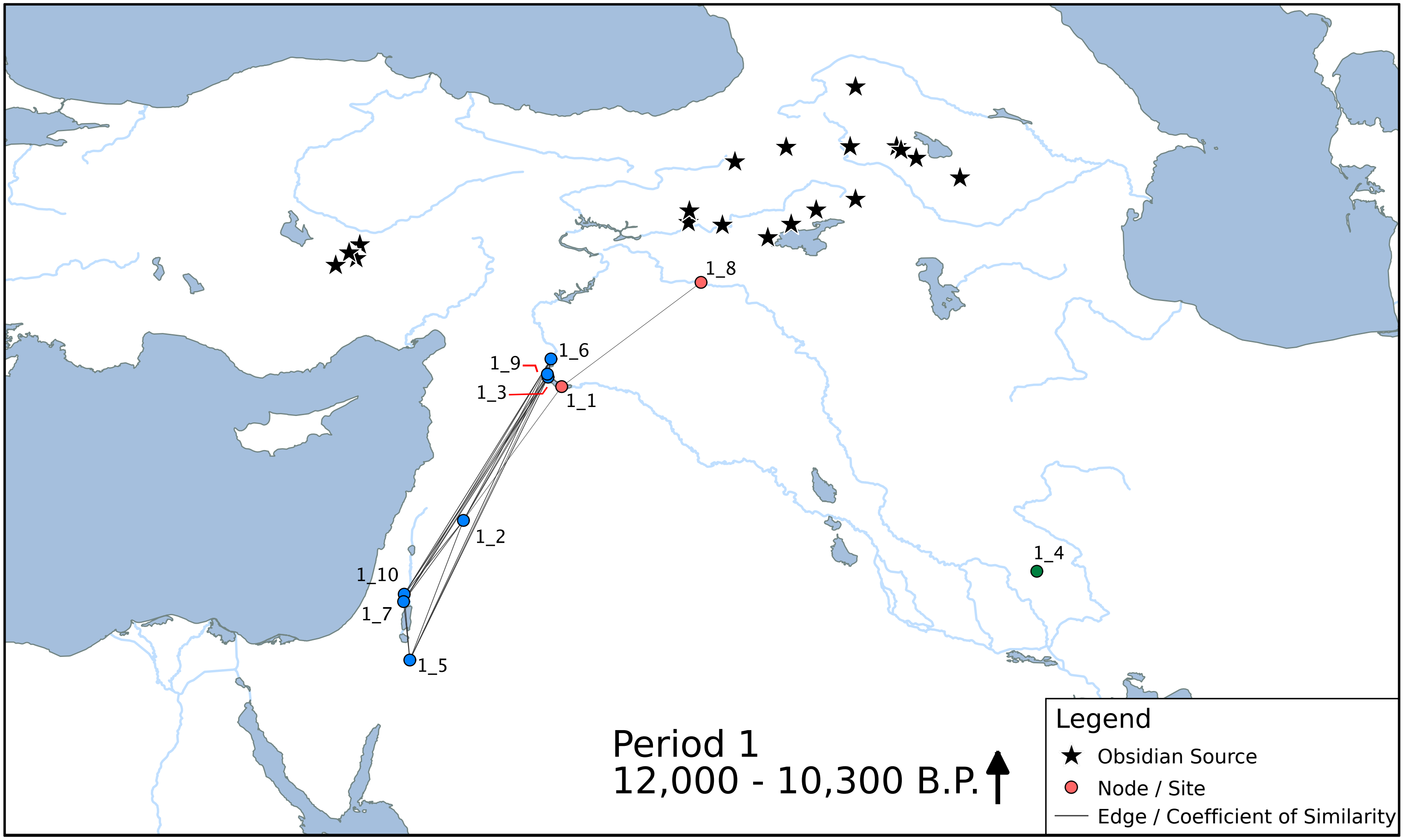


Figure 7.2 – Cartographical representation of modules distinguished after applying the Girvan-Newman method for community detection on the network constructed for Period 1.

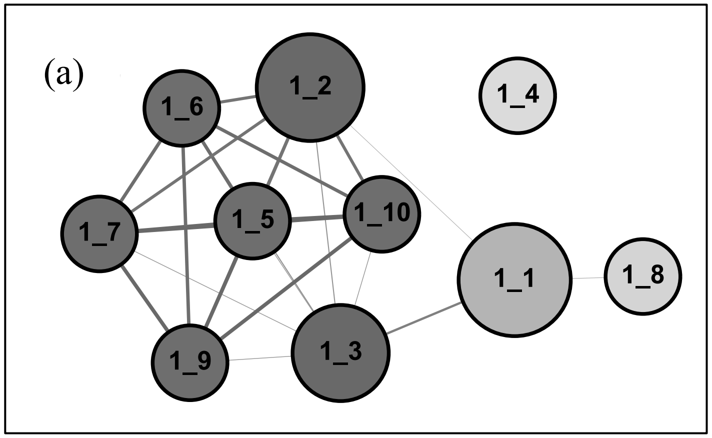
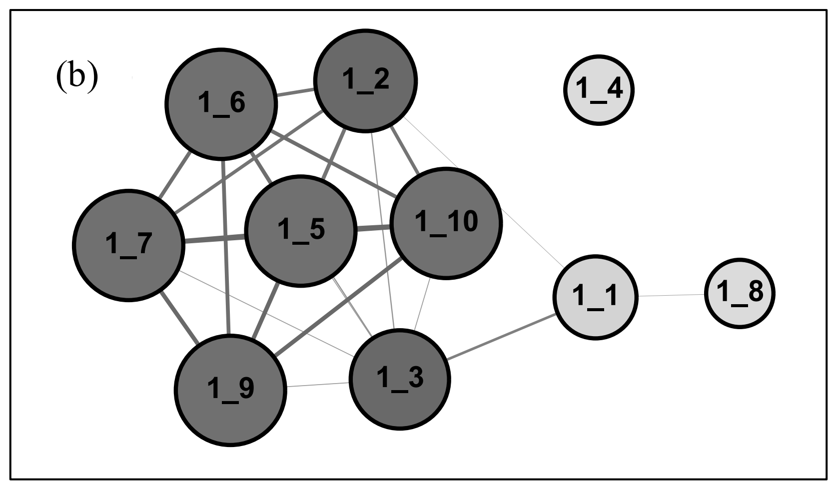


Figure 7.3 – Graphs illustrating the results pertaining to Period 1. In (a) communities a node's size reflects its between centrality, and its shade reflects its eigenvector centrality. In (b) a node's size reflects the number of triangles it participates in, and its shade reflects its local clustering coefficient. In both (a) and (b) larger diameters and darker shades represent higher values. Additionally, in both graphs thicker lines represents higher edge weight.



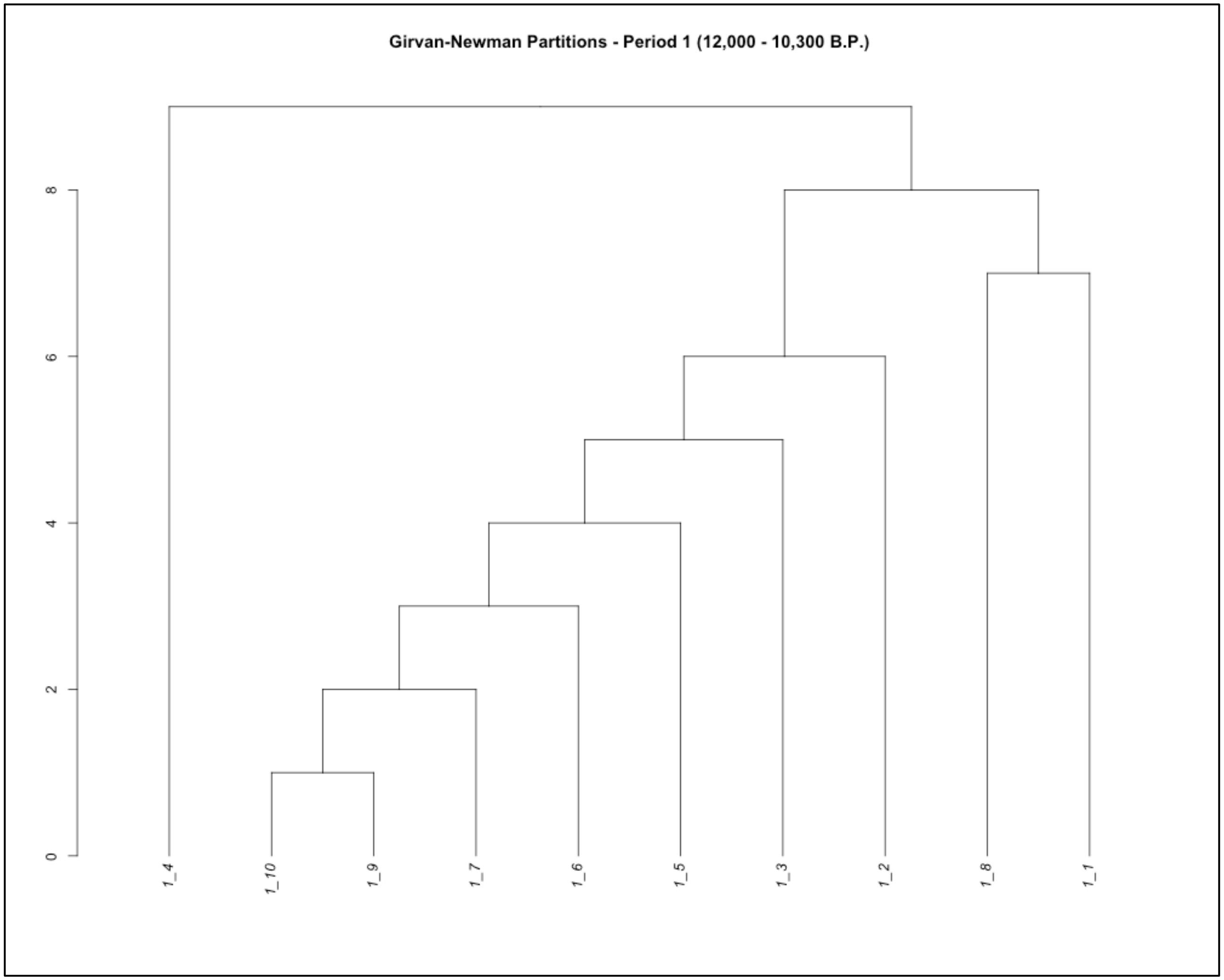


Figure 7.4 – Dendrogram illustrating the partitioning of modules in the network for Period 1 following the Girvin-Newman method for community detection.

ID	Site	Period	Country	Obsidian analyzed	Degree	Betweenness	Eigenvector	Clustering Coefficient	Number of Triangles	GN
1_1	Abu Hureyra	1	Syria	7	3	0.194	0.341	0.350	1	1
1_2	Aswad	1	Syria	11	7	0.167	1.000	0.792	16	2
1_3	Cheikh Hassan	1	Syria	27	7	0.111	1.000	0.739	16	2
1_4	East Chia Sabz	1	Iran	20	0	0.000	0.000	0.000	0	3
1_5	el Hemmeh	1	Jordan	18	6	0.000	0.951	1.000	15	2
1_6	Jerf el Ahmar	1	Syria	44	6	0.000	0.951	1.000	15	2
1_7	Jericho	1	Palestine	5	6	0.000	0.951	1.000	15	2
1_8	Kortik Tepe	1	Turkey	121	1	0.000	0.058	0.000	0	1
1_9	Mureybet	1	Syria	3	6	0.000	0.951	1.000	15	2
1_10	Netiv Hagdud	1	Palestine	8	6	0.000	0.951	1.000	15	2

Table 7.1 – The results of network analysis pertaining to Period 1.

7.3 Period 2

The network constructed for Period 2 consists of 41 nodes and 356 edges between them, representing the largest dataset analyzed for this thesis. After applying the Girvan-Newman method for community detection, two primary modules are highlighted. Each one is primarily composed of sites located in the eastern or western portions of the study area, with sites along the middle Euphrates split among both groups. Additionally, two nodes comprise their own respective modules. These nodes should not be interpreted as unique anthropological communities due to their separation from others in the network; rather, after examining the underlying data more closely, it is clear that their distinction is not caused by differential presence of raw materials, but by different degrees of evenness among them.

As with Period 1, there is limited data pertaining to obsidian distribution in the eastern portion of the study area. However it is notable that preforms and cores continue to be found, suggesting that the production of obsidian artefacts was still occurring locally amongst communities of this region (Darabi and Glascock 2013).

The middle Euphrates region is clearly a nexus where source distributions converge, with sites containing material from diverse geological origins. By examining the reduction strategies evident at these sites, further observations can be made concerning how obsidian was procured. Although at sites such as Abu Hureyra (*2_1*) and Mureybet (*2_29*) raw material was imported as worked nodules (as evident through lack of cortical debris), every stage of lithic reduction is accounted for, which indicates that artefacts were manufactured locally (these observations are based upon entire lithic assemblages, and information as it pertains to obsidian specifically is pending review [Carter, personal communication]). This indicates that the raw material was either initially worked at the sources or processed by intermediaries on its way to the Euphrates.

Additionally, elsewhere in northern Syria and southern Turkey there is evidence for small- and large-scale production of obsidian artefacts (Asouti 2006:102-103; Nishiaki and Nagai 2011) in addition to the acquisition of finished products not produced locally (Arimura 2013). This lack of consistency suggests that no single mechanism for exchange was in place with respect to the circulation of obsidian, and that there was in fact quite a bit of variability in this respect. Moreover, this varied system hints at power relations among sites that supplied finished tools and those that were supplied, which may have manifested themselves in other respects outside the context of obsidian circulation as well.

This variability seemingly disrupts any notion of homogeneity among sites, as implicitly posited by Kozlowski and Aurenche (2005) in their conceptualization of a 'golden triangle', an arbitrarily-defined region centered around the middle Euphrates that they speculate was the primary seat of Neolithization (Figure 2.4). While the middle Euphrates is clearly a point of convergence where people were procuring both eastern and Cappadocian obsidian, a more nuanced recognition of the specific ways that it was procured and transformed is also crucial to consider (Carter et al. 2013). In this way, obsidian circulation is not plainly examined as a geographical balancing act, but as a series of fluid human actions and modes of organization, as manifested in the archaeological record (Asouti 2006:119-120).

Already it has been possible to contemplate on the different ways that Cappadocian and Eastern obsidian was procured in Period 1 by the inhabitants of the Levant and southwest Iran respectively, however this was aided by the geographically led assumption that people exclusively used raw materials that were located relatively nearby. Thus it was possible to generalize specific source regions as the origins of all raw materials used to produce all obsidian artefacts, regardless of their other technological or typological facets. The same cannot be assumed for the middle Euphrates, which exhibited more raw material variability. If one would like to comment on the circulation patterns of specific obsidian variants using a similar approach for this region, it is important to ensure that each source be considered independently. This means that the typological and technological facets must be linked with the sourcing data. Unfortunately, most published techno-typological assessments and sourcing studies are not presented in a way that facilitates their comparison, which severely inhibits this kind of enquiry. For instance, universal object identifiers or reference codes are not always used in artefact sourcing publications, and the results of materials analysis are often mentioned in passing without providing specific information regards the number of artefacts analyzed or their specific features. However newly conducted studies are increasingly recognizing the need to join all facets of obsidian artefacts in light of renewed interest of a socialized approach to examine obsidian circulation.

While all actors certainly influenced the ways that obsidian was distributed, it is reasonable to suggest that sites closer to the volcanic sources have had a more pivotal role in determining the extent by which the materials circulated; obsidian must be gathered in large volumes close to the source if it is to be exchanged elsewhere in significant quantities. Along the middle Euphrates, obsidian artefacts were produced at a variety of locations over a large region. As such, it appears that there was no systematic or centralized distribution system in what Renfrew (1969) would call the ‘Supply Zone’.

Certain structures in the network representing the presence of similar raw materials also seem to match the distribution of observed assemblage-types that have been previously documented, namely the distinction between sites at the western edge of the Syrian Desert and those situated in the central and southern Levant (Cauvin and Cauvin 1993; Shea 2013:276-277). In the network, the former group is characterized by higher amounts of eastern material in obsidian assemblages, and exhibit higher betweenness centrality as a result. Thus the recognition of cultural differentiation based upon the presence of raw materials not found elsewhere in the vicinity is compounded by other technological and typological distinctions. This notable differentiation is clearly relatable to that made between sites in the same region for Period 1, and represents a continuation of interaction between the inhabitants of the middle Euphrates basin and of the south-central Levant via the western Syrian Desert. It is also tempting to suggest that the exchange of obsidian was not unidirectional, owing to the large volume of Cappadocian obsidian at sites along the middle Euphrates (at Q'deir 1 (*2_33*), for instance), however this notion cannot be confirmed until it is determined that obsidian was not arriving at the Euphrates from elsewhere (i.e. from the northwest) in comparable quantities. This can only be resolved through the collection of greater volumes of data concerning the origins of obsidian uncovered at sites in the northern Levant and along the middle Euphrates.

The possibility of intense bi-directional interaction between these two regions also prompts one to consider how obsidian would have arrived at the western edge of the Syrian Desert in the first place, prior to redistribution. The lack of obsidian sourcing data pertaining to sites in the northern Levant, along with records of Cappadocian obsidian on Cyprus, point towards the possibility that these materials were brought to the southern and central Levant via maritime transportation mechanisms. Alternatively, a case can be made for the occurrence of a down-the-line exchange mechanism that would have enabled obsidian artefacts to reach far distances from the raw materials' sources. In any case, all Levantine sites are identified as members of one cluster that can generally be characterized by a majority presence of Cappadocian obsidian. The tight grouping, which is evident in the nodes' high clustering coefficient metrics, is due to the relative homogeneity of raw material identified at these sites. However it is important to note that the Göllü Dağ source group, which is the most common variant used, actually consists of many different outcrops, and that artefacts made of material derived from these sources had to be lumped together for data analysis (Binder et al. 2011). When examining the typology and production strategies of lithics at sites in the Levant some variability is evident, which is also reflective of sites' roles in obsidian circulation systems. For instance, during the PPNB in the Levant obsidian generally makes up smaller proportions of lithic assemblages towards the south (Garfinkel 2008, Table 36), and is most commonly found in the form of bladelets, projectile points and knives, whose functionality would be greatly enhanced by the extreme sharpness that obsidian is well-suited for (Shea 2013:230). Moreover, obsidian artefacts tend to be smaller and more extensively retouched than those made of chert, however the methods by which flakes and cores were re-touched and rejuvenated remains the same for both materials (Shea 2013:230). This suggests that obsidian was curated differently, presumably to conserve it for extended use (Odell 1996). While it is understandable that the inhabitants of Levantine sites would want to conserve the sharper (and rarer) material, it is arguable that obsidian was perceived as a variant of the more common chert, which would trickle south once in a while via indirect exchange with northern groups. Through a comparative study more directly focused on interactions between the Levant and the Euphrates region at this time, while accounting for the variability of Cappadocian raw material variants being exchanged, it may be possible to investigate finer aspects of obsidian circulation. However such an endeavour is beyond the scope of this thesis.

In this discussion pertaining to Period 2, the east/west dichotomy that is commonly illustrated in top-down conceptualizations of obsidian distribution zones (see Figure 1.1) is indeed replicated using network analysis. However upon further evaluation of this network, in which the centrality of each node was also considered, greater insight regarding the connectivity of these wings was attained. Moreover, by considering aspects of obsidian artefacts besides raw material, a clearer understanding of the socio-economic landscape in various regions was ascertained. Although there is still work to be done in order to ameliorate or clarify these assertions, these more nuanced findings already show that the novel approach adopted for this thesis is a viable and productive methodology worth expanding upon.

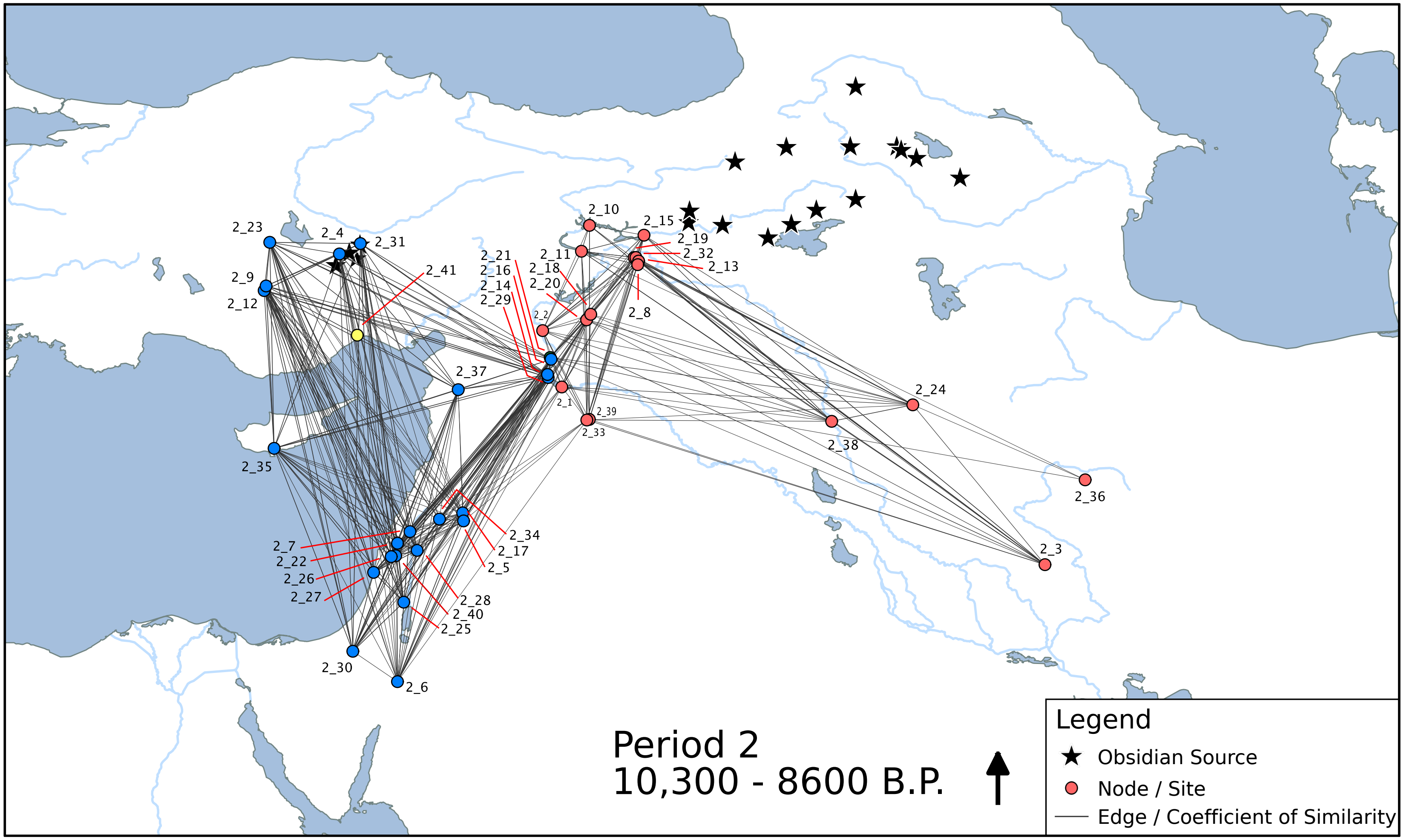


Figure 7.5 – Cartographical representation of modules distinguished after applying the Girvan-Newman method for community detection on the network constructed for Period 2.

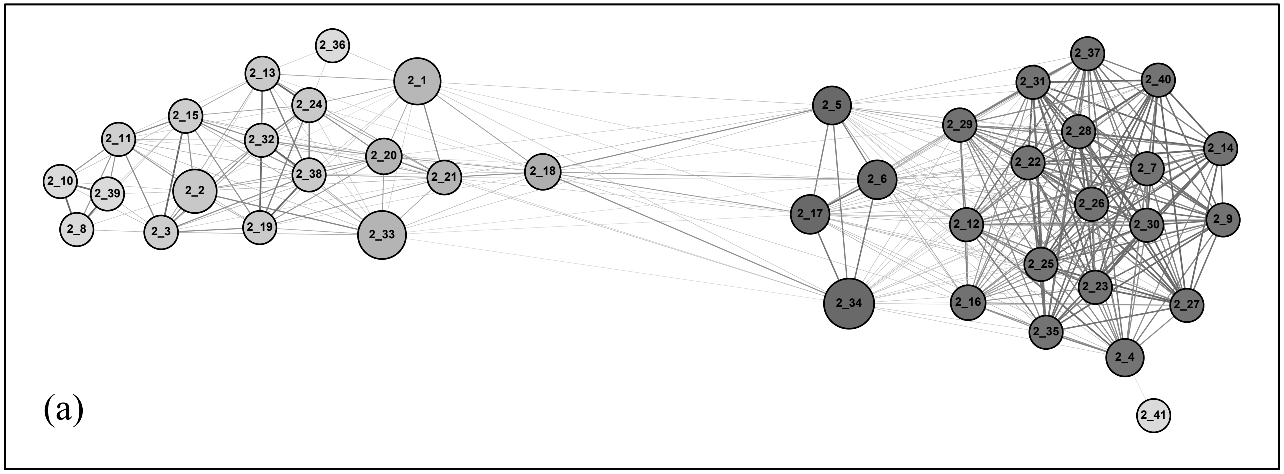
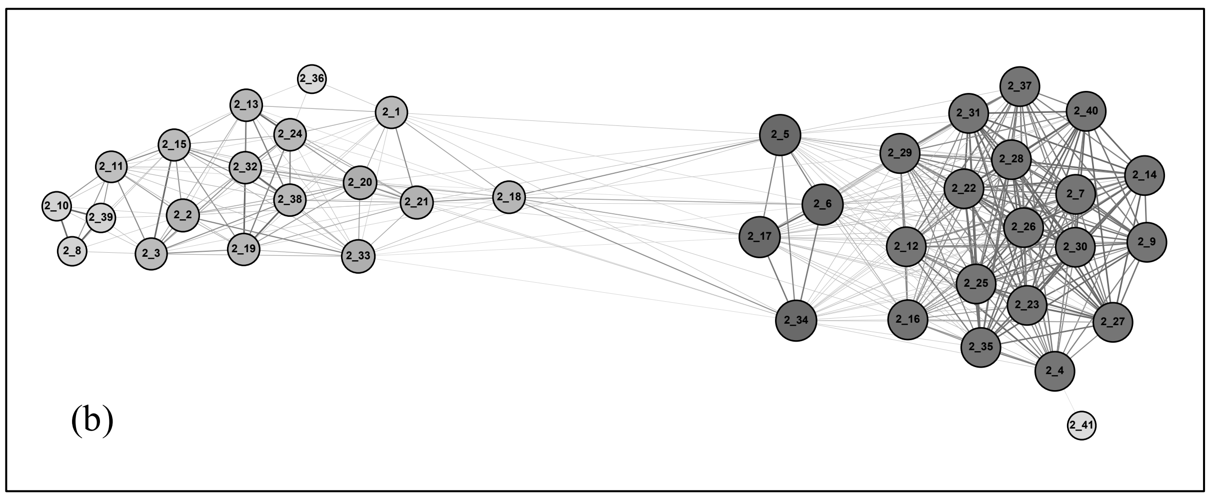


Figure 7.6 – Graphs illustrating the results pertaining to Period 2. In (a) communities a node's size reflects its between centrality, and its shade reflects its eigenvector centrality. In (b) a node's size reflects the number of triangles it participates in, and its shade reflects its local clustering coefficient. In both (a) and (b) larger diameters and darker shades represent higher values. Additionally, in both graphs thicker lines represents higher edge weight.



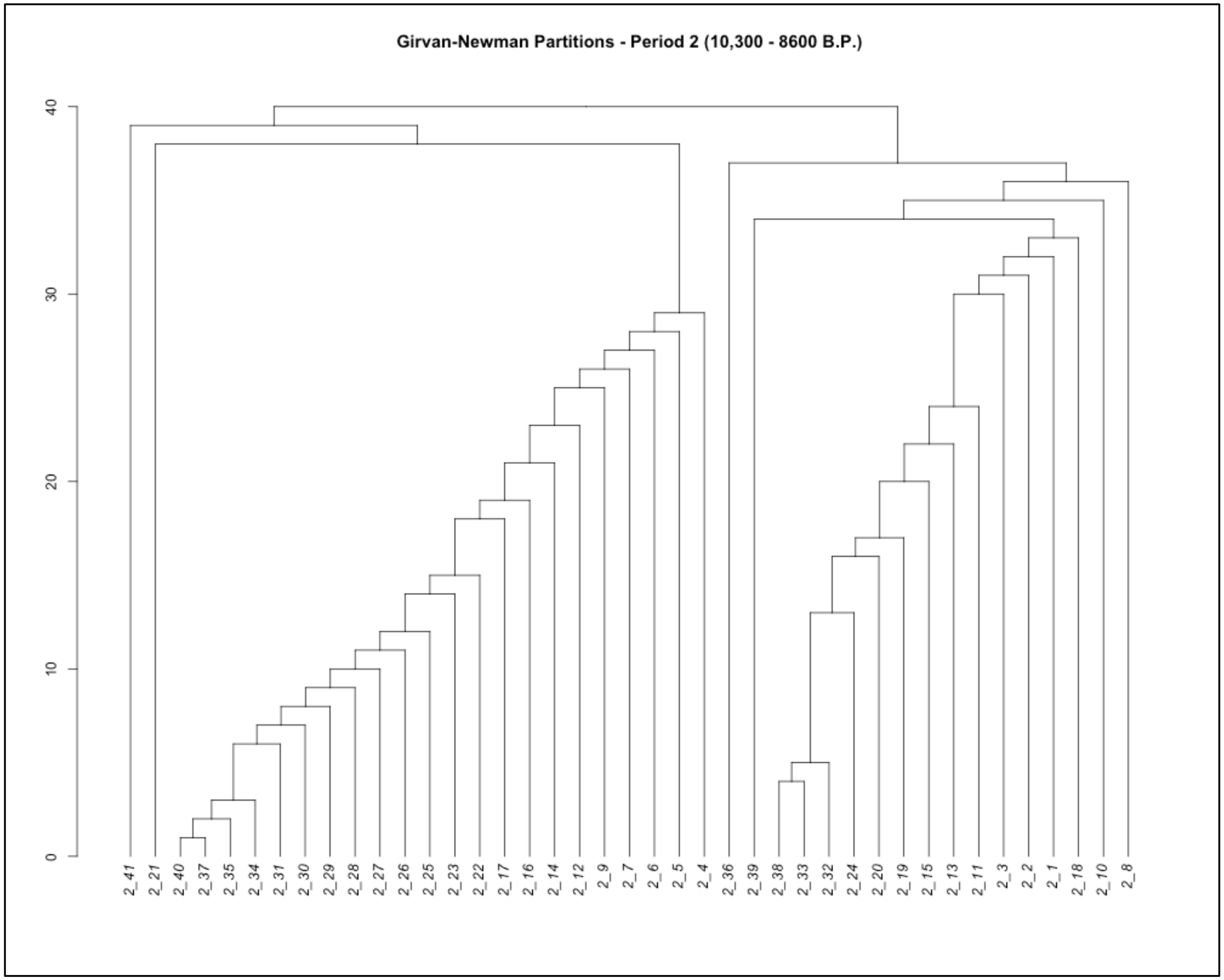


Figure 7.7 – Dendrogram illustrating the partitioning of modules in the network for Period 2 following the Girvin-Newman method for community detection.

ID	Site	Period	Country	Obsidian analyzed	Degree	Betweenness	Eigenvector	Clustering Coefficient	# of Triangles	GN
2_1	Abu Hureyra	2	Syria	22	15	0.156	0.338	0.672	69	1
2_2	Akarcay Tepe	2	Turkey	18	16	0.122	0.193	0.709	83	1
2_3	Ali Kosh	2	Iran	6	14	0.004	0.156	0.745	66	1
2_4	Asikli	2	Turkey	41	22	0.050	0.910	0.925	210	2
2_5	Aswad	2	Syria	83	26	0.056	1.000	0.738	237	2
2_6	Beidha	2	Jordan	3	26	0.064	1.000	0.753	237	2
2_7	Beisamoun	2	Israel	31	21	0.000	0.908	1.000	210	2
2_8	Birikin Magarasi	2	Turkey	2	6	0.000	0.048	1.000	15	1
2_9	Boncuklu	2	Turkey	61	21	0.000	0.908	1.000	210	2
2_10	Boy Tepe	2	Turkey	2	6	0.000	0.048	1.000	15	1
2_11	Cafer Huyuk	2	Turkey	21	13	0.000	0.138	0.731	57	1
2_12	Çatalhöyük East	2	Turkey	45	21	0.000	0.908	1.000	210	2
2_13	Cayonu	2	Turkey	12	14	0.010	0.185	0.823	73	1
2_14	Cheikh Hassan	2	Syria	12	21	0.000	0.908	1.000	210	2
2_15	Cinaz Huyuk	2	Turkey	3	14	0.004	0.156	0.745	66	1
2_16	Djade	2	Syria	56	22	0.018	0.928	0.937	215	2
2_17	Ghoraife	2	Syria	6	26	0.064	1.000	0.753	237	2
2_18	Gobekli	2	Turkey	100	16	0.029	0.418	0.645	76	1
2_19	Golbent Ergani	2	Turkey	2	13	0.000	0.183	0.921	71	1
2_20	Gurcutepe I	2	Turkey	34	17	0.028	0.363	0.708	93	1
2_21	Halula	2	Syria	8	16	0.008	0.354	0.719	84	3
2_22	Horvat Galil	2	Israel	5	21	0.000	0.908	1.000	210	2
2_23	Ilicapinar	2	Turkey	3	21	0.000	0.908	1.000	210	2
2_24	Jarmo	2	Iraq	10	14	0.010	0.185	0.823	73	1
2_25	Jericho	2	Palestine	2	21	0.000	0.908	1.000	210	2

2_26	K'far Hahoresh	2	Israel	8	21	0.000	0.908	1.000	210	2
2_27	Mikhmoret	2	Israel	6	21	0.000	0.908	1.000	210	2
2_28	Mujahiya	2	Israel	13	21	0.000	0.908	1.000	210	2
2_29	Mureybet	2	Syria	97	22	0.003	0.928	0.940	215	2
2_30	Nahal Lavan	2	Israel	68	21	0.000	0.908	1.000	210	2
2_31	Nevshehir Kogulalti	2	Turkey	4	21	0.000	0.908	1.000	210	2
2_32	Papazgolu	2	Turkey	2	13	0.000	0.183	0.921	71	1
2_33	Q'deir 1	2	Syria	517	17	0.176	0.363	0.700	93	1
2_34	Ramad	2	Syria	5	26	0.201	1.000	0.741	237	2
2_35	Shillourokambos	2	Cyprus	64	21	0.000	0.908	1.000	210	2
2_36	Tell Abdul Hosein	2	Iran	12	3	0.000	0.040	1.000	3	1
2_37	Tell el Kerkh 2	2	Syria	367	21	0.000	0.908	1.000	210	2
2_38	Tell es-Sinn	2	Syria	2	13	0.000	0.183	0.921	71	1
2_39	Umm et-Tlel	2	Syria	8	6	0.000	0.048	1.000	15	1
2_40	Yiftael	2	Israel	8	21	0.000	0.908	1.000	210	2
2_41	Yumuktepe	2	Turkey	42	1	0.000	0.042	0.000	0	4

Table 7.2 – The results of network analysis pertaining to Period 2.

7.4 Period 3

The network constructed for Period 3, which roughly corresponds with the transitional phase between the PPNB in the Levant and the early Pottery Neolithic towards the east, consists of 25 nodes and 134 edges between them. Notably, the scope of the dataset has shifted to include more sites situated in the northern Levant and on Cyprus than in northern Mesopotamia, which may be due to the relative lack of archaeological material that is characteristic of broader developments at this time.

After applying the Girvan-Newman method for community detection, two completely disconnected modules become apparent, exhibiting no strong ties between them. Some weaker connections are present only after reducing the similarity threshold to 25%. At this lower edge threshold, only sites situated in the north-central Levant and middle Euphrates region maintain connections between modules. These connections are only formed between sites across the western Syrian Desert, where the only Levantine sites with eastern obsidian are situated (Ras Shamra (*3_19*), Tell Aray 2 (*3_22*) and Tell Labweh (*3_23*)). The continuity of this region as a sensitive contact point is notable since this extends further into time the observations of direct contact between the Levant and the middle Euphrates, however it is important to consider that by lowering the threshold value for filtering edges, the chances of connections being observed are increased drastically.

The western module, which is largely composed of sites holding a majority of Cappadocian material, covers many sites located along the Mediterranean coast. This suggests that obsidian may have been transported with relatively great intensity over maritime channels, which may have been in use during the prior period as well.

In the module largely consisting of sites situated towards the east of the study region, the geographic distribution of available data poses problems. Although coverage is broad, sites are too evenly distributed to draw substantial comparisons between obsidian usage patterns adopted across the region. As such, many of the inter-regional developments that occurred at this time do not manifest themselves in the networks analyzed here.

The network examined here brings to mind Garfinkel's (2011) assertion that the relatively low volume of obsidian in the Levant at this time, in relation to the prior period, may be related to an overall disconnect among sites exhibiting more cultural heterogeneity. While the results of analysis do depict such a disconnect between the two detected modules, the clustering coefficients of sites in the Levant region are actually quite consistent and indicate similar use of the same raw material variants. Since it is likely that the disconnect between modules would have restricted access to eastern Anatolian obsidians in the Levant, it makes sense that those sites would have consistently used Cappadocian obsidians. Although it is certainly possible that cultural variability may have been expressed through differential use of these same raw materials, further integration of multiple aspects of obsidian artefacts is necessary in order to better recognize such patterning (cf. Carter et al. 2013).

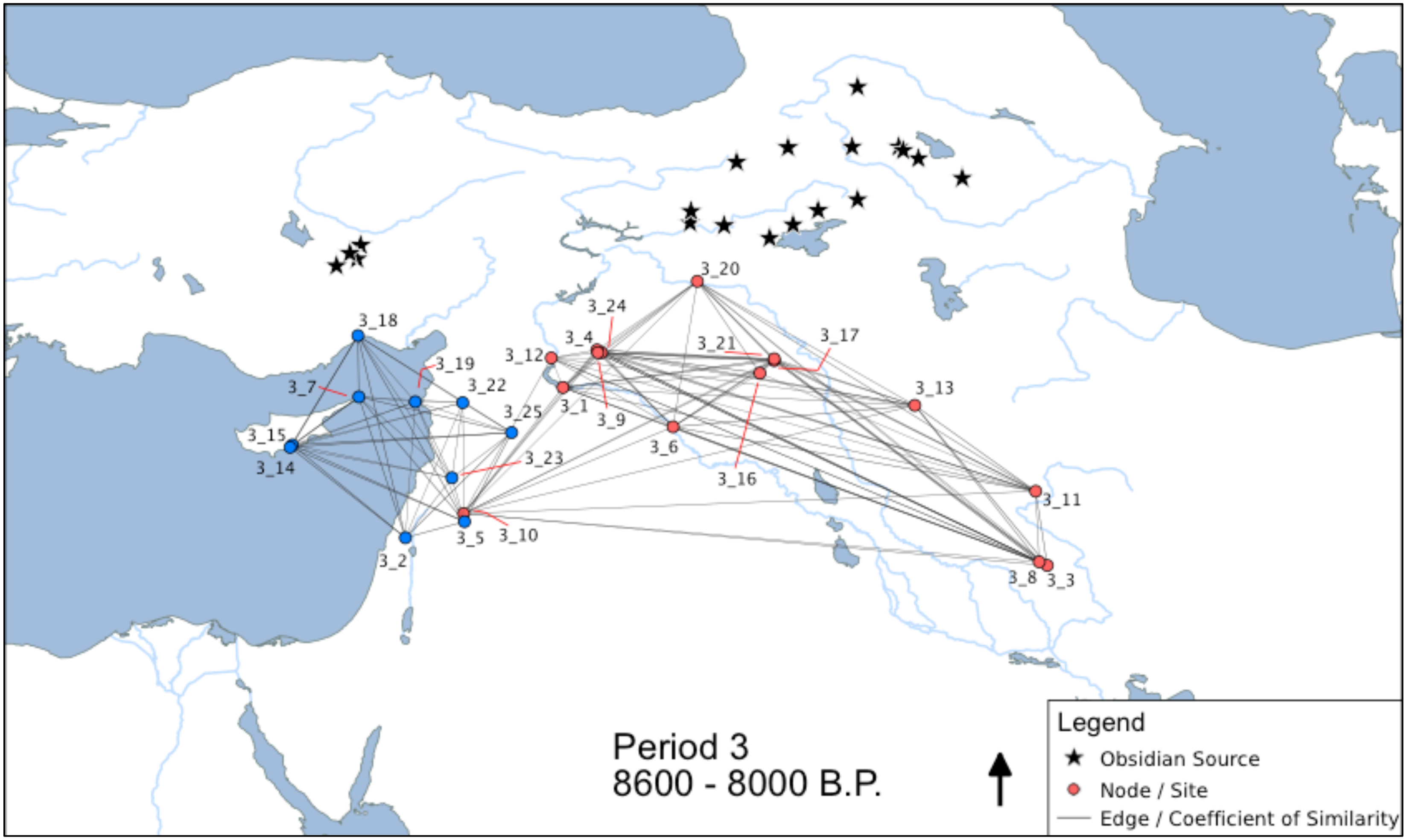


Figure 7.8 – Cartographical representation of modules distinguished after applying the Girvan-Newman method for community detection on the network constructed for Period 3.

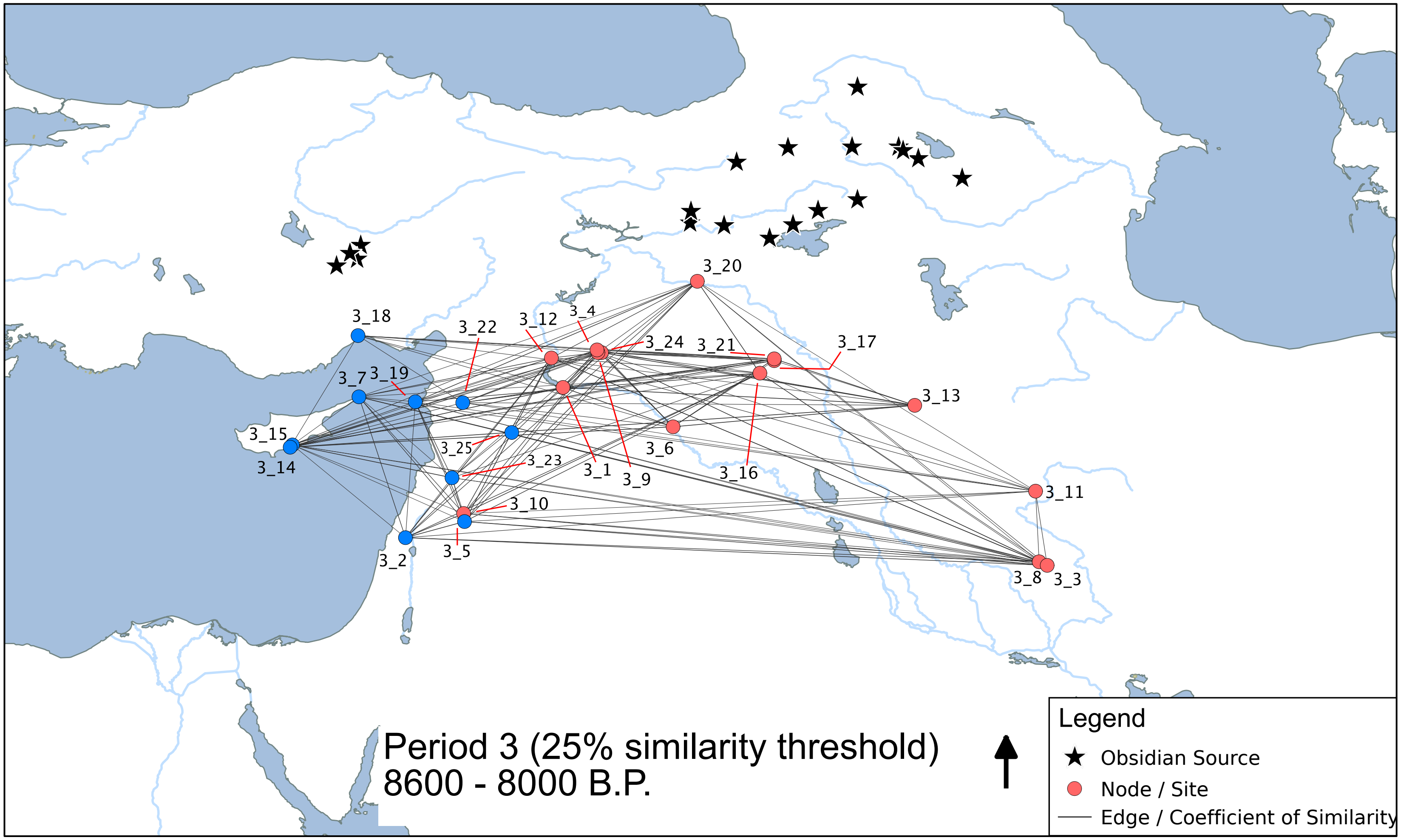


Figure 7.9 – Cartographical representation of modules distinguished after applying the Girvan-Newman method for community detection on the network constructed for Period 3, albeit with a lower threshold denoting the minimum coefficient of similarity needed to form an edge.

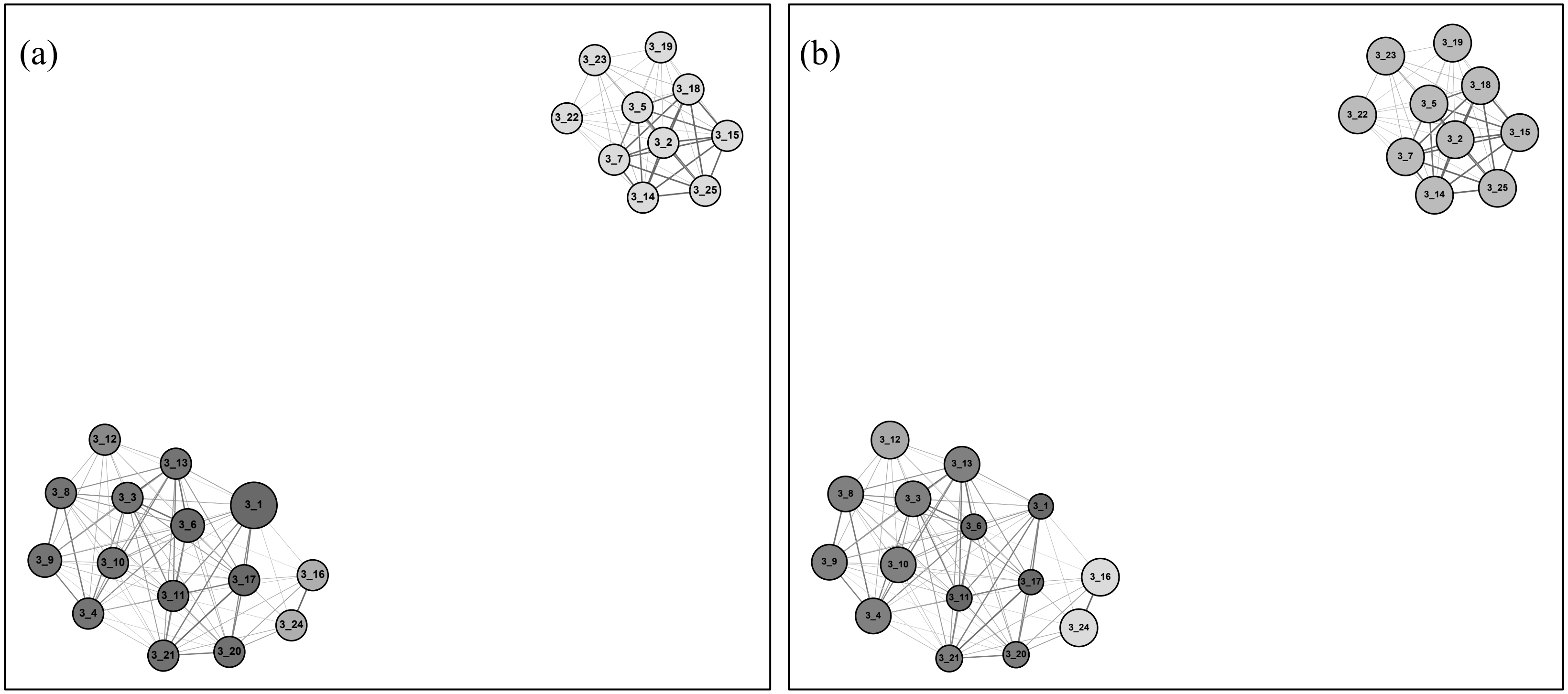


Figure 7.10 – Graphs illustrating the results pertaining to Period 3. In (a) communities a node's size reflects its between centrality, and its shade reflects its eigenvector centrality. In (b) a node's size reflects the number of triangles it participates in, and its shade reflects its local clustering coefficient. In both (a) and (b) larger diameters and darker shades represent higher values. Additionally, in both graphs thicker lines represents higher edge weight.

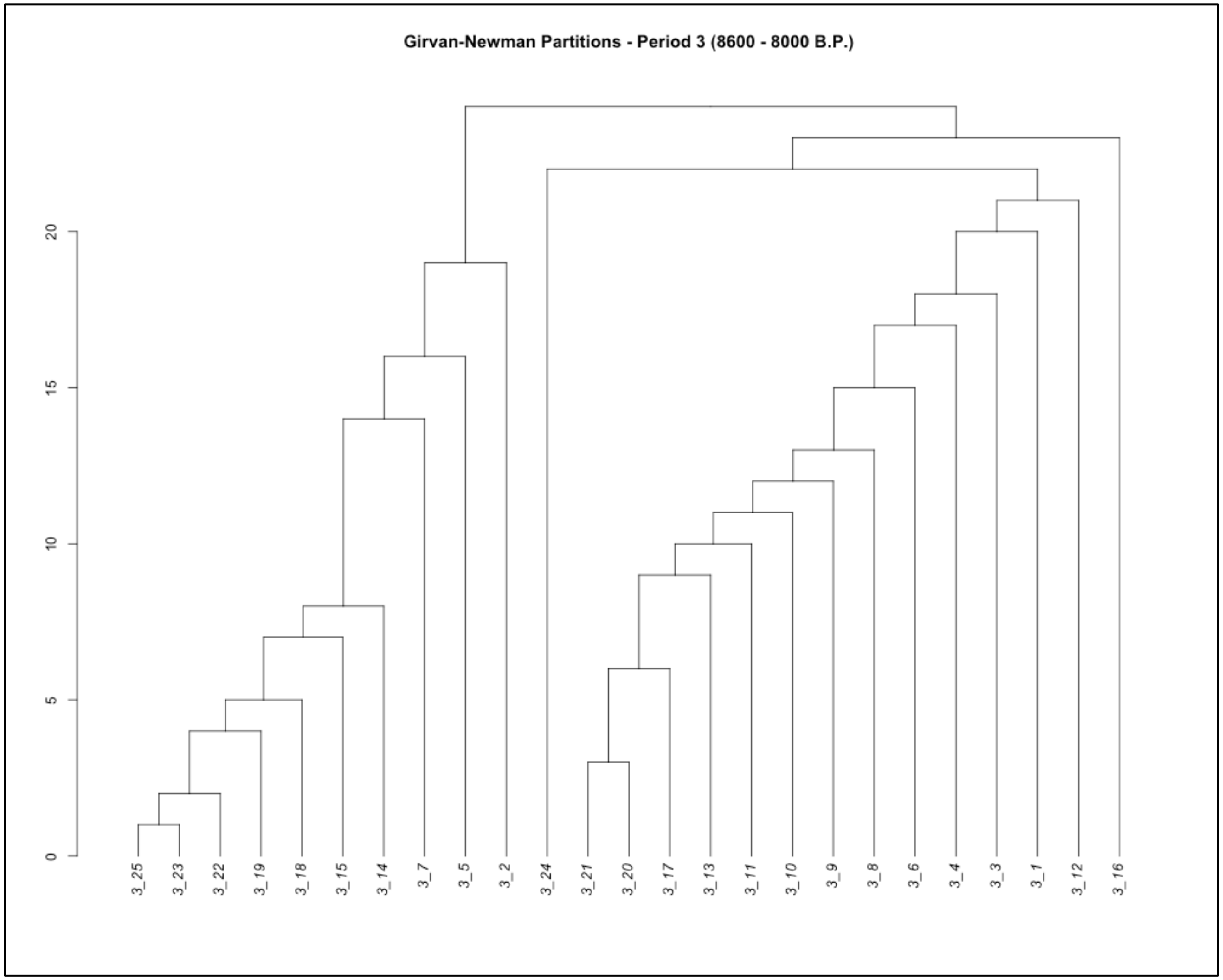


Figure 7.11 – Dendrogram illustrating the partitioning of modules in the network for Period 3 following the Girvin-Newman method for community detection.

ID	Site	Period	Country	Obsidian analyzed	Degree	Betweenness	Eigenvector	Clustering Coefficient	# of Triangles	GN
3_1	Abu Hureyra	3	Syria	23	14	0.043	1.000	0.841	75	1
3_2	Ain Miri	3	Israel	3	9	0.000	0.219	1.000	36	2
3_3	Ali Kosh	3	Iran	4	12	0.000	0.920	0.973	64	1
3_4	Assouad	3	Syria	5	12	0.000	0.920	0.974	64	1
3_5	Aswad	3	Syria	139	9	0.000	0.219	1.000	36	2
3_6	Bouqras	3	Syria	15	14	0.007	1.000	0.846	75	1
3_7	Cap Andreas	3	Cyprus	13	9	0.000	0.219	1.000	36	2
3_8	Choga Sefid	3	Iran	18	12	0.000	0.920	0.974	64	1
3_9	Damishliyya I	3	Syria	63	12	0.007	0.920	0.973	64	1
3_10	Ghoraife	3	Syria	18	12	0.000	0.920	0.973	64	1
3_11	Guran	3	Iran	10	14	0.000	1.000	0.845	75	1
3_12	Halula	3	Syria	14	10	0.000	0.778	1.000	45	1
3_13	Jarmo	3	Iraq	9	12	0.000	0.920	0.973	64	1
3_14	Kalavasos Tenta	3	Cyprus	6	9	0.000	0.219	1.000	36	2
3_15	Khirokitia	3	Cyprus	6	9	0.000	0.219	1.000	36	2
3_16	Kul Tepe	3	Iraq	4	7	0.000	0.524	1.000	21	1
3_17	Magzalia	3	Iraq	38	14	0.000	1.000	0.840	75	1
3_18	Mersin	3	Turkey	5	9	0.000	0.219	1.000	36	2
3_19	Ras Shamra	3	Syria	3	9	0.000	0.219	1.000	36	2
3_20	Salat Cami Yani	3	Turkey	74	13	0.000	0.941	0.853	66	1
3_21	Sotto	3	Iraq	7	13	0.000	0.941	0.861	66	1
3_22	Tell Aray 2	3	Syria	18	9	0.000	0.219	1.000	36	2
3_23	Tell Labweh	3	Lebanon	23	9	0.000	0.219	1.000	36	2

3_24	Tell Sabi Abyad II	3	Syria	21	7	0.000	0.524	1.000	21	1
3_25	Wadi Tumbaq	3	Syria	3	9	0.000	0.219	1.000	36	2

Table 7.3 – The results of network analysis pertaining to Period 3.

7.5 Period 4

The network constructed for Period 4 consists of 38 nodes and 218 edges between them. In general an extension of the processes interpreted during the prior period are observed, with a Mediterranean coastal exchange system in place, largely independent but now intermingling with one large module that seems to dominate the network, spanning much of the Fertile Crescent. Additionally, the strong east/west dichotomy generally observed earlier begins to dissolve at this time. Raw material breakdowns of assemblages at sites further west become much more fragmented due to the increased presence of eastern obsidian – from the Bingöl and Nemrut Dağ sources in particular. This is especially evident in the Northern Levant, which is a rather conspicuous zone of convergence at this time. This seems to mirror the wider distribution of Halaf pottery that occurred towards the end of this period, which is considered to represent participation within a broader regional community (Campbell 1999). The Hassuna and Samarra pottery traditions also gained widespread adoption prior to and contemporarily with the Halaf, however they have generally been subsumed by the end of this period. Although finer chronological resolution would be very helpful for documenting the changes that occurred within this relatively long period, this assessment is limited to a broader-scale examination. As such, the Hassuna and Samarra traditions are considered here to represent earlier stages of a larger transformation encompassing the early Pottery Neolithic, which is most easily characterized by reference to the Halaf given the circumstances.

In addition to the two aforementioned modules, isolated nodes are also observed. The assemblage at Hacilar (*4_14*) in Cappadocia is composed of obsidian from Acıgöl and Demenegaki on Melos, and at Hajji Firuz Tepe (*4_16*) on Lake Urmia only Armenian material is present. Notably, both of these sites use obsidian derived from previously unexploited sources.

Meydan Dağ obsidian, which was sparsely used during earlier periods, gains more widespread adoptions starting at this point. One cluster comprised of nodes representing Arpachiyah (*4_3*), Halaf (*4_17*) and Tilki Tepe (*4_35*), represents assemblages with higher proportions of this raw material. Chagar Bazar (*4_9*) and Nineveh (4_*24*) (an isolate with potential edges of weight slightly lower than the threshold value) also have this raw material present but in more even proportions with other variants, resulting in the formation of their own adjacent modules.

The geographical distribution of these network structures is notable. Obsidian originating from the Bingöl and Nemrut Dağ sources seems to be found in larger quantities at sites very distant from its geological origins, as has been the case for millennia by this point. However despite this, Meydan Dağ material, which is comparably accessible, has a limited range relative to the aforementioned variants. Only a few exceptional finds in the Levant have been uncovered, at Hagoshrim (*4_15*) for instance, however it is unknown whether the material was worked on site or was imported as finished products. If it is correct to assume that the networks being manifested through obsidian are actually representative of socio-economic ties, or in other words the socio-economic infrastructure over which the material was actually transferred, and the material was potentially readily available, then its limited range may be accounted for by limited or restricted demand. Therefore it is conceivable that Meydan Dağ obsidian was perceived differently than material derived from elsewhere. This notion can be more thoroughly investigated through finer analyses that account for more nuanced intra-site variability with regards to ways that different raw materials were worked and distributed, in a similar vein as the work done by Carter (et al. 2008) and Frahm and Feinberg (2013), *inter alia*, however such studies remain outside the scope of this thesis.

The geographically-concentrated exploitation of Meydan Dağ obsidian, as well as the introduction of other new raw materials into circulation (e.g. Arteni, Pasinler, Sarikamis and Sjunik), complement observations (Akkermans 2000; Frangipane 2007; LeBlanc and Watson 1973) that the Halaf truly represents a distributed and cooperative society, rather than a centralized one. A subset of people who subscribed to the Halaf pottery tradition may have also engaged in more fluid interactions with people in north-eastern Anatolia and Armenia, and the influx of these new materials may be manifestations of such connections. By identifying what processes were occurring locally in tandem with consideration of the types of artefacts that were made, it is possible to surmise whether obsidian was being worked in Mesopotamia to suit local desires, or whether it was brought down as finished products acquired through externalized contacts.

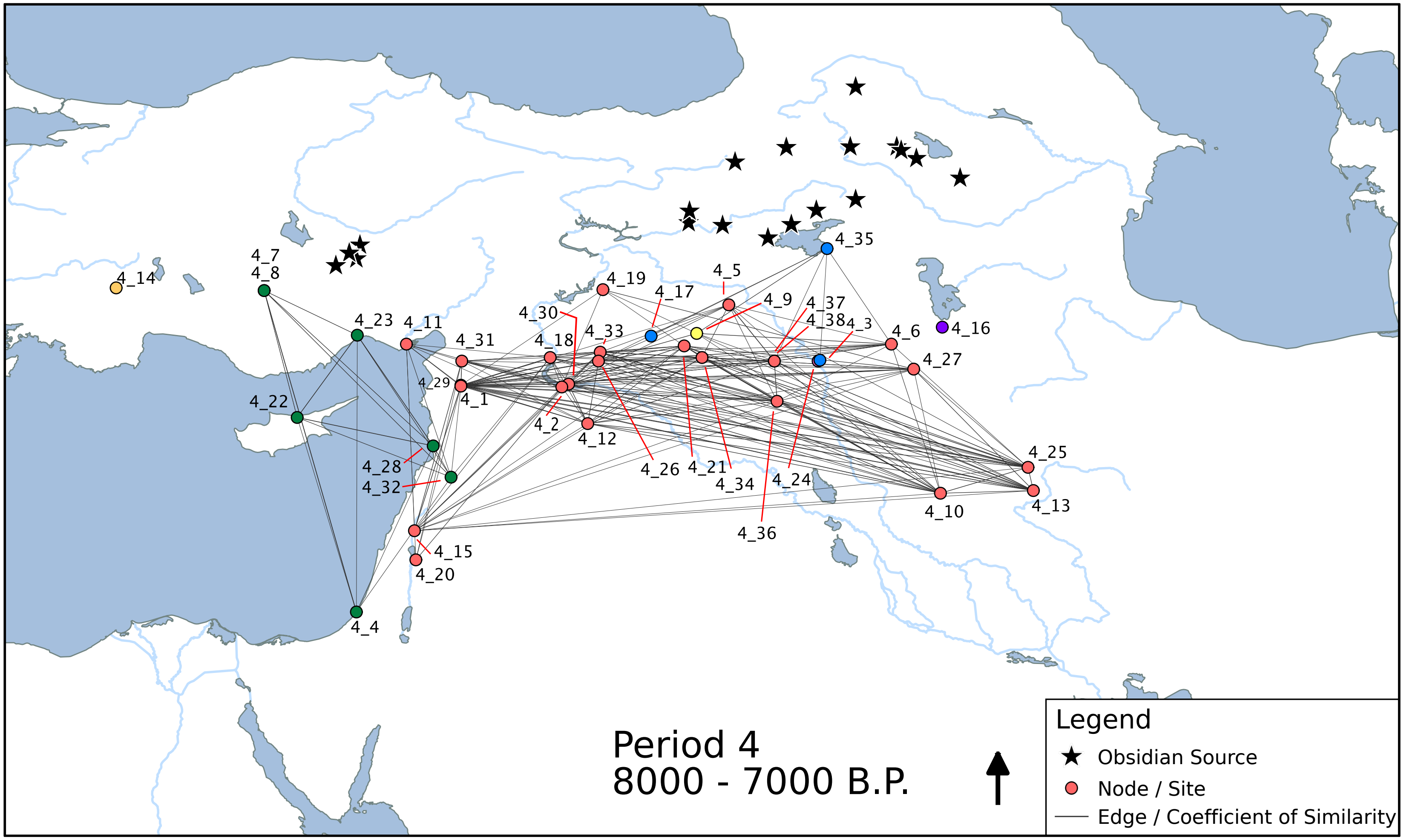


Figure 7.12 – Cartographical representation of modules distinguished after applying the Girvan-Newman method for community detection on the network constructed for Period 4.

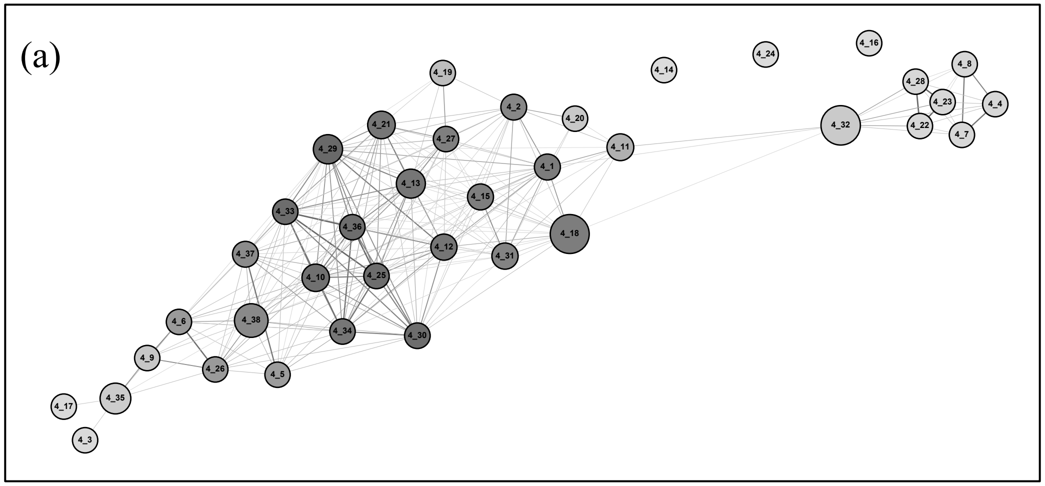
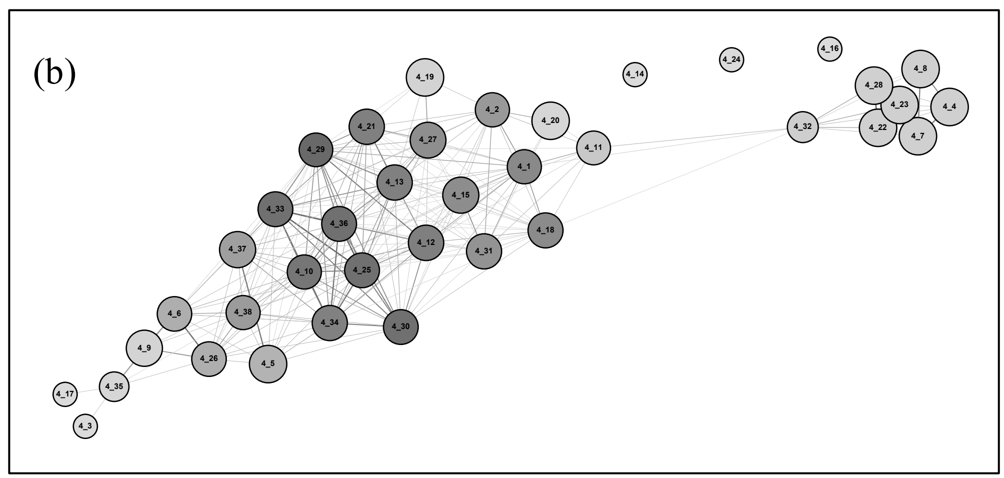


Figure 7.13 – Graphs illustrating the results pertaining to Period 4. In (a) communities a node's size reflects its between centrality, and its shade reflects its eigenvector centrality. In (b) a node's size reflects the number of triangles it participates in, and its shade reflects its local clustering coefficient. In both (a) and (b) larger diameters and darker shades represent higher values. Additionally, in both graphs thicker lines represents higher edge weight.



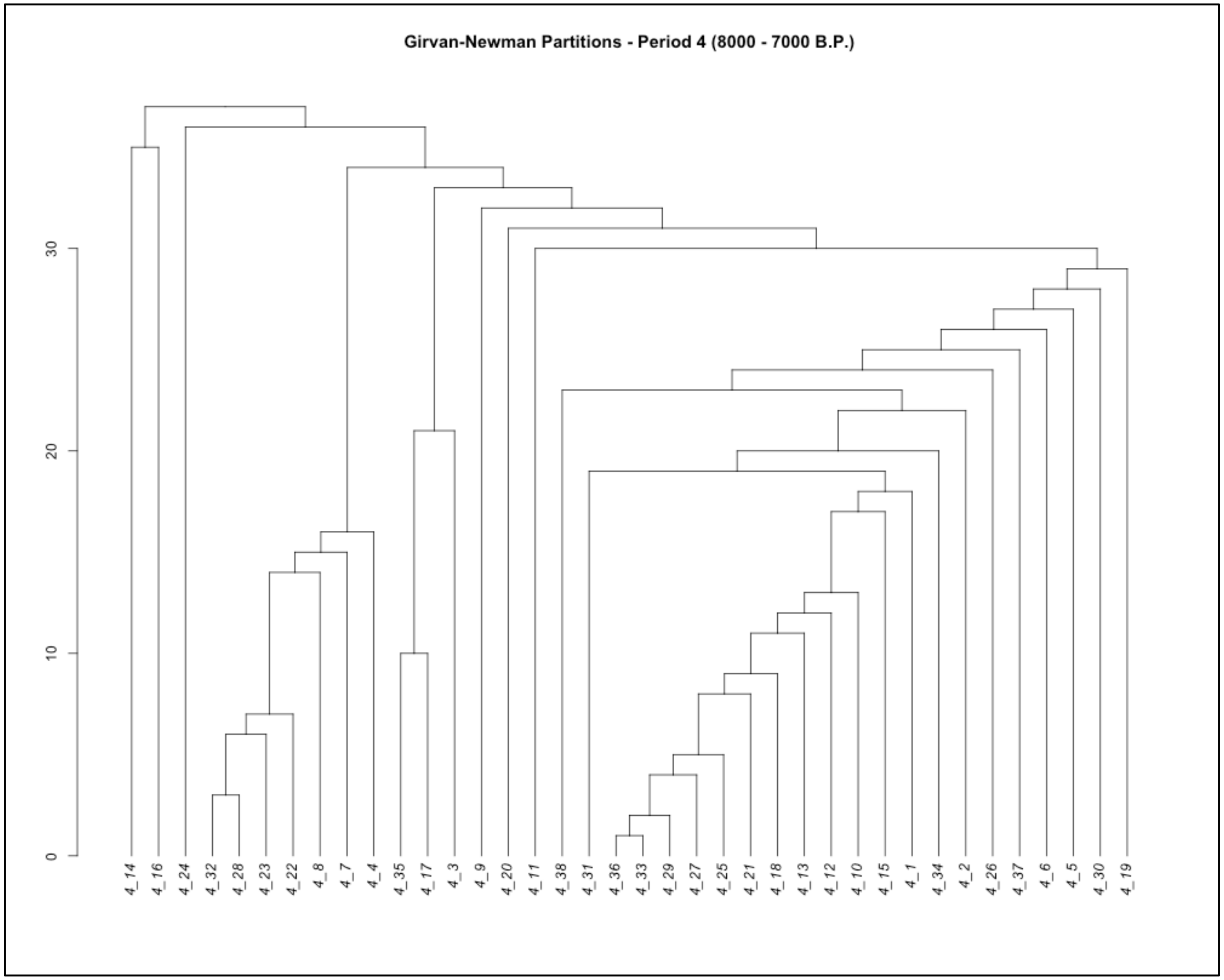


Figure 7.14 – Dendrogram illustrating the partitioning of modules in the network for Period 4 following the Girvin-Newman method for community detection.

ID	Site	Period	Country	Obsidian analyzed	Degree	Betweenness	Eigenvector	Clustering Coefficient	# of Triangles	GN
4_1	Abd el-Aziz	4	Syria	4	18	0.012	0.830	0.753	113	1
4_2	Abu Hureyra	4	Syria	209	16	0.009	0.733	0.758	91	1
4_3	Arpachiyah	4	Iraq	2	1	0.000	0.008	0.000	0	2
4_4	Ashkelon	4	Israel	11	6	0.000	0.029	1.000	15	3
4_5	Ayngerm	4	Turkey	5	11	0.000	0.548	1.000	55	1
4_6	Banahilk	4	Iraq	11	13	0.000	0.566	0.780	61	1
4_7	Çatalhöyük East	4	Turkey	230	6	0.000	0.029	1.000	15	3
4_8	Çatalhöyük West	4	Turkey	76	6	0.000	0.029	1.000	15	3
4_9	Chagar Bazar	4	Syria	2	5	0.000	0.175	0.906	9	4
4_10	Choga Mami	4	Iraq	47	20	0.038	0.933	0.754	139	1
4_11	Domuztepe	4	Turkey	50	9	0.027	0.369	0.730	26	1
4_12	El Kowm 2	4	Syria	17	18	0.015	0.890	0.851	127	1
4_13	Guran	4	Iran	4	18	0.066	0.884	0.838	125	1
4_14	Hacilar	4	Turkey	4	0	0.000	0.000	0.000	0	5
4_15	Hagoshrim	4	Israel	28	16	0.012	0.811	0.904	108	1
4_16	Hajji Firuz Tepe	4	Iran	3	0	0.000	0.000	0.000	0	6
4_17	Halaf	4	Syria	2	1	0.000	0.008	0.000	0	2
4_18	Halula	4	Syria	17	17	0.245	0.821	0.819	110	1
4_19	Hassek Huyuk	4	Syria	10	5	0.000	0.255	1.000	10	1
4_20	Horvat Usa	4	Israel	4	4	0.000	0.161	1.000	6	1
4_21	Kashkashok	4	Syria	9	18	0.041	0.884	0.838	125	1
4_22	Klepini-Troulli	4	Cyprus	3	6	0.000	0.029	1.000	15	3
4_23	Mersin	4	Turkey	5	6	0.000	0.029	1.000	15	3
4_24	Nineveh	4	Iraq	2	0	0.000	0.000	0.000	0	7

4_25	Sarab	4	Iran	6	20	0.001	0.964	0.805	148	1
4_26	Sawwan I	4	Iraq	6	13	0.000	0.566	0.785	61	1
4_27	Shimshara	4	Iraq	6	16	0.002	0.804	0.878	106	1
4_28	Tabbat al-Hammam	4	Syria	3	6	0.000	0.029	1.000	15	3
4_29	Tell Aray 1	4	Syria	26	22	0.070	1.000	0.718	158	1
4_30	Tell Kosak Shamali	4	Syria	9	20	0.006	0.964	0.799	148	1
4_31	Tell Kurdu	4	Turkey	21	16	0.017	0.771	0.831	99	1
4_32	Tell Labweh	4	Lebanon	141	9	0.252	0.143	0.511	18	3
4_33	Tell Sabi Abyad I	4	Syria	6	20	0.001	0.964	0.805	148	1
4_34	Tell Umm Qseir	4	Syria	8	18	0.002	0.880	0.833	124	1
4_35	Tilki Tepe	4	Turkey	11	6	0.098	0.125	0.411	6	2
4_36	Umm Dabighiyah	4	Iraq	3	20	0.001	0.964	0.805	148	1
4_37	Yarim I	4	Iraq	17	14	0.009	0.697	0.906	82	1
4_38	Yarim II	4	Iraq	42	16	0.149	0.715	0.749	88	1

Table 7.4 – The results of network analysis pertaining to Period 4.

7.6 Period 5

The network constructed for Period 5 is comprised of 15 nodes and 14 edges between them. Although the dataset is quite small and dispersed, certain observations do seem to fall into the larger narrative illustrated thus far. Two of the large modules both consist of sites where Bingöl and Nemrut Dağ obsidian has been uncovered, however the presence of tertiary raw materials (Meydan Dağ is the eastern-most cluster and Göllü Dağ in the western-most group) is mutually exclusive. Although the lack of data pertaining to sites in the area between these two modules raises some uncertainty, it seems that a core exchange system may have been in place that allowed for Bingöl and Nemrut Dağ obsidians to be circulated rather freely. However tertiary raw materials were accessed in exclusive spheres. Materials from Cappadocian sources may have arrived at sites closer to the Mediterranean coast via maritime exchange systems, and were thus not as accessible deeper inland. The localized presence of Meydan Dağ obsidian also seems consistent with the observations made for the prior period. One exception to this trend is a sample uncovered at Byblos (*5_2*) that was sourced to Meydan Dağ. Additionally, Matarrah's (*5_6*) membership to the western-most cluster is due to the lack if Meydan Dağ material uncovered there, and may relate to how the analyzed samples were selected. The two isolates are also exceptional in the sense that only material derived from these tertiary sources has been identified there.

Not much can be said with regards to the expansion of the Ubaid towards northern Mesopotamia due to the lack of obsidian sourcing data throughout this region. However the general detachment between the Levant and Mesopotamia, which has been noted in prior supra-regional comparisons (Streit 2012:61, 63-64; Yellin et al. 1996:367), is also apparent through this analysis.

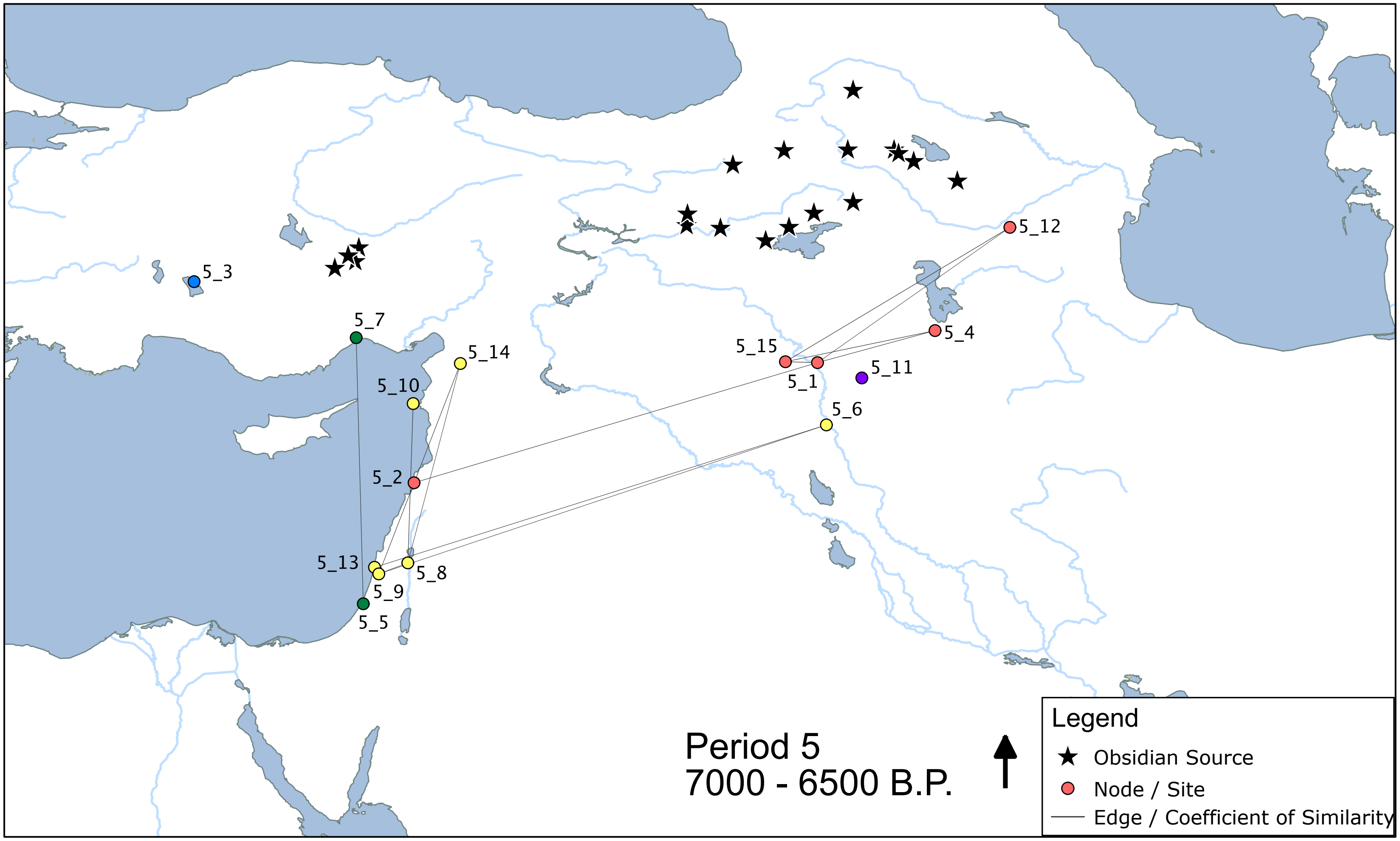


Figure 7.15 – Cartographical representation of modules distinguished after applying the Girvan-Newman method for community detection on the network constructed for Period 5.

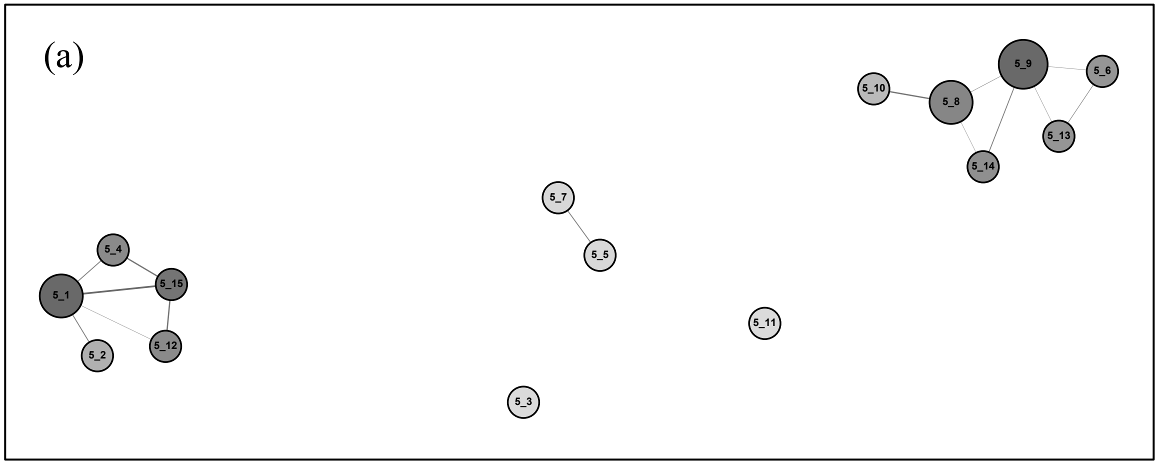
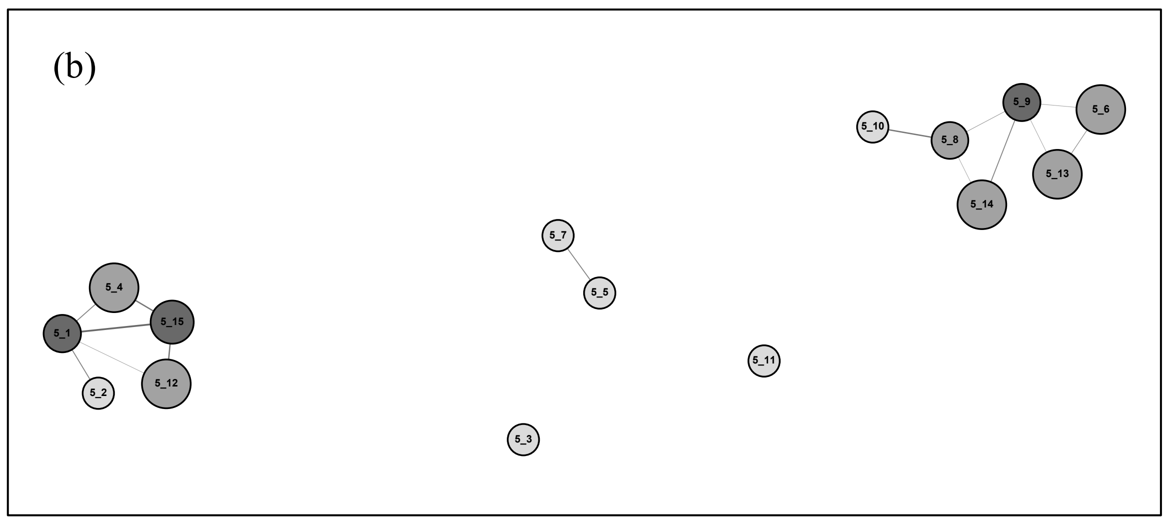


Figure 7.16 – Graphs illustrating the results pertaining to Period 5. In (a) communities a node's size reflects its between centrality, and its shade reflects its eigenvector centrality. In (b) a node's size reflects the number of triangles it participates in, and its shade reflects its local clustering coefficient. In both (a) and (b) larger diameters and darker shades represent higher values. Additionally, in both graphs thicker lines represents higher edge weight.



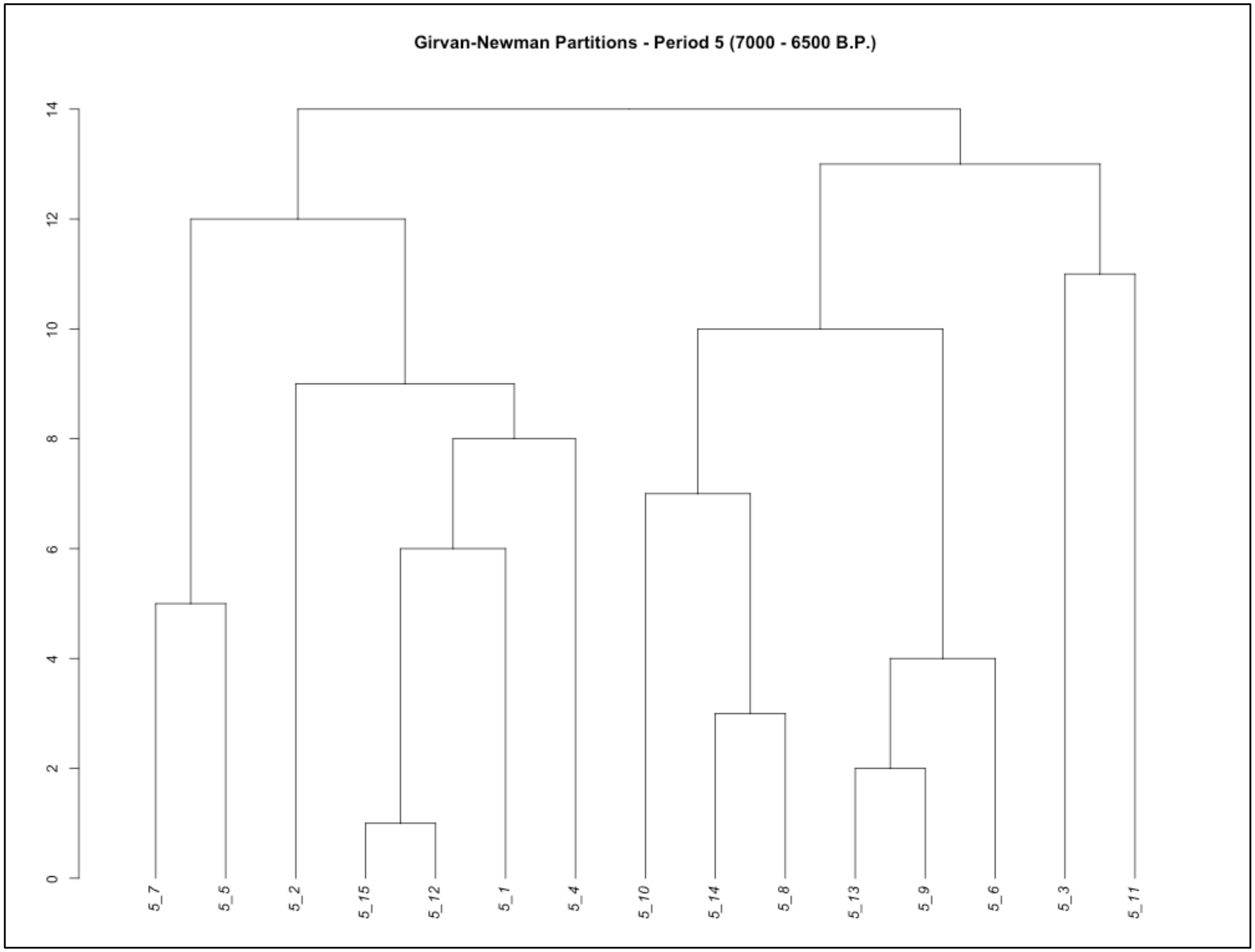


Figure 7.17 – Dendrogram illustrating the partitioning of modules in the network for Period 5 following the Girvin-Newman method for community detection.

ID	Site	Period	Country	Obsidian analyzed	Degree	Betweenness	Eigenvector	Clustering Coefficient	# of Triangles	GN
5_1	Arpachiyah	5	Iraq	10	5	0.119	0.617	0.534	5	1
5_2	Byblos	5	Lebanon	2	1	0.044	0.373	0.000	0	1
5_3	Cukurkent	5	Turkey	5	0	0.000	0.100	0.000	0	2
5_4	Dalma	5	Iran	2	5	0.067	0.890	0.417	4	1
5_5	Givat HaParsa	5	Israel	3	1	0.000	0.419	0.000	0	3
5_6	Matarrah	5	Iraq	3	4	0.000	0.779	1.000	6	4
5_7	Mersin	5	Turkey	10	1	0.000	0.485	0.000	0	3
5_8	Munhata	5	Israel	12	7	0.021	0.738	0.623	13	5
5_9	Nahal Zehora II	5	Israel	7	10	0.186	0.968	0.424	19	5
5_10	Ras Shamra	5	Syria	2	2	0.000	0.558	1.000	1	5
5_11	Shatanabad Tepe	5	Iraq	2	0	0.000	0.237	0.000	0	6
5_12	Tabia	5	Iran	3	3	0.000	0.237	1.000	3	1
5_13	Tel Mevorakh	5	Israel	3	4	0.000	0.822	1.000	6	4
5_14	Tell Kurdu	5	Turkey	6	5	0.000	0.989	1.000	10	5
5_15	Thalathat	5	Iraq	4	4	0.000	0.444	0.844	5	1

Table 7.5 – The results of network analysis pertaining to Period 5.

7.7 Period 6

The network constructed for Period 6 consists of 8 nodes and 6 edges between them. Four modules were detected, two of which are isolates. However the small dataset for this period, as well as the dispersed geographical distribution of sites for which data was available, impairs any reasonable interpretation of these results. It is very unfortunate that no insight may be attained regarding the nature of the transformations occurring in Mesopotamia around this time.

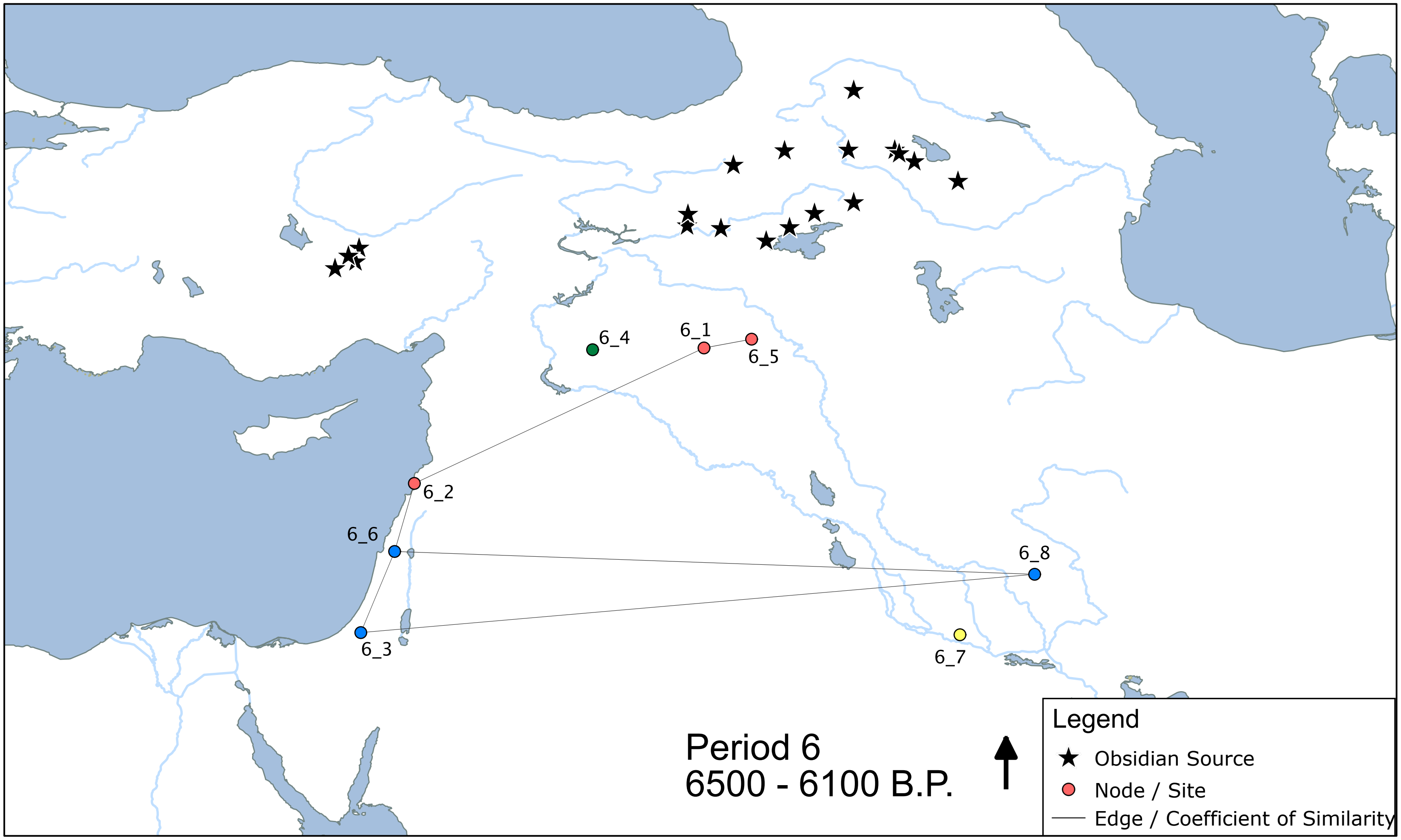


Figure 7.18 – Cartographical representation of modules distinguished after applying the Girvan-Newman method for community detection on the network constructed for Period 6.

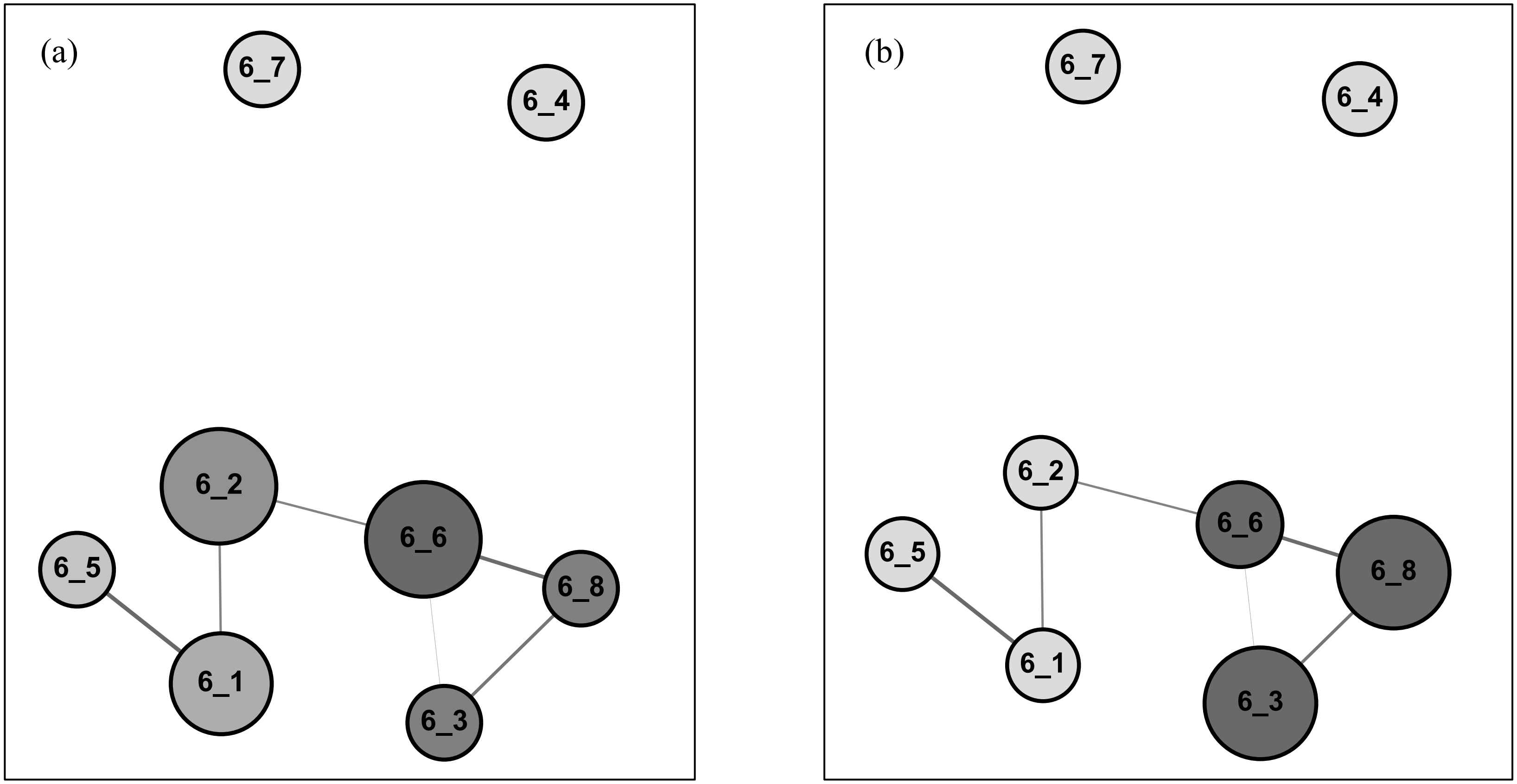


Figure 7.19 – Graphs illustrating the results pertaining to Period 6. In (a) communities a node's size reflects its between centrality, and its shade reflects its eigenvector centrality. In (b) a node's size reflects the number of triangles it participates in, and its shade reflects its local clustering coefficient. In both (a) and (b) larger diameters and darker shades represent higher values. Additionally, in both graphs thicker lines represents higher edge weight.

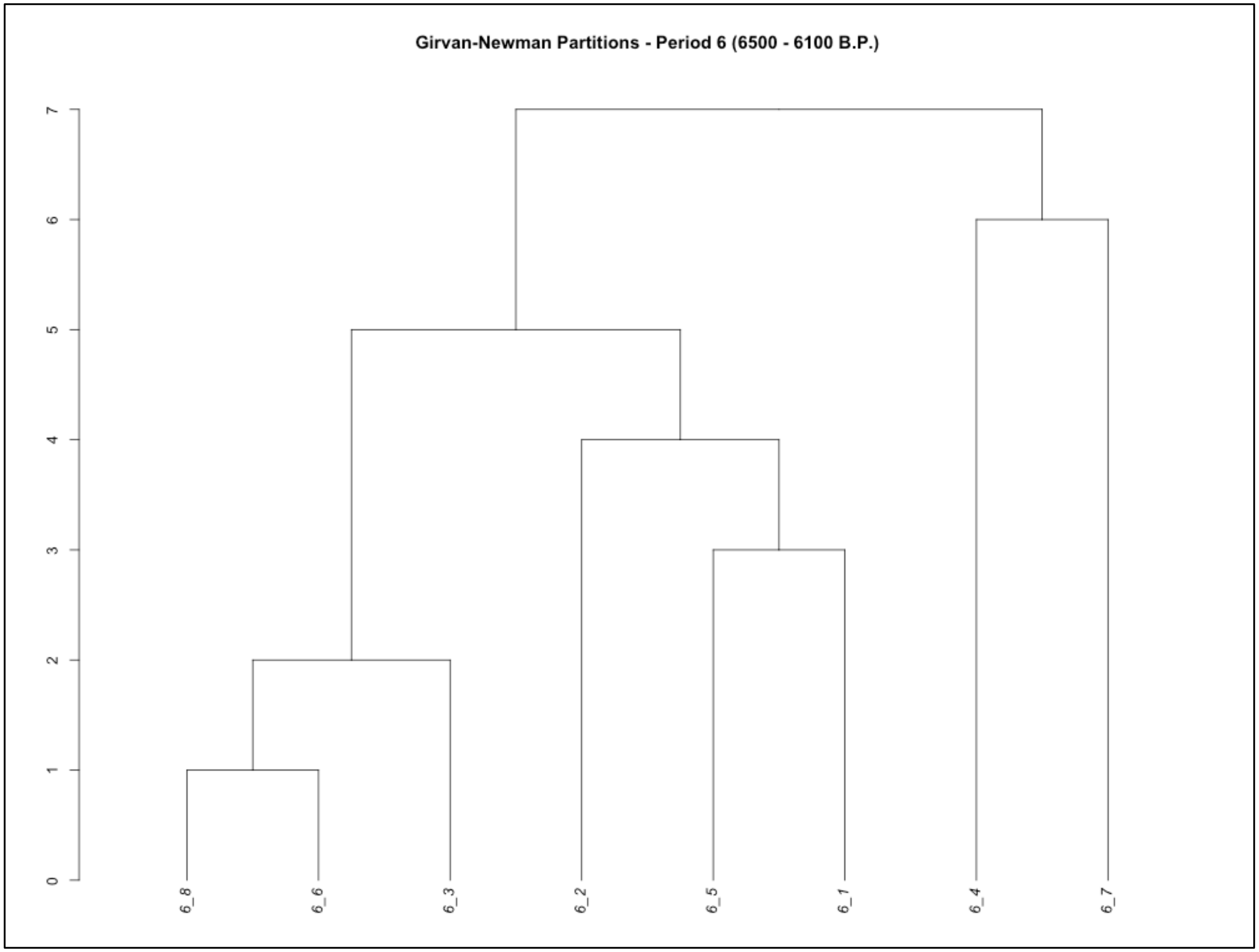


Figure 7.20 – Dendrogram illustrating the partitioning of modules in the network for Period 6 following the Girvin-Newman method for community detection.

ID	Site	Period	Country	Obsidian analyzed	Degree	Betweenness	Eigenvector	Clustering Coefficient	# of Triangles	GN
6_1	Brak	6	Syria	12	2	0.190	0.397	0.000	0	1
6_2	Byblos	6	Lebanon	4	2	0.286	0.640	0.000	0	1
6_3	Gilat	6	Israel	8	2	0.000	0.798	1.000	1	2
6_4	Hammam et Turkman	6	Syria	3	0	0.000	0.000	0.000	0	3
6_5	Hamoukar	6	Syria	42	1	0.000	0.194	0.000	0	1
6_6	Marj Rabba	6	Israel	4	3	0.286	1.000	0.329	1	2
6_7	Oueili	6	Iraq	5	0	0.000	0.000	0.000	0	4
6_8	Sabz	6	Iran	2	2	0.000	0.798	1.000	1	2

Table 7.6 – The results of network analysis pertaining to Period 6.

7.8 Period 7

The network constructed for Period 7 consists of 14 nodes and 32 edges between them. The dataset largely includes information pertaining to the eastern portion of the study area. One major module is detected, along with an isolate. While those in the majority group have quite diverse assemblages, only Bingöl A / Nemrut Dağ and Bingöl B material are uncovered at the site represented by the isolated node.

This final period is characterized by the first Uruk phase in southern Mesopotamia, along with development of the Late Chalcolithic in the north and in the Levant. Because most of the data originates from sites situated east of the Zagros mountain range, the material being exchanged is largely derived from Transcaucasian sources that were more accessible. Although many variants are widely distributed in this area, the fact that this region has not been widely covered in earlier periods makes it difficult to draw comparisons. However the larger amount of obsidian in southern Mesopotamia, some of which is derived from distant Cappadocian sources, may be attributed to the reconfiguration of supra-regional exchange systems at this time through the establishment of Uruk 'colonies' towards the north.

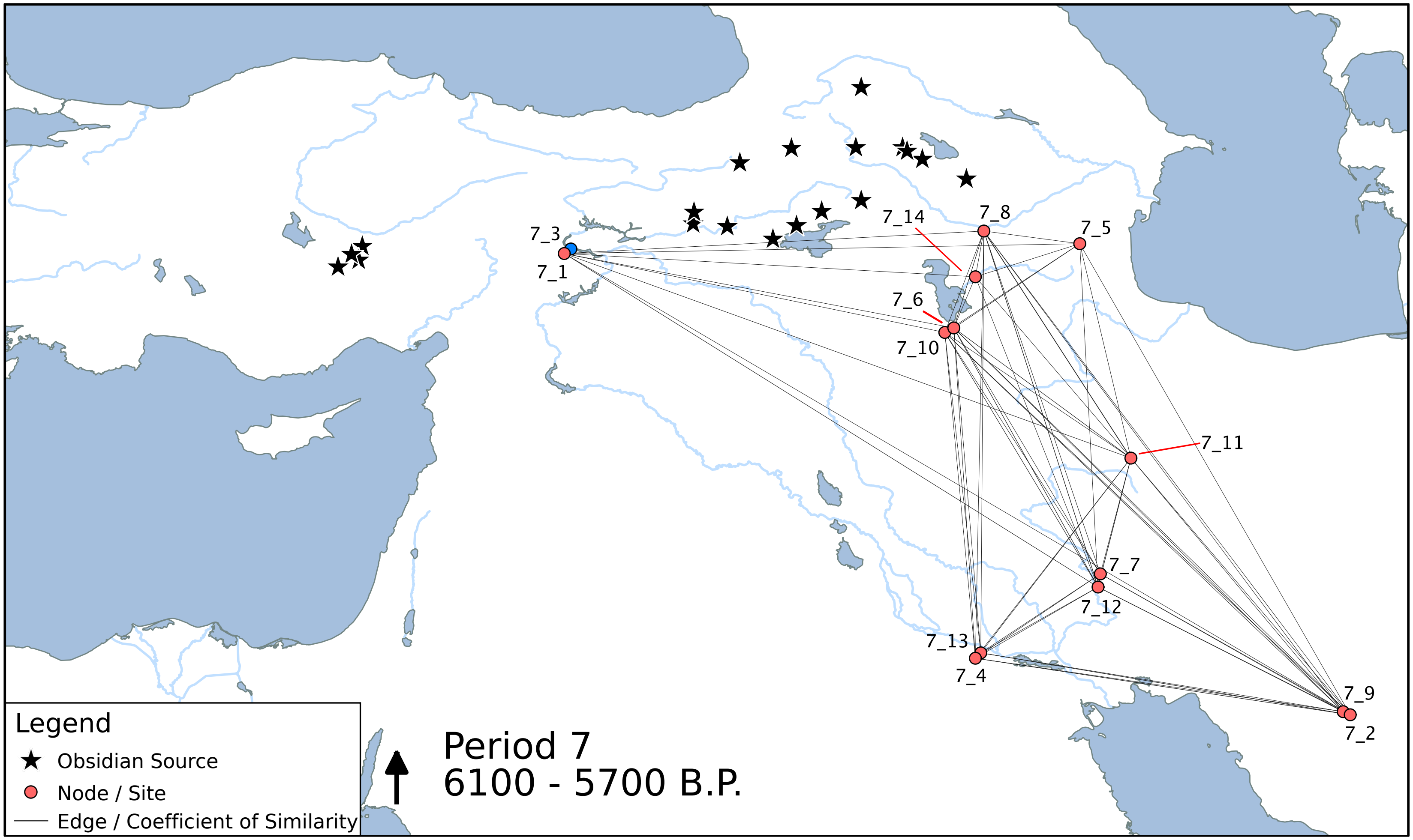


Figure 7.21 – Cartographical representation of modules distinguished after applying the Girvan-Newman method for community detection on the network constructed for Period 7.

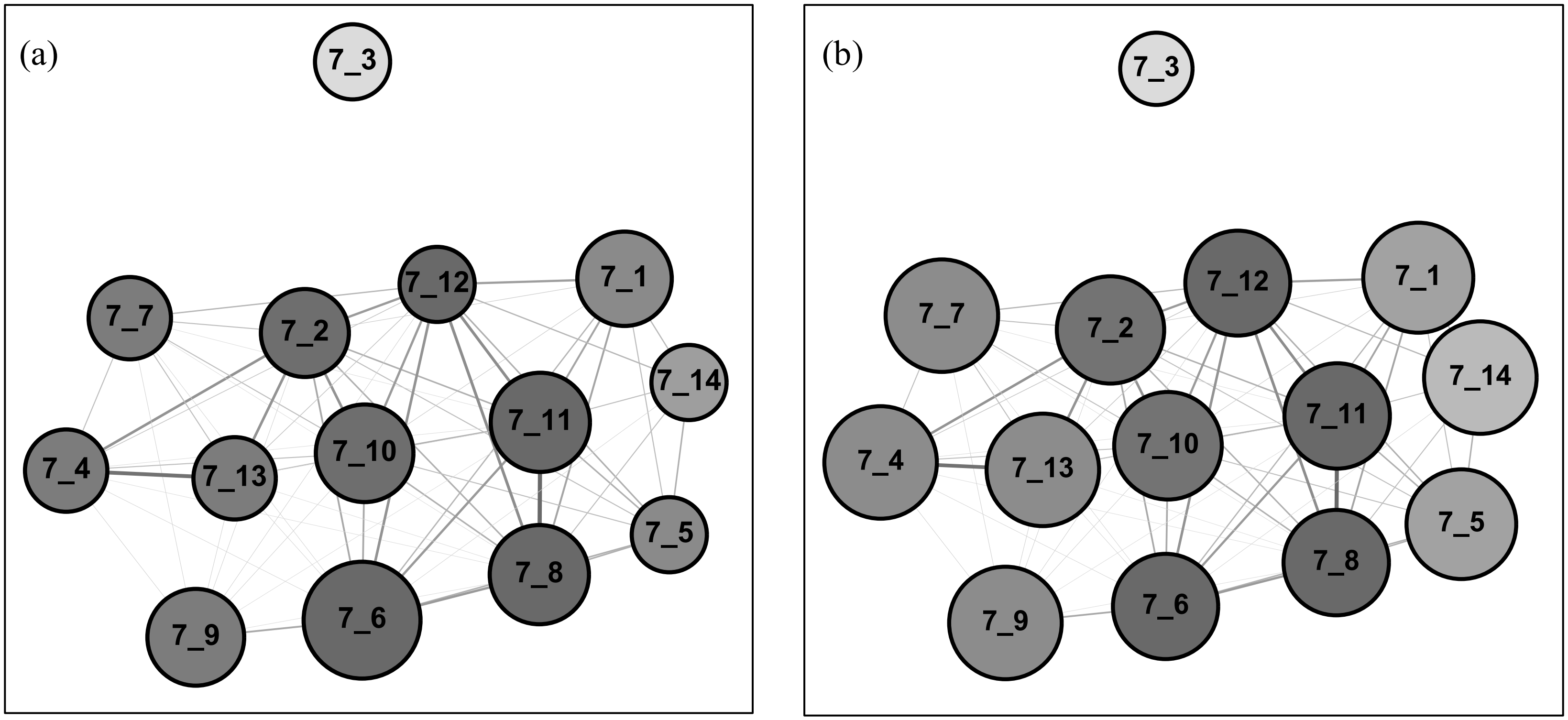


Figure 7.22 – Graphs illustrating the results pertaining to Period 7. In (a) communities a node's size reflects its between centrality, and its shade reflects its eigenvector centrality. In (b) a node's size reflects the number of triangles it participates in, and its shade reflects its local clustering coefficient. In both (a) and (b) larger diameters and darker shades represent higher values. Additionally, in both graphs thicker lines represents higher edge weight.

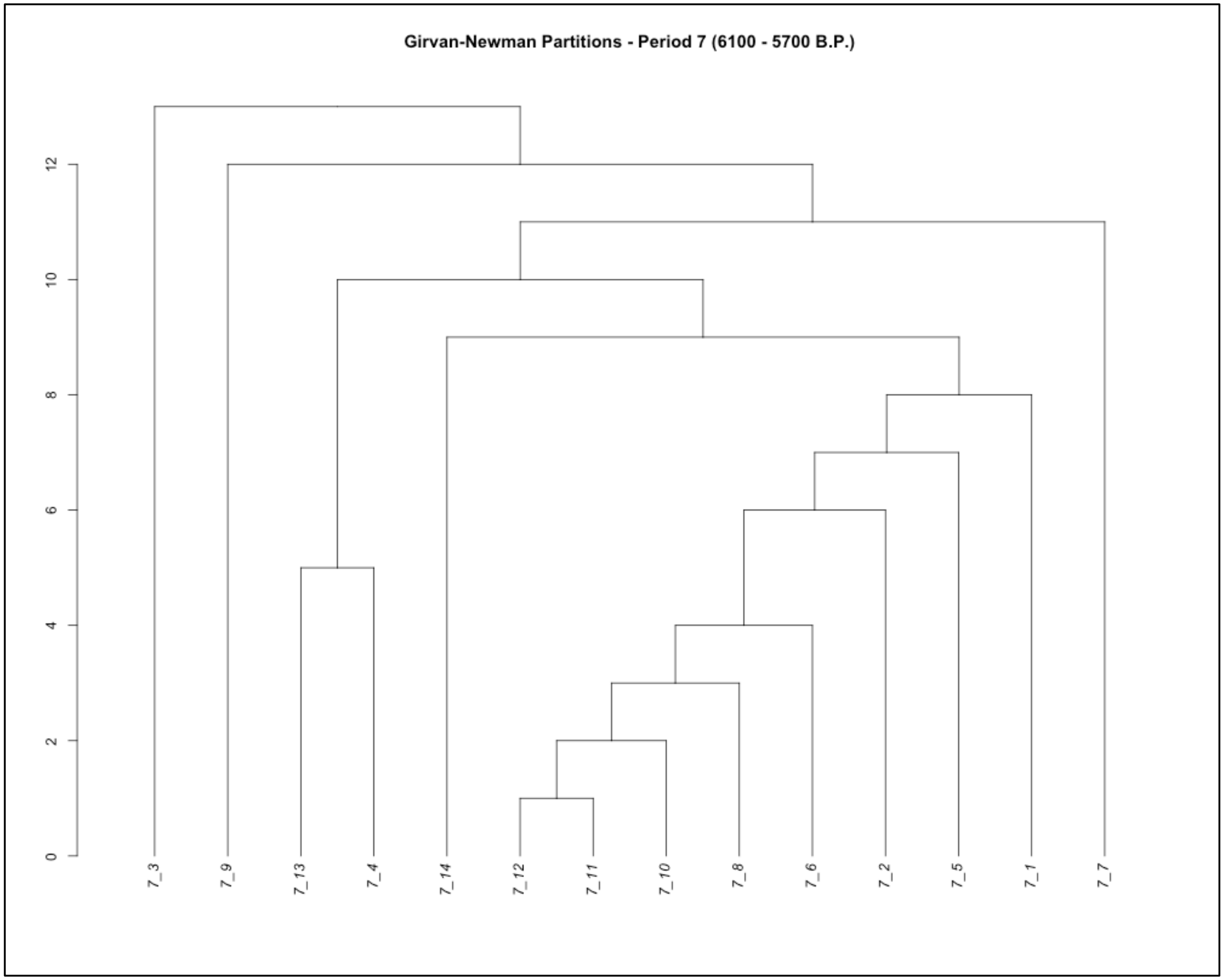


Figure 7.23 – Dendrogram illustrating the partitioning of modules in the network for Period 7 following the Girvin-Newman method for community detection.

ID	Site	Period	Country	Obsidian analyzed	Degree	Betweenness	Eigenvector	Clustering Coefficient	# of Triangles	GN
7_1	Arslantepe	7	Turkey	31	6	0.026	0.778	0.808	12	1
7_2	Bakun B	7	Iran	3	7	0.256	0.756	0.509	11	1
7_3	Degirmentepe	7	Turkey	13	0	0.000	0.000	0.000	0	2
7_4	Eridu	7	Iraq	4	2	0.000	0.145	1.000	1	3
7_5	Ghosha Tepe	7	Iran	141	6	0.026	0.778	0.796	12	1
7_6	Hasanlu	7	Iran	8	8	0.192	0.944	0.622	17	1
7_7	Jaffarabad	7	Iran	2	1	0.000	0.157	0.000	0	4
7_8	Kul Tepe	7	Iran	20	7	0.026	0.924	0.837	17	1
7_9	Marvdasht	7	Iran	5	1	0.000	0.148	0.000	0	5
7_10	Pisdeli	7	Iran	4	5	0.000	0.713	1.000	10	1
7_11	Seh Gabi	7	Iran	9	7	0.026	0.924	0.837	17	1
7_12	Susa	7	Iran	11	9	0.192	1.000	0.555	19	1
7_13	Ubaid	7	Iraq	20	2	0.000	0.145	1.000	1	3
7_14	Yanik Tepe	7	Iran	25	3	0.000	0.400	1.000	3	1

Table 7.7 – The results of network analysis pertaining to Period 7.

7.9 Synthesis

Networks were constructed and analyzed using obsidian sourcing data pertaining to roughly contemporaneous sites, and the patterns that were detected reflect broader socio-economic phenomena that have been documented through other archaeological materials as well. In many cases the detected clusters clearly matched observations made according to top-down models, however the groupings identified here were detected with different considerations in mind. The patterns that were highlighted using network analysis were determined by rendering obsidian sourcing data comparable in order to represent socio-economic similarity as expressed through similar preferences for particular raw materials. As such, the properties of each site, including their membership to a particular module, were derived from the distribution of socio-economic ties among them. Thus the observed patterns and measurements of connectivity are emergent from data-driven associations among the individual entities being characterized, rather than dictated based upon arbitrary presumptions of rank and spatial patterning of culturally representative finds. Although the results presented above may not completely overwrite more established observations concerning regional interaction, and actually support commonly held beliefs, they do provide an alternative perspective that emphasizes the actual relationships between sites.

That being said, certain particularly interesting observations were made in key areas. For instance, documenting the changing degree of intensity and locations of overlap between detected modules in the Levant and in the Euphrates basin provided insight with regards to the shifting nature of contact between these regions. The western region of the Syrian Desert was identified as a major interface throughout the Pre-Pottery Neolithic, however the northern Levant eventually performed a larger role in supra-regional systems of interactions later on. Interpreting measurements of centrality pertaining to each site made these observations clear.

The changing homogeneity of raw materials exploited at sites in Mesopotamia was also of particular interest. The more widespread use of certain obsidian variants seems to have mirrored broader developments that are well documented through other forms of material culture such as pottery and architecture. While morphological and technological information remain undocumented with regards to sourced artefacts, the networks did highlight sites in which novel materials were introduced. The structures and spatial distributions of these groupings point towards changing degrees of regional clustering or dispersal of material culture, which may be indicative of various degrees of cultural heterogeneity or the potential centralization of trade. The results for Periods 4 and 5 suggest that de-centralized systems were in place that facilitated the dispersal of certain eastern materials westward, however the limited distribution of otherwise rarely found obsidians, concentrated towards the peripheries of the aforementioned cluster, suggests that a degree of distinction should also be made. While it is possible that this may be the result of lumping cultural contexts together, this would be impossible to verify given the chronological resolution of the data at hand. It is also very unfortunate that the lack of obsidian sourcing information for the final two periods limits discussion on the immense socio-economic developments that were occurring during these times.

8 – CONCLUSION

The aim of this thesis was to evaluate the circulation of obsidian in southwest Asia and Anatolia during the Neolithic and Chalcolithic Periods from a heterarchical approach, in order to provide an alternative perspective to top-down models of supra-regional interaction. The proportions of obsidian raw material variants present at 151 sites were compared to construct networks deemed representative of relative access to particular resources or of the structures of systems of regional interaction recognized at broad spatial and temporal scales. These networks were subsequently analyzed in order to highlight groups of sites that shared more interconnections among themselves than they did with others in the system, and to determine various measures of connectivity pertaining to each site and to the system as a whole. This methodology was employed since it enables the roles of each site to be determined as a result of their ties with others, which are unrestricted and data-driven. This methodological framework thus vies remarkably well with heterarchical perspectives, which posit that in a system of unranked entities, which hold the same potential to interact with each other, each entity holds the same potential to be ranked in accordance with its position relative to others in the system (Crumley 1995:3). Moreover, this pairing of network methods and heterarchical theory is poised to address the concerns raised by certain archaeologists who have called for more astute recognition of the heterogeneous or mosaic-like nature of Neolithization processes and cultural patterning that are recognized in Neolithic and Chalcolithic contexts of southwest Asia and Anatolia (cf. Asouti 2006; Carter et al. 2013; Fuller et al. 2011, 2012; Gebel 2004; Watkins 2008).

The results of network analysis were interpreted in light of a broad-scale and long-term narrative of regional interaction in the examined regions in order to determine how they fare against common understandings of broad-scale connectivity at various points in time. While certain discrepancies have been noted, the findings generally complement already-established notions of supra-regional interactions in the setting of interest. However the observations made through this thesis are emergent from the relationships among sites, rather than recognized based upon presumptions relating to spatial distribution of material culture or preconceived ranking of sites. The consistency of the findings with more established views show that thinking of obsidian distribution in terms of a heterarchical and mosaic-like system is viable and realistic.

Certain aspects of the analyzed networks were given particular attention, namely the nature of contact between detected clusters, and the degree of connectivity of nodes in each such group. Clusters were detected by determining groups of nodes (representing archaeological sites) sharing more edges (strong ties of similarity, as calculated through comparison of obsidian assemblages) among them than with others in the system. While this alone overcomes the categorization of sites according to pre-defined criteria following top-down models, the variable connectivity within each cluster, and the reasons behind the lack of connections between them, actually shed more light on regional interaction than the detected patterns themselves. Such inconsistent connectivity within a cluster may point towards localized idiosyncrasies that may be further evaluated using finer resolution data or integration of alternative vectors of information.

In addition to the insights produced through the analyses presented here, which are detailed in more depth in Chapter 7, this thesis was written to prompt reflection on how network analysis may be better used to evaluate regional interaction as observed by archaeologists at broad spatial and temporal scales. It is hoped that any readers of this thesis have gained a better understanding of how network analysis may be situated within the archaeological toolbox, how this methodology may be coordinated with theoretical concerns, and how to evaluate the usefulness of the underlying data so that similar approaches may be conducted effectively and successfully in the future.

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Appendix A – Dataset

ID	Site	Period	Country	Latitude	Longitude	Obsidian analyzed	Acıgöl	Göllü Dag East	Göllü Dag West	Nenezi Dag	Hasan Dag	Pasinler	Sarikamis	Bingol B	Nemrut Dag / Bingol A	Meydan Dag	Tendurek Dag	Suphan Dag	Mus	Aragats / Arteni	Gegham	Sjunik	Kojun Dag / Chikiani	Demenegaki	3d	1e-f	Unknown
1_1	Abu Hureyra	1	Syria	35.867	38.383	7	0	3	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0
1_2	Aswad	1	Syria	33.367	36.550	11	0	10	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1_3	Cheikh Hassan	1	Syria	36.100	38.117	27	0	16	0	0	0	0	0	9	1	0	0	0	0	0	0	0	0	0	0	0	1
1_4	East Chia Sabz	1	Iran	32.417	47.250	20	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0
1_5	el Hemmeh	1	Jordan	30.758	35.550	18	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1_6	Jerf el Ahmar	1	Syria	36.383	38.183	44	0	42	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
1_7	Jericho	1	Palestine	31.850	35.433	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1_8	Kortik Tepe	1	Turkey	37.814	40.984	121	0	0	0	0	0	0	0	67	53	0	0	0	1	0	0	0	0	0	0	0	0
1_9	Mureybet	1	Syria	36.043	38.129	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1_10	Netiv Hagdud	1	Palestine	31.988	35.445	8	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2_1	Abu Hureyra	2	Syria	35.867	38.383	22	0	11	0	0	0	0	0	6	30	0	0	0	0	0	0	0	0	0	0	0	0
2_2	Akarcay Tepe	2	Turkey	36.919	38.026	18	0	3	0	0	0	0	0	11	4	0	0	0	0	0	0	0	0	0	0	0	0
2_3	Ali Kosh	2	Iran	32.550	47.400	6	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0
2_4	Asikli	2	Turkey	38.350	34.233	41	1	34	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2_5	Aswad	2	Syria	33.367	36.550	83	0	50	0	0	0	0	0	9	24	0	0	0	0	0	0	0	0	0	0	0	0
2_6	Beidha	2	Jordan	30.367	35.317	3	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2_7	Beisamoun	2	Israel	33.167	35.550	31	0	27	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1
2_8	Birikin Magarasi	2	Turkey	38.150	39.800	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2_9	Boncuklu	2	Turkey	37.752	32.865	61	0	58	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2_10	Boy Tepe	2	Turkey	38.883	38.900	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0

ID	Site	Period	Country	Latitude	Longitude	Obsidian analyzed	Acigöl	Göllü Dag East	Göllü Dag West	Nenezi Dag	Hasan Dag	Pasinler	Sarikamis	Bingol B	Nemrut Dag / Bingol A	Meydan Dag	Tendurek Dag	Suphan Dag	Mus	Aragats / Arteni	Gegham	Sjunik	Kojun Dag / Chikiani	Demenegaki	3d	1e-f	Unknown
2_11	Cafer Huyuk	2	Turkey	38.400	38.750	21	0	0	0	0	0	0	0	17	4	0	0	0	0	0	0	0	0	0	0	0	0
2_12	Çatalhöyük East	2	Turkey	37.666	32.828	45	0	39	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2_13	Cayonu	2	Turkey	38.217	39.817	12	0	0	0	0	0	0	0	6	9	0	0	0	0	0	0	0	0	0	0	0	0
2_14	Cheikh Hassan	2	Syria	36.100	38.117	12	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2_15	Cinaz Huyuk	2	Turkey	38.700	39.917	3	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0
2_16	Dja'de	2	Syria	36.383	38.183	56	1	45	0	0	0	0	0	9	1	0	0	0	0	0	0	0	0	0	0	0	0
2_17	Ghoraife	2	Syria	33.517	36.533	6	0	4	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
2_18	Gobekli	2	Turkey	37.223	38.923	100	0	41	0	0	0	0	0	15	38	0	0	0	0	0	0	0	0	0	0	0	6
2_19	Golbent Ergani	2	Turkey	38.283	39.767	2	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
2_20	Gurcutepe I	2	Turkey	37.120	38.846	34	0	6	0	1	0	0	0	12	15	0	0	0	0	0	0	0	0	0	0	0	0
2_21	Halula	2	Syria	36.417	38.167	8	0	2	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0	0
2_22	Horvat Galil	2	Israel	32.950	35.317	5	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2_23	Ilicapinar	2	Turkey	38.567	32.933	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2_24	Jarmo	2	Iraq	35.533	44.933	10	0	0	0	0	0	0	0	4	6	0	0	0	0	0	0	0	0	0	0	0	0
2_25	Jericho	2	Palestine	31.850	35.433	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2_26	K'far Hahoresh	2	Israel	32.700	35.200	8	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2_27	Mikhmoret	2	Israel	32.406	34.872	6	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2_28	Mujahiya	2	Israel	32.817	35.683	13	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2_29	Mureybet	2	Syria	36.043	38.129	97	0	84	0	0	0	0	0	7	6	0	0	0	0	0	0	0	0	0	0	0	0
2_30	Nahal Lavan	2	Israel	30.933	34.483	68	0	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2_31	Nevshehir Kogulalti	2	Turkey	38.544	34.624	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2_32	Papazgolu	2	Turkey	38.283	39.733	2	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0

ID	Site	Period	Country	Latitude	Longitude	Obsidian analyzed	Acigöl	Göllü Dag East	Göllü Dag West	Nenezi Dag	Hasan Dag	Pasinler	Sarikamis	Bingol B	Nemrut Dag / Bingol A	Meydan Dag	Tendurek Dag	Suphan Dag	Mus	Aragats / Arteni	Gegham	Sjunik	Kojun Dag / Chikiani	Demenegaki	3d	1e-f	Unknown
2_33	Q'deir 1	2	Syria	35.250	38.850	517	0	143	0	4	0	0	0	248	122	0	0	0	0	0	0	0	0	0	0	0	0
2_34	Ramad	2	Syria	33.400	36.100	5	0	3	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
2_35	Shillourokambos	2	Cyprus	34.721	33.014	64	0	61	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2_36	Tell Abdul Hosein	2	Iran	34.133	48.150	12	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	1
2_37	Tell el-Kerkh 2	2	Syria	35.817	36.450	367	1	322	0	25	0	0	0	10	5	0	0	0	0	0	0	0	0	0	0	0	4
2_38	Tell es-Sinn	2	Syria	35.225	43.419	2	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
2_39	Umm et-Tlel	2	Syria	35.262	38.897	8	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
2_40	Yiftael	2	Israel	32.717	35.283	8	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2_41	Yumuktepe	2	Turkey	36.833	34.567	42	1	15	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3_1	Abu Hureyra	3	Syria	35.867	38.383	23	0	5	0	0	0	0	0	15	37	0	0	0	0	0	0	0	0	0	0	0	0
3_2	Ain Miri	3	Israel	33.067	35.450	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3_3	Ali Kosh	3	Iran	32.550	47.400	4	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
3_4	Assouad	3	Syria	36.567	39.017	5	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0
3_5	Aswad	3	Syria	33.367	36.550	139	0	134	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
3_6	Bouqras	3	Syria	35.133	40.433	15	0	0	0	0	0	0	0	7	8	0	0	0	0	0	0	0	0	0	0	0	0
3_7	Cap Andreas	3	Cyprus	35.692	34.583	13	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3_8	Choga Sefid	3	Iran	32.617	47.250	18	0	0	0	0	0	0	0	12	6	0	0	0	0	0	0	0	0	0	0	0	0
3_9	Damishliyya I	3	Syria	36.517	39.033	63	0	0	0	0	0	0	0	44	19	0	0	0	0	0	0	0	0	0	0	0	0
3_10	Ghoraife	3	Syria	33.517	36.533	18	0	4	0	0	0	0	0	7	7	0	0	0	0	0	0	0	0	0	0	0	0
3_11	Guran	3	Iran	33.933	47.183	10	0	0	0	0	0	0	0	4	6	0	0	0	0	0	0	0	0	0	0	0	0
3_12	Halula	3	Syria	36.417	38.167	14	3	1	0	0	0	0	0	7	3	0	0	0	0	0	0	0	0	0	0	0	0
3_13	Jarmo	3	Iraq	35.533	44.933	9	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0

ID	Site	Period	Country	Latitude	Longitude	Obsidian analyzed	Acigöl	Göllü Dag East	Göllü Dag West	Nenezi Dag	Hasan Dag	Pasinler	Sarikamis	Bingol B	Nemrut Dag / Bingol A	Meydan Dag	Tendurek Dag	Suphan Dag	Mus	Aragats / Arteni	Gegham	Sjunik	Kojun Dag / Chikiani	Demenegaki	3d	1e-f	Unknown
3_14	Kalavasos Tenta	3	Cyprus	34.752	33.303	6	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3_15	Khirokitia	3	Cyprus	34.795	33.345	6	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3_16	Kul Tepe	3	Iraq	36.133	42.050	4	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
3_17	Magzalia	3	Iraq	36.400	42.317	38	0	0	0	0	0	0	0	11	25	0	0	0	0	0	0	0	0	0	0	0	2
3_18	Mersin	3	Turkey	36.833	34.567	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3_19	Ras Shamra	3	Syria	35.600	35.633	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
3_20	Salat Cami Yani	3	Turkey	37.846	40.885	74	0	0	0	0	0	0	0	15	57	0	0	0	0	0	0	0	1	0	1	0	0
3_21	Sotto	3	Iraq	36.367	42.317	7	0	0	0	0	0	0	0	2	5	0	0	0	0	0	0	0	0	0	0	0	0
3_22	Tell Aray 2	3	Syria	35.583	36.517	18	0	10	0	4	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
3_23	Tell Labweh	3	Lebanon	34.183	36.317	23	0	16	0	2	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
3_24	Tell Sabi Abyad II	3	Syria	36.517	39.100	21	0	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0
3_25	Wadi Tumbaq	3	Syria	35.027	37.429	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4_1	Abd el-Aziz	4	Syria	35.883	36.500	4	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1
4_2	Abu Hureyra	4	Syria	35.867	38.383	209	0	65	0	0	0	0	0	127	52	0	0	0	0	0	0	0	0	0	5	0	0
4_3	Arpachiyah	4	Iraq	36.367	43.200	2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
4_4	Ashkelon	4	Israel	31.667	34.550	11	0	7	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4_5	Ayngerm	4	Turkey	37.400	41.500	5	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
4_6	Banahilk	4	Iraq	36.667	44.533	11	0	0	0	0	0	0	0	0	7	4	0	0	0	0	0	0	0	0	0	0	0
4_7	Çatalhöyük East	4	Turkey	37.666	32.828	230	1	134	0	90	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
4_8	Çatalhöyük West	4	Turkey	37.666	32.828	76	1	39	0	35	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
4_9	Chagar Bazar	4	Syria	36.867	40.900	2	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
4_10	Choga Mami	4	Iraq	33.883	45.450	47	0	0	0	0	0	0	0	11	23	4	0	0	0	0	0	0	0	0	0	0	9

ID	Site	Period	Country	Latitude	Longitude	Obsidian analyzed	Acigöl	Göllü Dag East	Göllü Dag West	Nenezi Dag	Hasan Dag	Pasinler	Sarikamis	Bingol B	Nemrut Dag / Bingol A	Meydan Dag	Tendurek Dag	Suphan Dag	Mus	Aragats / Arteni	Gegham	Sjunik	Kojun Dag / Chikiani	Demenegaki	3d	1e-f	Unknown
4_11	Domuztepe	4	Turkey	36.667	35.483	50	0	23	0	0	0	6	0	14	7	0	0	0	0	0	0	0	0	0	0	0	0
4_12	El Kowm 2	4	Syria	35.183	38.867	17	1	2	0	0	0	0	0	5	8	0	0	0	0	0	0	0	0	0	0	0	4
4_13	Guran	4	Iran	33.933	47.183	4	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
4_14	Hacilar	4	Turkey	37.717	30.067	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
4_15	Hagoshrim	4	Israel	33.183	35.633	28	0	5	0	0	0	0	4	6	7	3	0	0	0	0	0	0	0	0	0	0	3
4_16	Hajji Firuz Tepe	4	Iran	36.983	45.483	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
4_17	Halaf	4	Syria	36.817	40.050	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
4_18	Halula	4	Syria	36.417	38.167	17	2	4	0	1	0	0	0	3	5	0	0	0	0	0	0	0	0	0	0	0	2
4_19	Hassek Huyuk	4	Syria	37.683	39.150	10	0	0	0	0	0	0	0	7	1	0	0	0	0	0	0	0	0	0	0	0	2
4_20	Horvat Usa	4	Israel	32.640	35.660	4	0	1	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0
4_21	Kashkashok	4	Syria	36.633	40.667	9	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	1	0	0
4_22	Klepini-Troulli	4	Cyprus	35.298	33.445	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4_23	Mersin	4	Turkey	36.833	34.567	5	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
4_24	Nineveh	4	Iraq	36.350	43.167	2	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
4_25	Sarab	4	Iran	34.367	47.083	6	0	0	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0	0
4_26	Sawwan I	4	Iraq	36.350	39.067	6	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0
4_27	Shimshara	4	Iraq	36.200	44.950	6	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0
4_28	Tabbat al-Hammam	4	Syria	34.767	35.983	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4_29	Tell Aray 1	4	Syria	35.900	36.500	26	0	2	0	0	0	0	0	8	11	0	0	0	0	0	0	0	0	0	0	0	5
4_30	Tell Kosak Shamali	4	Syria	35.920	38.510	9	0	1	0	0	0	0	0	2	6	0	0	0	0	0	0	0	0	0	0	0	0
4_31	Tell Kurdu	4	Turkey	36.350	36.517	21	0	5	0	0	0	0	4	7	4	1	0	0	0	0	0	0	0	0	0	0	0
4_32	Tell Labweh	4	Lebanon	34.183	36.317	141	2	105	0	2	0	0	0	21	11	0	0	0	0	0	0	0	0	0	0	0	0

ID	Site	Period	Country	Latitude	Longitude	Obsidian analyzed	Acigöl	Göllü Dag East	Göllü Dag West	Nenezi Dag	Hasan Dag	Pasinler	Sarikamis	Bingol B	Nemrut Dag / Bingol A	Meydan Dag	Tendurek Dag	Suphan Dag	Mus	Aragats / Arteni	Gegham	Sjunik	Kojun Dag / Chikiani	Demenegaki	3d	1e-f	Unknown
4_33	Tell Sabi Abyad I	4	Syria	36.517	39.100	6	0	0	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0	0
4_34	Tell Umm Qseir	4	Syria	36.417	41.000	8	0	0	0	0	0	0	0	2	5	0	0	0	0	0	0	0	0	0	0	0	1
4_35	Tilki Tepe	4	Turkey	38.450	43.333	11	0	0	0	0	0	0	0	0	3	6	0	0	0	0	0	0	0	0	1	0	1
4_36	Umm Dabighiyah	4	Iraq	35.600	42.400	3	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0
4_37	Yarim I	4	Iraq	36.350	42.350	17	0	0	0	0	0	0	0	1	16	0	0	0	0	0	0	0	0	0	0	0	0
4_38	Yarim II	4	Iraq	36.350	42.350	42	0	0	0	0	0	0	0	1	29	5	0	3	0	0	0	0	0	0	4	0	0
5_1	Arpachiyah	5	Iraq	36.367	43.200	10	0	0	0	0	0	0	0	2	2	6	0	0	0	0	0	0	0	0	0	0	0
5_2	Cukurkent	5	Turkey	37.883	31.533	5	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5_3	Dalma	5	Iran	36.967	45.400	2	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
5_4	Givat HaParsa	5	Israel	31.850	34.700	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5_5	Matarrah	5	Iraq	35.200	43.367	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
5_6	Mersin	5	Turkey	36.833	34.567	10	0	7	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5_7	Munhata	5	Israel	32.617	35.533	12	0	5	0	0	0	0	0	4	3	0	0	0	0	0	0	0	0	0	0	0	0
5_8	Nahal Zehora II	5	Israel	32.410	34.990	7	0	1	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	2
5_9	Ras Shamra	5	Syria	35.600	35.633	2	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
5_10	Shatanabad Tepe	5	Iraq	36.080	44.030	2	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
5_11	Tabia	5	Iran	38.900	46.800	3	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1
5_12	Tel Mevorakh	5	Israel	32.533	34.910	3	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
5_13	Tell Kurdu	5	Turkey	36.350	36.517	6	0	2	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
5_14	Thalathat	5	Iraq	36.383	42.600	4	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0
6_1	Brak	6	Syria	36.650	41.067	12	0	0	0	0	0	0	0	3	8	1	0	0	0	0	0	0	0	0	0	0	0
6_2	Byblos	6	Lebanon	34.117	35.650	4	0	1	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0

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6_3	Gilat	6	Israel	31.326	34.649	8	2	2	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1
6_4	Hammam et Turkman	6	Syria	36.617	38.983	3	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0
6_5	Hamoukar	6	Syria	36.814	41.957	42	0	0	0	0	0	0	0	2	36	2	0	0	0	0	0	0	0	0	0	0	2
6_6	Marj Rabba	6	Israel	32.844	35.281	4	0	2	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
6_7	Oueili	6	Iraq	31.286	45.854	5	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	3	0	0	0	0	0
6_8	Sabz	6	Iran	32.417	47.250	2	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
7_1	Arslantepe	7	Turkey	38.382	38.361	31	0	2	0	0	0	0	0	0	6	16	0	10	0	0	0	0	0	0	0	0	0
7_2	Bakun B	7	Iran	29.817	52.933	3	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0
7_3	Degirmentepe	7	Turkey	38.467	38.483	13	0	0	0	0	0	0	0	10	2	0	0	0	0	0	0	0	0	0	0	0	1
7_4	Eridu	7	Iraq	30.867	45.983	4	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
7_5	Ghosha Tepe	7	Iran	38.565	47.919	141	0	0	0	0	0	0	0	0	6	8	0	0	0	3	7	0	0	0	0	0	2
7_6	Hasanlu	7	Iran	37.000	45.583	8	0	0	0	0	2	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0
7_7	Jaffarabad	7	Iran	32.433	48.300	2	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
7_8	Kul Tepe	7	Iran	38.800	46.140	20	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	1
7_9	Marvdasht	7	Iran	29.874	52.803	5	0	0	0	0	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
7_10	Pisdeli	7	Iran	36.917	45.417	4	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0	0	0	0	0
7_11	Seh Gabi	7	Iran	34.583	48.867	9	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	4
7_12	Susa	7	Iran	32.189	48.258	11	0	1	0	0	0	0	0	0	5	5	0	0	0	0	0	0	0	0	0	0	0
7_13	Ubaid	7	Iraq	30.967	46.083	20	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	1	0	1
7_14	Yanik Tepe	7	Iran	37.950	45.983	25	0	2	0	0	0	0	0	0	0	4	0	0	0	0	2	0	0	0	0	0	0

This dataset is also available online at: https://zackbatist.github.io/DObsiSS

Appendix B – R Code

```
### INITIATE IGRAPH ###

library(igraph)

### LOAD NETWORK DATA ###

dat=read.csv(file.choose(),header=TRUE,row.names=1,check.nam
es=FALSE)

m=as.matrix(dat)

g=graph.adjacency(m,mode="undirected",weighted=TRUE,diag=FAL
SE)

g

### ADD ATTRIBUTES ###

a=read.csv("attribs.csv") ##### MODIFY THIS FILE PATH AND
ATTRIBUTE NAMES AS NECESSARY

V(g)$name=as.character(a$Site[match(V(g)$name,a$SafeName)])

V(g)$site_id=as.character(a$Site.ID[match(V(g)$name,a$Site)]
)

V(g)$obsi_analyzed=as.character(a$Obsidian.Analyzed[match(V(
g)$name,a$Site)])

V(g)$name=as.character(a$Site[match(V(g)$name,a$SafeName)])

V(g)$latitude=as.character(a$Latitude[match(V(g)$name,a$Site
)])

V(g)$longitude=as.character(a$Longitude[match(V(g)$name,a$Si
te)])

V(g)$country=as.character(a$Country[match(V(g)$name,a$Site)]
)

V(g)$region=as.character(a$Region[match(V(g)$name,a$Site)])

V(g)$period=as.character(a$Period[match(V(g)$name,a$Site)])
```

```
### ANALYSIS ###

# Betweenness Centrality
bw=betweenness(g, v=V(g), directed = FALSE, nobigint = TRUE,
normalized = TRUE, weights = NULL)
bw
V(g)$betweeness=bw

# Closeness Centrality
clo=closeness(g, vids=V(g), mode = c("all"), weights = NULL,
normalized = TRUE)
clo
V(g)$closeness=clo

# Local Clustering Coefficient
cc=transitivity(g, type=c("barrat"), vids = NULL, weights =
NULL, isolates = c("zero"))
cc
V(g)$local_cc=cc

# Global Clustering Coefficient
gcc=transitivity(g, type=c("globalundirected"), vids = NULL,
weights = NULL, isolates = c("zero"))
gcc
g$global_cc=gcc

# Average Local Clustering Coefficient
acc=transitivity(g, type=c("localaverageundirected"), vids =
NULL, isolates = c("zero"))
acc
g$average_local_cc=acc

# Degree
deg=degree(g,  v=V(g),  mode  =  c("all"),  loops  =  NULL,
normalized = FALSE)
deg
V(g)$degree=deg

# Weighted Degree
wdeg=graph.strength (g, vids = V(g), mode = c("all"), loops
= NULL, weights = NULL)
wdeg
V(g)$weighted_degree=wdeg
```

```
# Average Degree
adeg=mean(V(g)$degree)
adeg
g$average_degree=adeg

# Average Path Length
apl=average.path.length(g, directed=FALSE, unconnected=TRUE)
apl
g$average_path_length=apl

# Edge Betweenness Communities
ebc=edge.betweenness.community (g, weights = E(g)$weight,
directed = FALSE, edge.betweenness = TRUE, merges = TRUE,
bridges = TRUE, modularity = TRUE, membership = TRUE)
ebc
V(g)$GN=ebc$membership
g$ebc_modularity=ebc$modularity

# Edge Betweenness
eb=edge.betweenness(g, e=E(g), directed = FALSE, weights =
NULL)
eb
E(g)$edge_betweeness=eb

# Density
den=graph.density(g, loops=FALSE)
den
g$density=den

# Diameter
diam=diameter(g, directed = FALSE, unconnected = TRUE,
weights = NULL)
diam
g$diameter=diam

# Eccentricity
eccen=eccentricity(g, vids=V(g), mode=c("all"))
eccen
g$eccentricity=eccen

# Radius
rad=radius(g, mode=c("all"))
rad
g$radius=rad
```

```
# Number of Triangles
tri=adjacent.triangles (g, vids = V(g))
tri
V(g)$triangles=tri

# Size of Largest Clique
lcli=clique.number(g)
lcli
g$largest_clique=lcli

### WRITE GRAPH TO FILE ### MODIFY OUTPUT FILE NAMES AS
NECESSARY ###


write.graph(g, "g.gml", format=c("gml"))
write.graph(g, "g.net", format=c("pajek"))

### EDGE-BETWEENNESS COMMUNITIES DENDROGRAM ###
V(g)$name<-V(g)$site_id
ebc=edge.betweenness.community (g, weights = E(g)$weight,
directed = FALSE, edge.betweenness = TRUE, merges = TRUE,
bridges = TRUE, modularity = TRUE, membership = TRUE)
dend=as.dendrogram(ebc)

png("ebc_dend.png",width=1000,height=800)
par(cex=1,font=3)
plot(dend, main="Title") ##### MODIFY TITLE
dev.off()

### SUMMARY ###

g

### COMPLETE ###
```