Transforming Legacy Spatial Data into Testable Hypotheses about Socioeconomic Organization

Colin P. Quinn and Daniel Fivenson

ABSTRACT

As archaeologists expand the accessibility of legacy data, they have an opportunity to use these datasets to design future research. We argue that legacy data can be a critical resource to help predict characteristics of sites and socioeconomic systems. In this article, we present a combined geographic information system (GIS) and network analysis methodology that turns site location data into testable hypotheses about site characteristics and the organization of regional settlement systems. We demonstrate the utility of this approach with a case study: Bronze Age (2700–1100 BC) settlement patterns in the mining region of Hunedoara in southwest Transylvania, Romania. We leverage unsystematically collected site location information in legacy datasets to develop testable predictions about sites, regional networks, and socioeconomic systems that can be evaluated through future systematic surveys and large-scale excavations. Such testable hypotheses can inform archaeological research design by providing a quantitative basis for determining where to focus research efforts and can also help secure funding and fieldwork permits. The method developed here can be applied in diverse archaeological contexts to reinvigorate legacy data as part of future archaeological research design.

Keywords: archaeological survey, Bronze Age, GIS, institutionalized inequality, least-cost path analysis, legacy data, network analysis, settlement systems, Transylvania

A medida que los arqueólogos amplían la accesibilidad de los datos legados, tenemos la oportunidad de utilizar estos datos para diseñar investigaciones futuras. Proponemos que los datos legados pueden ser un recurso crítico para predecir las características de sitios arqueológicos y sistemas socioeconómicos. En este manuscrito, presentamos una metodología combinada de análisis de redes y SIG que convierte los datos de ubicación de sitios arqueológicos en hipótesis comprobables sobre las características del sitio y la organización de los sistemas regionales de asentamiento. Demostramos la utilidad de este enfoque con un caso práctico: patrones de asentamiento de la Edad de Bronce (2700-1100 aC) en la región minera de Hunedoara en el suroeste de Transilvania, Rumania. Aprovechamos la información de ubicación de sitios recopilada de manera no sistemática en conjuntos de datos legados para desarrollar predicciones comprobables sobre sitios, redes regionales y sistemas socioeconómicos que se pueden evaluar a través de encuestas sistemáticas futuras y excavaciones de gran escala. Dichas hipótesis comprobables pueden informar el diseño de la investigación arqueológica al proporcionar una base cuantitativa para determinar dónde enfocar los esfuerzos de investigación y utilizarse para ayudar a asegurar la financiación y los permisos de trabajo de campo. El método desarrollado aquí puede aplicarse en muchos contextos arqueológicos en todo el mundo para revitalizar los datos legados como parte del diseño de investigaciones arqueológicas futuras.

Palabras clave: prospección arqueológica, Edad del Bronce, SIG, desigualdades, análisis de rutas óptimas, datos heredados, análisis de redes, sistemas regionales de asentamiento, Transilvania

Legacy data from previously published and unpublished research have a critical role to play in future archaeological research. Traditionally, it has been difficult or even impossible to discover, access, and use data from both previously published research and gray literature (McManamon et al. 2017:239). Consequently, archaeologists have made concerted efforts to expand the accessibility of data by investing in their long-term curation. These efforts include the expansion of digital repositories, such as the Digital Archaeological Record (McManamon et al. 2017), Open Context (Kansa 2010), the Digital Index of North American Archaeology (Wells et al. 2014), the Comparative Archaeology Database (Drennan et al. 2019), and the Canadian Archaeological Radiocarbon Database (Martindale et al. 2016). Archaeologists can promote ethical stewardship of archaeological resources by

Advances in Archaeological Practice 8(1), 2020, pp. 65–77

DOI:10.1017/aap.2019.37

integrating this increasingly accessible legacy data into new research (Altschul 2016; Cook et al. 2018; Kintigh 2006; McManamon et al. 2017).

To meet this goal, archaeologists must pursue strategies that transform legacy data into new research questions and hypotheses. As we develop new theoretical approaches to understanding past lifeways, existing datasets may provide a critical launch point. A dataset that archaeologists compiled to answer one research question can help archaeologists answer another. Indeed, there has been a recent push for archaeologists seeking new insights on major anthropological and archaeological topics to start their inquiry with existing data (Altschul 2016; Cook et al. 2018; Kintigh 2006; Kintigh et al. 2015, 2018; McManamon et al. 2017; Witcher 2008). These recent calls have emphasized the need to develop new analytical techniques to transform legacy data into testable hypotheses.

There are well-documented challenges and potentials of working with legacy data (see Bauer-Clapp and Kirakosian 2017; Kansa and Kansa 2018; Kintigh 2006; McManamon et al. 2017). In many parts of the world, archaeologists have recorded site locations as well as other site characteristics (e.g., site size, socioeconomic activities, temporal and cultural affiliations) via large-scale systematic survey. Researchers have developed new techniques to use systematically collected legacy databases to address questions about regional organization and social dynamics in the past (see Casarotto et al. 2016, 2019; Spencer and Bevan 2018; Ullah 2015).

In many parts of the world, however, archaeologists have not conducted large-scale systematic surveys. In these areas, the discovery of archaeological sites was often driven by opportunity. Professional archaeologists often learn about these sites from amateur archaeologists, farmers who turn up artifacts while plowing their fields, or local informants who have knowledge of cultural landscapes. Our knowledge of these sites is often incomplete. Find spots may only be dots on a map, with no other information about site characteristics. Without this information, it is difficult to discuss aspects of social, economic, political, and ideological organization that are of interest to anthropological archaeologists. These partial datasets, however, are an important resource available to archaeologists. Legacy settlement datasets that lack detail or regular coverage will remain an underused resource without appropriate methodologies for making sense of them. Geospatial analytical techniques may provide the tools necessary to make use of these legacy data.

In this paper, we present a combined GIS and network analysis methodology that uses unsystematically collected site location data to generate testable hypotheses about site characteristics and the organization of regional settlement systems. While the individual components of this methodology are common in landscape archaeology, this methodology represents a novel combination of these techniques. We argue that legacy data can be a critical resource to help predict characteristics of sites and socioeconomic systems (Witcher 2008). We demonstrate the utility of this approach with a case study: Bronze Age (2700–1100 BC) settlement patterns in the mining region of Hunedoara in southwest Transylvania, Romania.

SETTLEMENT SYSTEMS AND EMERGENT HIERARCHY IN BRONZE AGE MINING LANDSCAPES

For decades, archaeologists have analyzed settlement systems to understand past socioeconomic organization (e.g., Blanton et al. 1979; Flannery 1976; Wilkinson 2000). The ways that people organize themselves in space, connect with each other, and interact with their environment have distinct material consequences (see Barrier and Horsley 2014; Birch 2012, 2014; Duffy 2015; Gyucha 2019; Wright 2014; Wright and Henry 2013). With new technologies and conceptual models, archaeologists continue to improve their understanding of the relationship between people and place. These new approaches include innovative satellite imagery and lidar analyses (e.g., Ebert et al. 2016), incorporation of drones into data collection (e.g., Olson and Rouse 2018), and least-cost path and social network analysis of spatial data (e.g., Hill et al. 2015; White and Surface-Evans 2012).

For archaeologists working on Bronze Age Europe, settlement systems are an important line of evidence in the study of socioeconomic organization and transformation (Duffy 2014, 2015; Earle and Kristiansen 2010; Galaty 2005; Quinn and Ciugudean 2018). During the Bronze Age, socioeconomic organization became increasingly centralized and hierarchical (Earle 2002). Ultimately, these social transformations resulted in the transcendence of village autonomy and the emergence of complex regional polities with institutionalized inequality (Earle and Kristiansen 2010). Population aggregation and growth led to the development of settlement hierarchies with contemporaneously occupied large towns, small villages, and more isolated hamlets and farmsteads. Monitoring the changing ways in which people positioned themselves relative to other communities and features in the environment can help archaeologists elucidate the socioeconomic processes that led to the emergence of complex regional polities.

There remains significant debate about how hierarchical polities emerged in Bronze Age Europe. Political economic approaches, which are the most common explanatory framework, focus on elite control (see Earle et al. 2015). Emerging elites may have gained advantages by turning differential access into control of the flows of people and material (Earle 2002; Earle and Kristiansen 2010; Earle et al. 2015). Even within political economic models, however, there are numerous potential bottlenecks in material flows that emerging elites could control. In Bronze Age Europe, this might have included controlling (1) the extraction of raw materials such as copper, tin, gold, and salt; (2) access to nonlocal resources, such as metal, salt, amber, obsidian, and faience; (3) the labor needed to manufacture goods such as metal objects, ceramics, and boats; (4) the modes and paths of movement of materials including rivers, roads, boats, wagons, oxen, horses, and carts; and (5) the human power needed to defend communities and resources, conduct raids or more organized military excursions, and construct fortifications. Each of these political economic mechanisms, which are not necessarily mutually exclusive, has its own set of material consequences. For some of these factors, we can use spatial analyses of settlement systems to reconstruct the

https://doi.org/10.1017/aap.2019.37 Published online by Cambridge University Press

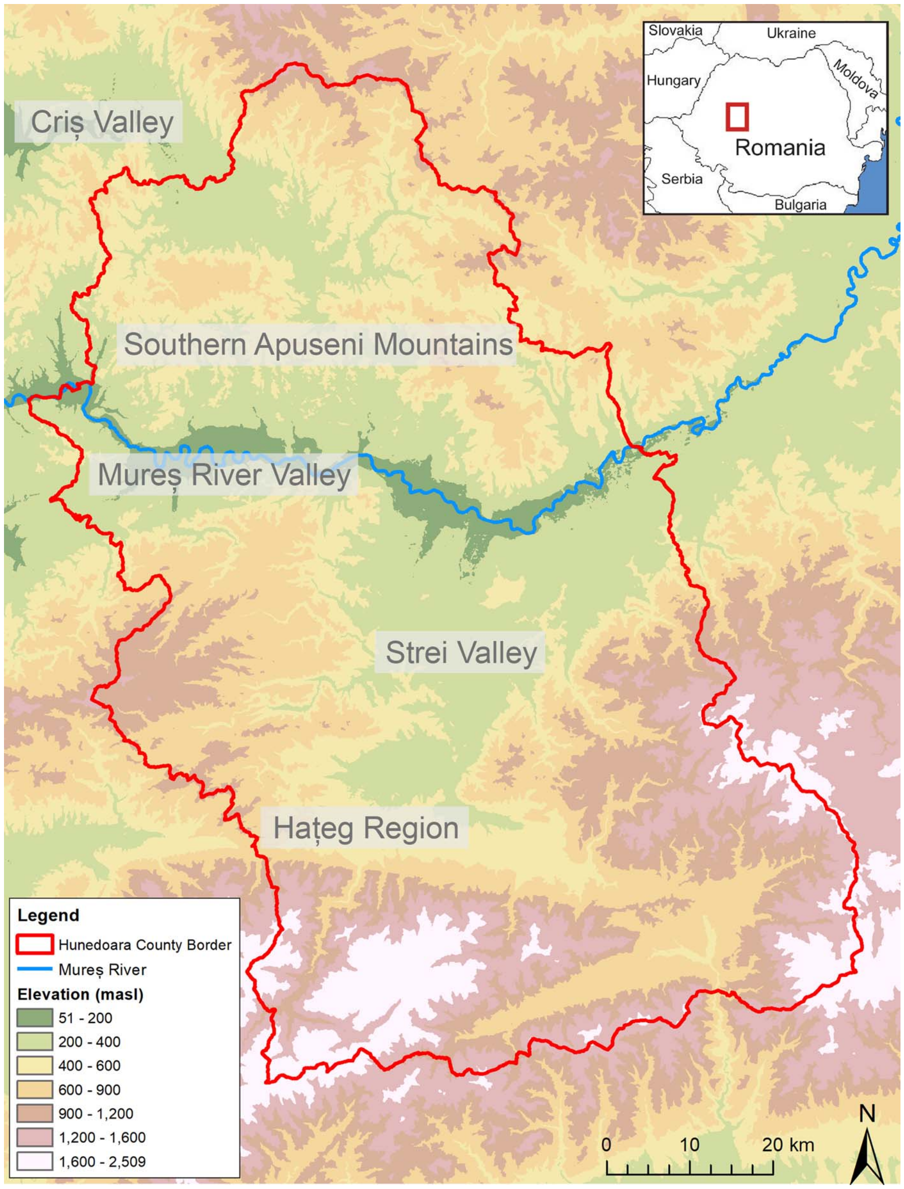

FIGURE 1. Map of Hunedoara County with major topographical features and rivers.

socioeconomic processes that underpinned the creation and persistence of social hierarchies.

As a case study, we focus our analysis on the Bronze Age settlement systems in Hunedoara County in southwest Transylvania, Romania (Figure 1). Hunedoara is an ideal context in which to study how socioeconomic processes fueled the emergence of complex hierarchical polities. Southwest Transylvania is home to the largest gold deposits in Europe along with major deposits of copper, salt, silver, and tin (Quinn et al. 2019). Resources from this region were traded widely during the Bronze Age (Stos-Gale 2014). Unlike many areas where the control of access to metal has been argued to have been a major factor in the emergence of hierarchical polities (e.g., Earle and Kristiansen 2010), metal is abundant and locally available. Hunedoara is also a key crossroads between the Carpathian Basin to the west and the Transylvanian Plateau to the east. The Mureș River, a major river and corridor for exchange during the Bronze Age (see O'Shea 2011), passes through the center of the county. In the southern and central parts of the county, an important overland trade route connects the Carpathian Basin to Transylvania through the Hațeg region. By investigating how communities in this critical resource procurement zone positioned their settlements relative to metal resources and trade routes, we can begin to test models about political economic mechanisms that led to the development of complex polities in the region.

Despite Hunedoara's critical geographic position and mineral resources, archaeologists investigating emergent social complexity in the European Bronze Age have largely overlooked the

https://doi.org/10.1017/aap.2019.37 Published online by Cambridge University Press

region. This omission is primarily due to the lack of systematic archaeological surveys in the county. The counties around Hunedoara—Alba to the east and Arad to the west—have been the focus of recent research into the development of social complexity in the Bronze Age (see Nicodemus 2014; O'Shea 1996, 2011; O'Shea and Nicodemus 2019; O'Shea et al. 2019; Quinn 2017). Hunedoara also encompasses the headwaters of the Körös River, known as the Criș in Romania, which has seen significant regional archaeological work (Duffy 2014, 2015; Duffy, Paja et al. 2019; Duffy, Parditka et al. 2019; Duffy et al. 2013). Therefore, Hunedoara is an important next piece of the regional puzzle.

The first step in designing systematic archaeological research in Hunedoara is to develop testable models of the socioeconomic organization of Bronze Age communities. This is where extant legacy datasets can be most impactful. In the next section, we present an integrated least-cost path and network analysis approach to developing testable hypotheses about the structure and evolution of community organization in Hunedoara. We use legacy data derived from the unsystematically generated archaeological site gazetteer compiled by Luca (2008). Luca (2008) describes the chronological affiliation of sites as assigned by the original archaeologists or museum specialists who accessioned finds. We digitized settlements (excluding cemeteries and other special purpose sites) affiliated with each of the three chronological subphases of the Bronze Age (Table 1): Early (EBA; 2700–2000 BC), Middle (MBA; 2000–1500 BC), and Late (LBA; 1500–1100 BC). The diachronic study of survey data can highlight fluctuations in settlement pattern centralization and use of different areas of the landscape (Spencer and Bevan 2018:71).

TABLE 1. Bronze Age Chronology and Archaeological Cultural Affiliations for Southwest Transylvania.

Phase	Years	Cultural Affiliations
Early Bronze Age	2700–2000 BC	Livezile Șoimuș Iernut
Middle Bronze Age	2000–1500 BC	Wietenberg Balta Sarata
Late Bronze Age	1500–1100 BC	Noua Band-Cugir Susani

LEAST-COST PATH AND NETWORK MODEL IN TRANSYLVANIAN LANDSCAPES

The development of testable hypotheses about settlement and socioeconomic systems from unsystematically collected survey data involves two broad analytical steps: (1) conducting least-cost path (LCP) analysis in a GIS to build a settlement network, and (2) conducting network analysis to examine the characteristics of the network and individual settlements therein. While LCP and network analyses are not new to archaeologists, the method here represents a novel combination designed to address social questions. The model we present here is simple enough to be replicable but is also amenable to layering on additional complexities where appropriate (e.g., Monte Carlo simulation, multicost surfaces). In this section, we outline the process used in the creation of hypotheses about socioeconomic organization in Hunedoara during the Bronze Age (Figure 2).

Building the Network

LCP analysis provides a way to better approximate the movement of people in Hunedoara than simply using the geographic ("as the crow flies") distance between settlements. LCP analyses have become a staple of landscape archaeological approaches (see Howey 2007, 2011; White and Surface-Evans 2012). LCP analyses create a path between two known features that minimizes the costs for the traveler. The most likely paths people took between two sites was not a straight line. People consider the characteristics of the landscape, often taking a more circuitous route if it will be significantly easier. In mountainous landscapes, such as Hunedoara, LCP analysis can provide data that better match theoretical models of movement and interaction. We focus on the time it would take to walk between sites. We believe that travel time would have been a relevant variable for Bronze Age communities, as it would have been more easily recognized than other ways in which costs can be measured (e.g., calorie expenditure). We next outline the steps and justifications for the model, while the ArcGIS model itself can be found in Supplemental Material 1.

The first step in building the settlement network was creating a cost surface map for LCP analysis. A cost surface is a raster map in which each pixel is given a value for the cost it takes to traverse that pixel. For the mountainous landscape in Hunedoara, we modeled the cost surface using slope. We used an Aster Digital Elevation Model (DEM) with 30 m pixels. The slope for each pixel was calculated in ArcGIS, which is derived from the changes in elevation between pixels in the DEM. A cost surface map was then generated by assigning each pixel a cost (in this case, the time it would take someone to walk across a 30 m pixel with a given slope). The time it takes to walk a set distance at a particular slope can be calculated using Tobler's Hiking Function (Seubers 2016; Tobler 1993). We grouped slopes together into categories, (e.g., 0 to 3 degrees of slope; 3 to 6 degrees of slope, etc.) and assigned them a time based on Tobler's Hiking Function (Table 2).

The second step was to digitize the site locations from the legacy dataset for Hunedoara. Site locations (UTM; Zone 34 N) were derived from maps published in the Hunedoara County site gazetteer (Luca 2008). The information available about these Bronze Age settlements is highly variable. Some sites have been systematically excavated, whereas others are find spots reported by local community members that have not been investigated further. We used ArcGIS to create shapefiles for each Bronze Age subphase: EBA, MBA, and LBA. The differences between the ceramics of these subphases in Transylvania are robust and are likely reliable indicators of this chronological assessment (see Table 1 for cultural affiliations associated with each subphase). However, finer-grained chronological categorization within each subphase is not possible without excavation and radiocarbon dating (see Quinn et al. 2019).

Third, we calculated cost distance maps for each site in ArcGIS and used the resulting raster to calculate the time it would take to move along the least costly path to each contemporary Bronze

https://doi.org/10.1017/aap.2019.37 Published online by Cambridge University Press

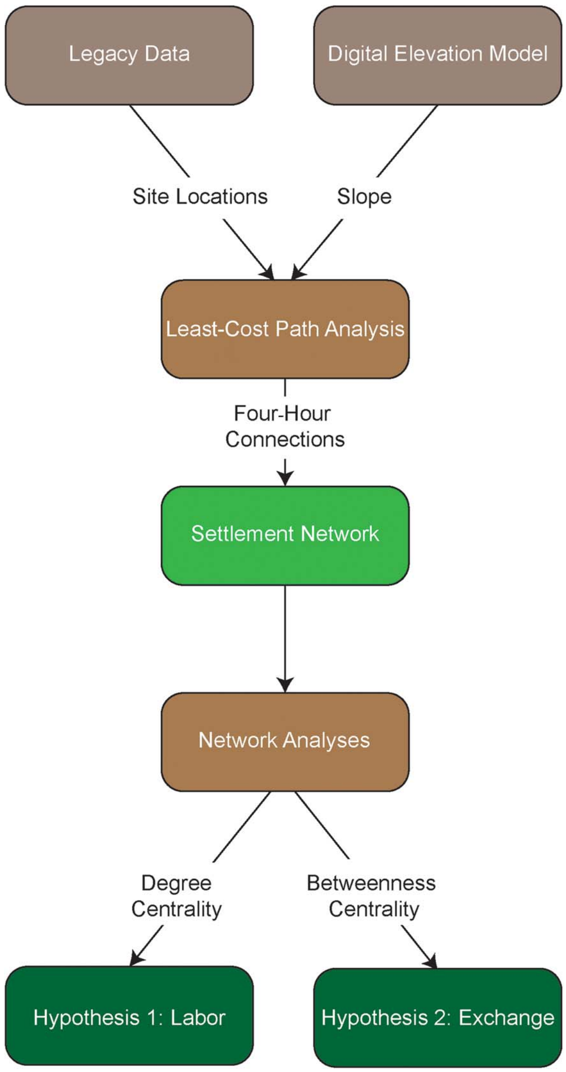

FIGURE 2. Conceptual map of the least-cost path and network analysis method.

Age settlement. Cost distance maps compile the time it would take to move from the original settlement to any other part of the DEM. The amount of time it would take to travel between all sites, calculated using the site shapefiles and cost distance rasters for each site, was compiled for all pairs of sites.

The fourth and final step in creating the settlement network was to make an "edge" between settlements that are within a four-hour walk of each other. Anthropologists and archaeologists have established that complex regional polities are usually limited in spatial extent by a need to control their territory while lacking internally specialized administrative units (of more complex state-level societies) that can allow for delegation of authority to lower-tier settlements (Livingood 2012). In particular, the upper-level distance from the center of a regional polity that political control could extend is limited to within a half-day's journey (Livingood 2012:174–175; Spencer 1990:6–8). This distance would allow a chief to interact with all communities in the polity without having to impose on their hospitality, and to mobilize a force to

TABLE 2. Cost Surface Values for Walking across the Landscape.

Slope (degrees)	Walking Speed (km/hr)	Time to Traverse DEM Pixel (seconds)
0 to 3	4.19	22
3 to 6	3.49	27
6 to 9	2.89	32
9 to 12	2.39	39
12 to 15	1.97	48
15 to 18	1.62	58
18 to 21	1.31	72
21 to 24	1.06	89
24 to 27	0.85	112
27 to 30	0.67	142
30 to 33	0.52	183
33 to 36	0.40	239
Over 36	<0.01	1000

defend more distant settlements and return within a day (Livingood 2012:175). For nonelites, being located within a half-day's journey of the center would also allow them to access social and economic opportunities in the regional center (Livingood 2012:175). This last point is critical for middle-range societies lacking centralized political authority, as even without chiefs, interaction would be much more common between communities within a half-day's journey than with communities at greater distances. We use four hours as a cutoff for a half-day's journey. All other potential links between sites that were longer than four hours were discarded. This is not to say that people would have never interacted with communities farther than four hours away. Rather, it assumes that the interaction between communities within a half-day's walk would have occurred much more often than with settlements that would have required overnight stays. With this last modification, we are left with a settlement network for each Bronze Age subphase made up of nodes (settlements) and edges (links between sites within a four-hour walk).

Analyzing Networks and Generating Hypotheses

Network analyses are ideally suited for exploratory analysis of legacy site location data. The applications of archaeological network analysis have grown significantly in their depth and diversity over the past decade (see Brughmans 2010, 2013; Knappett 2011, 2012; Knappett, ed. 2013; Mills et al. 2015; Peeples et al. 2016). In the Carpathian Basin, network analyses have played a growing role in characterizing the organization and evolution of settlement systems (see Duffy et al. 2013; Quinn 2018). Network analyses are relatively easy and cheap to conduct, can help generate quantitative data for comparison across datasets at different temporal and spatial scales, and are designed to explore central topics in archaeological research, such as interaction and integration. From patchy or incomplete datasets, archaeologists can develop multiple testable hypotheses for how settlement systems were organized. Using the settlement network from Hunedoara, based exclusively upon site locations and local topography, we illustrate

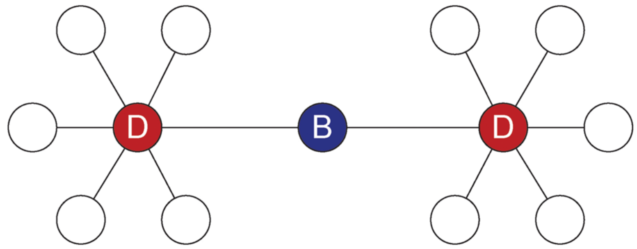

FIGURE 3. Network showing how different nodes within the same network will have higher centrality scores based on the centrality measure used. The nodes in red have high degree (d) centrality (connected to the most other nodes), while the node in blue has high betweenness (b) centrality (most critical to the flow of materials, people, or information across the network).

how testable hypotheses can be developed using network analysis techniques.

The first step of network analysis was to convert our database of linked sites into a network database in UCINET, a free software platform for network analysis. The settlement network from Hunedoara does not assume directionality on the relationship between sites (e.g., for tribute or redistribution). Instead, we modeled the edges as undirected; that is, where people, goods, and ideas could have flowed equally between both settlements.

In the second and final step, we used UCINET to calculate centrality measurements for the networks for EBA, MBA, and LBA settlement systems in Hunedoara. We focus on two centrality measures in particular: *degree centrality* and *betweenness centrality*. While considerable conceptual overlap exists between different measures of network centrality, they are distinct from each other and measure different characteristics of the network (Valente et al. 2008). Degree measures the number of other nodes to which a node is connected. In our model, degree is the number of sites one could walk to within a four-hour radius. Betweenness measures the extent to which a node lies between other actors in a network. Betweenness is how often a particular site falls along a path between other sites. Sites with high betweenness are ones that are difficult to avoid when traveling across a network. Even within the same network, these alternative network centrality measures may identify different critical nodes within the network (Figure 3).

The use of multiple centrality measures can help archaeologists test alternative models of socioeconomic organization. Settlements that have high degree centrality can directly influence the highest number of other communities, suggesting that they may be able to mobilize the most people for communal labor projects, warfare, and defense. Settlements that have high betweenness centrality will be able to control the flow of information and nonlocal goods and resources through a system, creating bottlenecks that emergent elites may be able to manipulate. Archaeologists can use the result of these network analyses to identify key sites to prioritize for future systematic investigation. If site characteristics (e.g., site size, quantity of prestige goods) match one of the predicted networks, we would have evidence of the differential importance of the mobilization of labor (if degree centrality predicted the key sites) or the control of trade and exchange (if betweenness centrality predicted the key sites).

RESULTS: MODELED NETWORKS FOR BRONZE AGE HUNEDOARA

The GIS and network analyses reveal significant transformations in settlement systems throughout the Bronze Age.

Early Bronze Age Networks

Thirty-five settlements are attributed to the EBA (Supplemental Material 2). All but five of these sites are integrated into one settlement interaction network, with the other five sites positioned high in the Apuseni Mountains (Figure 4). The settlement network is densest in the Mureș River valley, with connections to the Criș (Hungarian: Körös) river system to the northwest. Four of the six sites with the highest degree centrality are in the modern town of Deva positioned along the Mureș River, on its southern terrace (Table 3). While this may be partially the result of oversampling due to the presence of the modern town, it is important to note that this area is not overrepresented in other time periods. Deva is strategically located at the intersection of the Strei and Mureș Valleys, with views up toward the metal-rich southern Apuseni Mountains. The other sites with high degree centrality, Boholt-*Ciuta* and Cărpiniș-*Comoara*, are located as close to the Mureș as possible, while still being within easy access of nearby mineral deposits. The site with the highest betweenness centrality is Dealu Mare-*Ruști*, positioned near the region's rich metal resources and the land between the Mureș Valley and the headwaters of the Criș. The next two sites with the highest betweenness centrality (Brănișca-*La Tău 2*, Brad-*Dealul Ștefanului*) are also located in the metal-rich Apuseni Mountains in the northwest quadrant of the county.

Middle Bronze Age Networks

Significantly more sites in Hunedoara, 79 in total, have been assigned to the MBA than the EBA (Supplemental Material 3). All but three of the 79 sites are integrated into a single settlement network (Figure 5). Unlike the EBA, the MBA settlement system centered on the Mureș and Strei Valleys. The Strei Valley connects to the Timiș River system southwest of Hunedoara through the Hațeg region (also known as the "Transylvanian Iron Gates"). This would have been a path for the movement of people and goods overland, as this pathway does not fall along a highly navigable river like the Mureș. The Mureș Valley continues to be critical during the MBA, while the Apuseni Mountains are less of a focus for settlement than during the EBA. The four sites with the highest degree centrality are all positioned along trade routes: one at the confluence of the Mureș and Strei Valleys (Deva-*Cimitirul Ceangăilor*) and three further south along the Strei (Bretea Streiului-*Grumedea*, Peștișu Mare-*La Țărmure Sud*, Silvașu de Jos-*Între Ogăși*; Table 3). Similarly, the four sites with the highest betweenness values also focus on the Mureș (Rapoltu Mare-*Șeghi*) and Strei Valleys (Bercu-*Vârcolin*, Silvașu de Jos-*Între Ogăși*, Strei-*Canton CFR*). None of the sites with the highest degree or betweenness centrality values are in areas where communities

https://doi.org/10.1017/aap.2019.37 Published online by Cambridge University Press

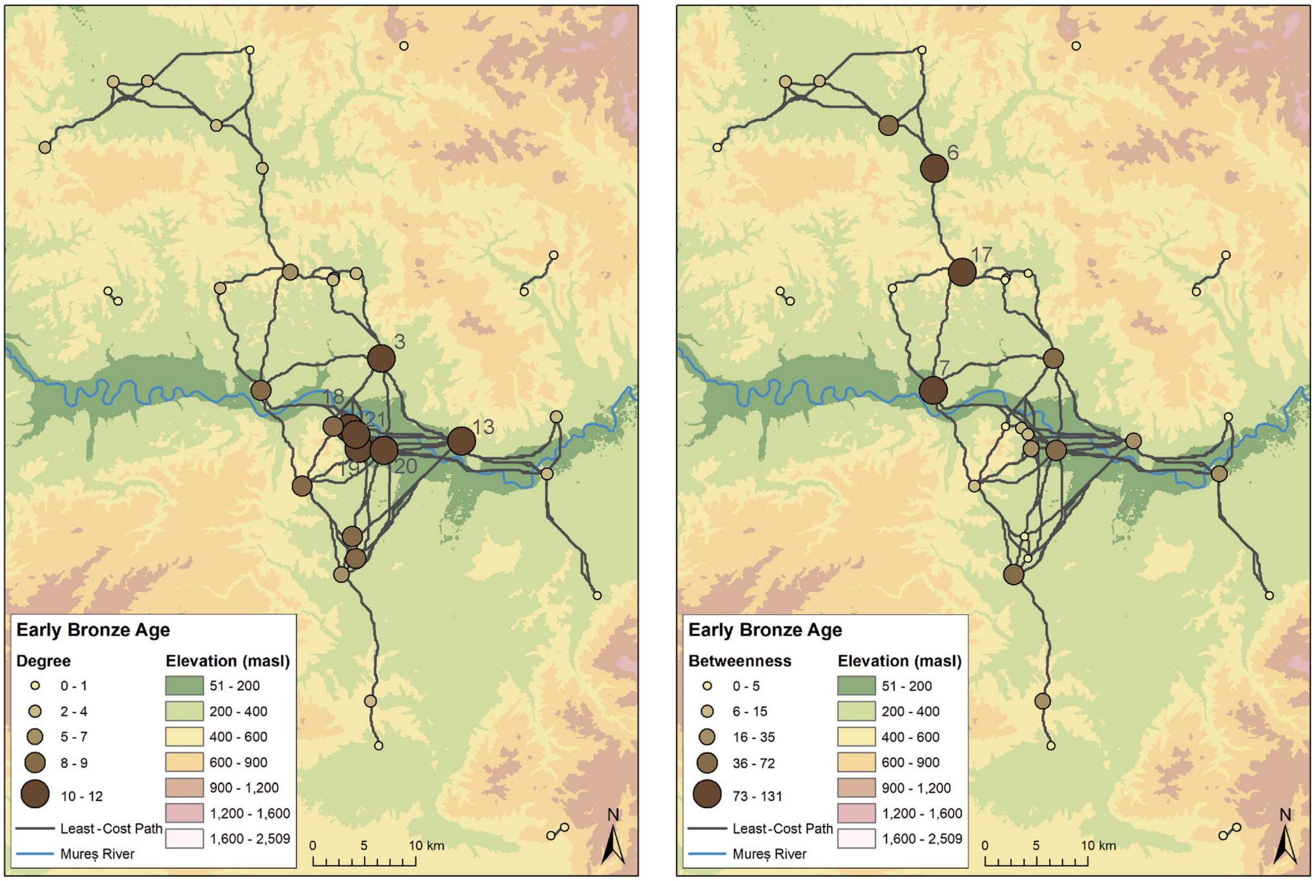

FIGURE 4. EBA settlement network with nodes reflecting degree centrality and betweenness centrality. Key sites, labeled by their Site IDs, are (3) Boholt-*Ciuta*, (6) Brad-*Dealul Ştefanului*, (7) Brănişca-*La Tău 2*, (13) Cărpiniş-*Comoara*, (17) Dealu Mare-*Ruşti*, (18) Deva-*Cartierul Viile Noi*, (19) Deva-*Cimitirul Reformat*, (20) Deva-*Dâmbul Popii*, and (21) Deva-*Magna Curia*.

would have had direct access to the most abundant metal deposits.

Late Bronze Age Networks

Only 13 sites are attributed to the Late Bronze Age (Supplemental Material 4). The sites are separated into two clusters, with two sites alone on the southern and northern edges of the county (Figure 6). The larger cluster, connecting eight sites, centers on the western side of the Strei Valley. Most sites in this cluster are set back in the uplands above the valley, though two are located to the north along the Mureș River. There are only three sites in the smaller network, along the southern terrace of the Mureș River in the eastern half of the county. Valea Nandrului is predicted to be a critical site by both centrality measures (Table 3). This is in contrast to the EBA and MBA, when no single site has the highest value across both centrality measures. This is the type of pattern we would expect for the presence of institutionalized regional hierarchies where elites have control across multiple dimensions of socioeconomic organization. The site has a strategic position within the network that would allow elites to both marshal labor from nearby communities as well as control the flow of goods, resources, and people within the local area. However, Valea Nandrului is set back from the trade corridors along the Mureș River and the floor of the Strei Valley that had been key to the MBA settlement network.

DISCUSSION: BRONZE AGE HUNEDOARA SOCIOECONOMIC ORGANIZATION AND TESTABLE HYPOTHESES FROM LEGACY DATA

The results of the GIS and network analyses allow us to construct a model for the development of settlement systems in Hunedoara. Over the course of the Bronze Age, there was an increased focus on monitoring interregional trade routes in the lowlands at the expense of controlling ore-rich mountain landscapes. During the EBA, communities placed their sites and constructed interaction networks that connected people living in the Mureș Valley with communities in the southern Apuseni Mountains. More so than in other periods, EBA communities centered their interactions within metal-rich landscapes. Beyond settlement patterns, evidence in burial practices supports the conclusion that there was significant interaction among communities in the mountains. EBA communities in southwest Transylvania primarily buried their dead under

https://doi.org/10.1017/aap.2019.37 Published online by Cambridge University Press

TABLE 3. Sites Predicted to Be Prominent Based on Legacy Data in Luca (2008).

Phase	Centrality Measure	Site ID	Site Name	Centrality Measure Value
Early Bronze Age	Degree (Hypothesis 1—Labor)	20	Deva-*Dâmbul Popii*	12
		19	Deva-*Cimitirul Reformat*	11
		3	Boholt-*Ciuta*	10
		13	Cărpiniș-*Comoara*	10
		18	Deva-*Cartierul Viile Noi*	10
		21	Deva-*Magna Curia*	10
	Betweenness (Hypothesis 2—Exchange)	17	Dealu Mare-*Ruști*	130.9
		7	Brănișca-*La Tău 2*	119.3
		6	Brad-Dealul *Ștefanului*	114.0
Middle Bronze Age	Degree (Hypothesis 1—Labor)	60	Peștișu Mare-*La Țărmure Sud*	25
		69	Silvașu de Jos-*Între Ogăși*	25
		14	Bretea Streiului-*Grumedea*	23
		28	Deva-*Cimitirul Ceangăilor*	22
	Betweenness (Hypothesis 2—Exchange)	11	Bercu-*Vârcolin*	338.5
		61	Rapoltu Mare-*Șeghi*	292.9
		69	Silvașu de Jos-*Între Ogăși*	277.1
		71	Strei-*Canton CFR*	261.2
Late Bronze Age	Degree (Hypothesis 1—Labor)	12	Valea Nandrului-*(no name)*	5
		5	Deva-*Cartierul Viile Noi*	4
		7	Peștișu Mare-*La Tarmure Sud*	4
		8	Peștișu Mic-*(no name)*	4
	Betweenness (Hypothesis 2—Exchange)	12	Valea Nandrului-*(no name)*	10.7
		3	Cerișor-*Peștera Mare*	6.0
		5	Deva-*Cartierul Viile Noi*	6.0

stone- or earthen-covered tombs along mountain ridges (Ciugudean 2011). By placing tombs in highly visible positions, EBA communities could mark territory and secure access to local resources through their ancestors (see Goldstein 1981). The investment in these monuments makes sense if people were routinely traversing these highland landscapes as they moved between settlements.

By the MBA, settlement networks had changed significantly. MBA communities placed their sites along the most important interregional trade routes along the Mureș River and the Strei Valley at a greater rate than before. These valleys are significant interregional trade routes, especially along the Mureș River and the overland route through the Strei Valley and Hațeg region. Because of the significant increase in the number of sites attributed to the MBA, the settlement network was much denser, and more connected, than other subphases of the Bronze Age. Some of this may be the product of assuming contemporaneity, as not all sites were occupied for the entire 500-year sequence. However, Duffy and coauthors (2013) have also documented an increase in network connectivity due to an increase in the number of sites in the MBA in the Körös region.

There was another shift in settlement networks in the LBA. During this period, the drop in the number of sites could have been the product of population aggregation, as seen in neighboring regions at this time (e.g., Szentmiklosi et al. 2011). Communities continued to construct settlement networks that centered on the major interregional trade routes. Some LBA communities, however, placed their sites at a distance from the Mureș River and Strei lowlands in more prominent topographic positions. From these positions, communities would have been able to monitor exchange networks but would also have been insulated from the risks (e.g., raiding) and benefits (less costly access to trade) of living along these key pathways.

The overall pattern in Hunedoara settlement networks that we reconstruct here is similar to the patterns seen in neighboring regions during the Bronze Age. Using a different GIS analytical method, Quinn and Ciugudean (2018) demonstrated the shift away from metal procurement landscapes toward interregional trade routes from the EBA to the MBA. The shift in settlement networks from the MBA to the LBA is also consistent with disruptions in the organization of settlement systems seen after 1500 BC throughout the Carpathian Basin and Transylvania (see Ciugudean and Quinn 2015; Duffy, Parditka et al. 2019; O'Shea 2011; O'Shea et al. 2019). The emergence of large fortified sites during the LBA is consistent with the presumed population aggregation and selection of more-defensible site locations seen in this model (e.g., Gogâltan and Sava 2010; Szentmiklosi et al. 2011; Uhnér et al. 2018).

We are now ready to ask the question: What were the socioeconomic processes that underlay this model of changing community organization within Hunedoara throughout the Bronze Age? To answer this question, we must conduct systematic fieldwork in Hunedoara. We can use the results of the GIS and network analyses to help design future research.

We now have two alternative hypotheses (see Table 3). If Hunedoara communities were organized around controlling labor, then we predict that the sites with the highest degree centrality would be the most prominent sites within the settlement systems. If differential positioning within the network to control

https://doi.org/10.1017/aap.2019.37 Published online by Cambridge University Press

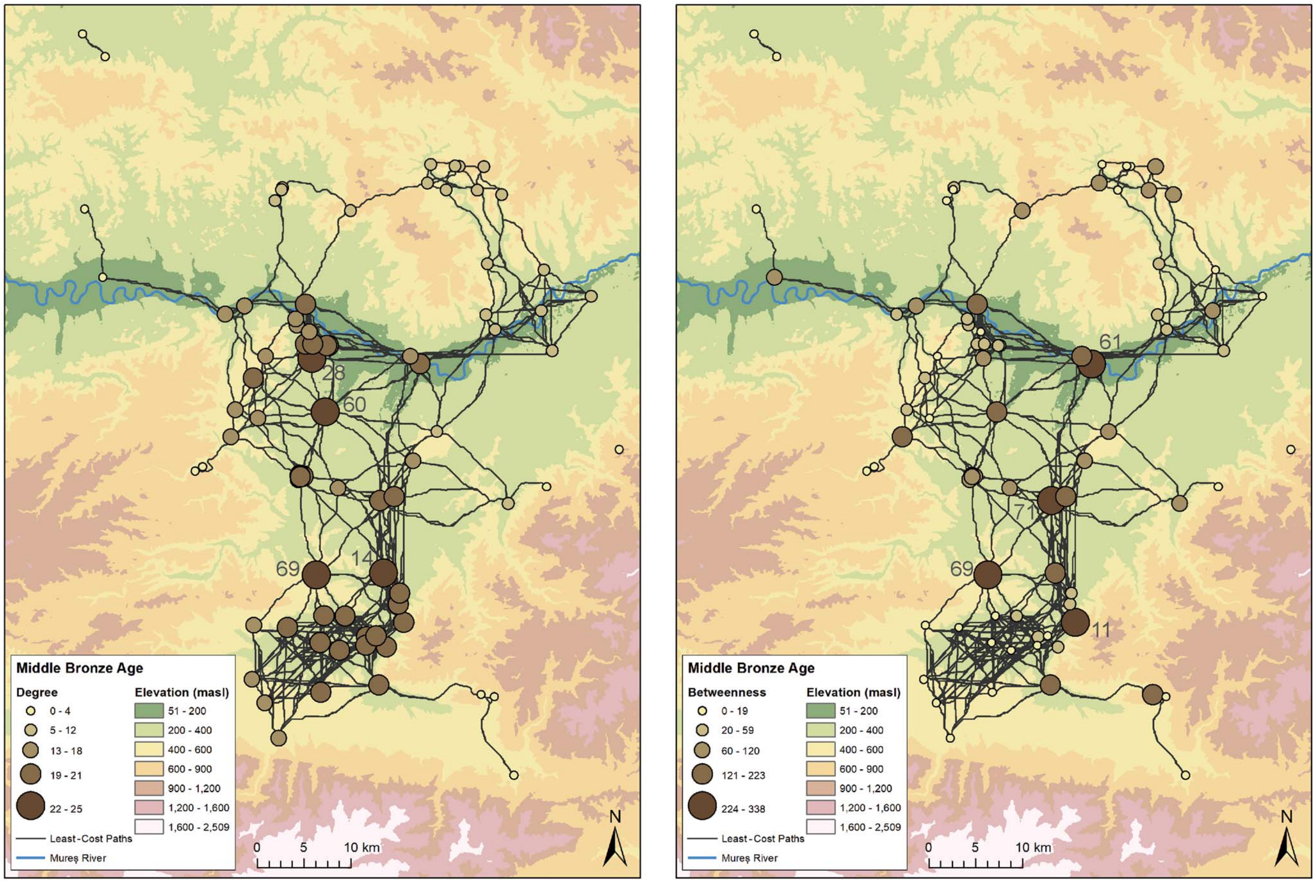

FIGURE 5. MBA settlement network with nodes reflecting degree centrality and betweenness centrality. Key sites, labeled by their Site IDs, are (11) Bercu-*Vârcolin*, (14) Bretea Streiului-*Grumedea*, (28) Deva-*Cimitirul Ceangăilor*, (60) Peștișu Mare-*La Țărmure Sud*, (61) Rapoltu Mare-*Șeghi*, (69) Silvașu de Jos-*Între Ogăși*, and (71) Strei-*Canton CFR*.

the flow of materials locally and through long-distance exchange were more critical to socioeconomic organization at the regional level, then we predict that the sites with the highest betweenness centrality would be the most prominent. Prominence, in this case, may be measured in site sizes (demographic prominence) or evidence for differential access to material wealth (e.g., exotics, fineware ceramics, ornamental metalwork). Alternatively, sites that have low centrality (see Supplemental Materials 2, 3, and 4) would be expected to have lower regional prominence, depending on whether control of labor or exchange networks were more important factors in the regional settlement system.

To evaluate these two hypotheses, we must design and conduct systematic archaeological investigations based on assessing the predicted site characteristics. We recommend a research program that combines mapping the horizontal extent of settlement, assessing the depth of deposits, and collecting datable material associated with diagnostic material culture. Documenting site sizes and economic activities through additional survey and excavations will provide the data needed to support one of these two hypotheses. If neither degree centrality nor betweenness centrality accurately predicts the key sites within the region, then it is likely that other factors that are not part of these models would have been the most important factors in organizing people in space during the Bronze Age in Hunedoara. We can use the models derived from legacy data to inform our choice of which sites to prioritize for future research. Archaeologists should target sites that the model predicts are important based on the centrality measures (see Table 3 for specific sites) as well as sites that are predicted to be less important to the overall settlement network. These models also generate pilot data, which are necessary to secure funding and permits within Hunedoara.

Legacy data are notoriously unreliable, even in regions that archaeologists have systematically surveyed (e.g., Ullah 2015). In Hunedoara, where there has been no systematic survey, there are likely many unrecorded sites. This may affect the models we have developed in different ways. For example, there is a gap between two settlement clusters during the LBA. If there were sites in this region that were not included in the gazetteer, they would instantly become critical nodes (with high betweenness) in the settlement network model. This model is more sensitive to missing data when there are few known sites (e.g., LBA) than when there is a more robust sample (e.g., EBA and MBA). There are additional analytical concerns, including whether all sites were contemporaneously occupied (e.g., during the MBA), or whether certain types of sites are overrepresented or underrepresented. During the MBA, for example, ceramics belonging to the

https://doi.org/10.1017/aap.2019.37 Published online by Cambridge University Press

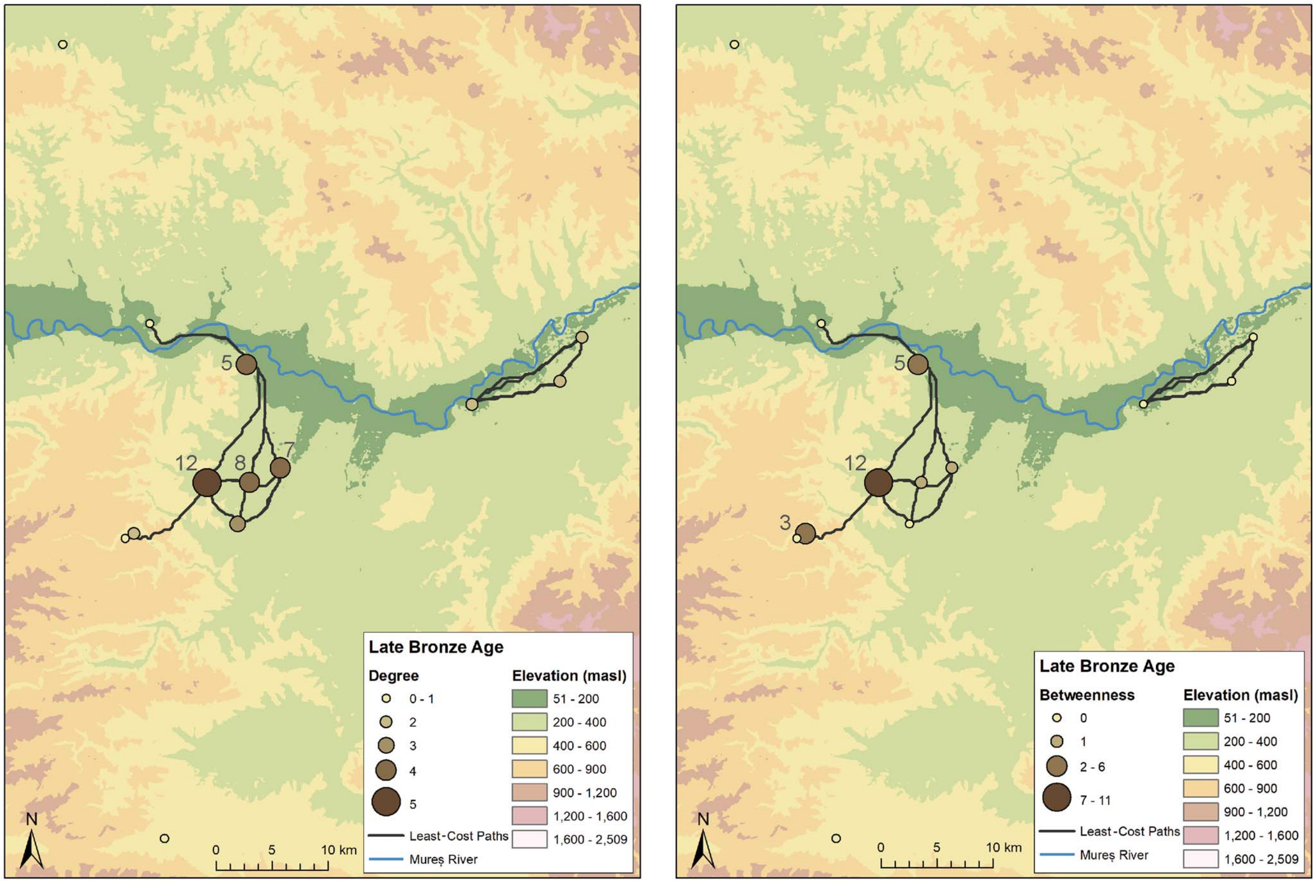

FIGURE 6. LBA settlement network with nodes reflecting degree centrality and betweenness centrality. Key sites, labeled by their Site IDs, are (3) Cerișor-*Peștera Mare*, (5) Deva-*Cartierul Viile Noi*, (7) Peștișu Mare-*La Tarmure Sud*, (8) Peștișu Mic-*(no name)*, and (12) Valea Nandrului-*(no name)*.

Wietenberg Culture were decorated with diagnostic motifs and techniques (Bălan et al. 2016). The visibility of these motifs, and comparably fewer diagnostic designs for the EBA and LBA, might have resulted in an overrepresentation of MBA sites when compared with the other subphases of the Bronze Age. Recently revised chronological models also suggest that the Wietenberg persisted into the LBA in southwest Transylvania (Quinn et al. 2019). The potential problems with the legacy dataset cannot be resolved without new systematic survey, excavation, and radiocarbon dating programs.

As we gain more insights into the nature of the archaeological record in Hunedoara, we can start to add more complexity to our model. With stochastic approaches such as Monte Carlo simulations, we can test how the duration of occupation affects the organization of the settlement network. To construct these simulations, we must better understand duration of occupation of sites in Hunedoara—something that requires more fieldwork and radiocarbon dating. We could also vary the travel costs within the landscape. We could include the cost of crossing waterways, time diverted from traveling for social obligations when passing a village, and efficiency of different modes of travel such as by boat or horse. We have chosen to wait to add these other criteria to the cost model presented here, as each has built-in assumptions (e.g., available technology, how prehistoric land use varied from modern land use, etc.). While we argue that the topography of the mountainous Hunedoara would have been the most significant cost, we hope that future modeling can involve running multiple scenarios with multi-criteria cost surfaces. These more complex approaches will have greater value if the simple models presented here do not accurately predict site characteristics.

More broadly, archaeologists can use the method described here to model the socioeconomic processes that underpinned settlement networks in any region where site location information is available. As shown here, the method works with piecemeal legacy datasets. However, the method also has significant potential to add to our understanding of settlement systems in places with systematically collected survey data. Many of the classic archaeological surveys, in locations such as the Viru Valley (Willey 1953) and the Valley of Oaxaca (Blanton et al. 1982), remain critical datasets that archaeologists continue to use to conduct research. Archaeologists can apply the LCP and network analysis method to test alternative hypotheses about how these settlement systems were organized. The data to evaluate hypotheses in these contexts, including site sizes, presence of exotics, and evidence of wealth inequality, may already be contained in these survey reports. This is especially important in some of the older systematic survey datasets. In many of these places, human-led development and climate change have destroyed the sites in the years

https://doi.org/10.1017/aap.2019.37 Published online by Cambridge University Press

and decades since archaeologists recorded them. In these cases, legacy data from large-scale surveys will remain the only archaeological data about settlement patterns after the destruction of these nonrenewable resources.

CONCLUSION

In this article, we demonstrate how archaeologists can use legacy data to develop testable hypotheses about socioeconomic organization in the past. We present a new integrated GIS and network analysis model for predicting site characteristics using site location data. Using a case study from southwest Transylvania during the Bronze Age, we show that this approach is useful for characterizing settlement networks. In Hunedoara, settlement systems increasingly centered on interregional trade routes over metal-rich mountain landscapes throughout the Bronze Age. Using the results of GIS and network analyses, archaeologists can more efficiently design a fieldwork-based research program to explore when, and how, regional communities became hierarchically organized. Researchers can employ this method in any archaeological context where site location and terrain information are available. Across North America, there are many regions where legacy site location data could be explored using this geospatial technique. The method is particularly useful in contexts where there have been no previous systematic archaeological surveys, and therefore inconsistent or incomplete information about each site within the region. This method can also be applied to systematically collected settlement pattern data, with the potential to contribute new insights into previously surveyed regions. Network analyses and LCP analyses continue to provide new perspectives into past settlement systems as they become an increasingly important part of landscape archaeologists' tool kit. As site location data becomes increasingly accessible through digital repositories, state archaeology site files, dissertations, theses, and technical reports, archaeologists can use geospatial techniques such as the method presented here to develop novel insights into settlement systems and socioeconomic organization in almost any archaeological context. As we have shown, these methods can reinvigorate legacy data as part of future archaeological research design.

Supplemental Material

For supplemental material accompanying this article, visit https://doi.org/10.1017/aap.2019.37.

Supplemental Material 1: Least-cost path model used in this study.

Supplemental Material 2: Complete list of Early Bronze Age settlement locations and results of network analyses.

Supplemental Material 3: Complete list of Middle Bronze Age settlement locations and results of network analyses.

Supplemental Material 4: Complete list of Late Bronze Age settlement locations and results of network analyses.

Acknowledgments

We would like to thank Lisa Young for guidance in this study. This study has also been significantly improved by insightful comments and suggestions made by Lacey Carpenter, Bree Doering, Christina Sampson, Horia Ciugudean, Sarah Herr, and three anonymous reviewers. We also thank Sofía Pacheco-Fores for help preparing the Spanish abstract.

Data Availability Statement

Data employed in this study are included as supplemental material.

REFERENCES CITED

Altschul, Jeffery H.
2016 The Role of Synthesis in American Archaeology and Cultural Resource Management as Seen through an Arizona Lens. *Journal of Arizona Archaeology* 4:68–81.
Bălan, Gabriel, Colin P. Quinn, and Gregory Hodgins
2016 The Wietenberg Culture: Periodization and Chronology. *Dacia* 60:67–92.
Barrier, Casey R., and Timothy J. Horsley
2014 Shifting Communities: Demographic Profiles of Early Village Population Growth-and-Decline in the Central American Bottom. *American Antiquity* 79:295–313.
Bauer-Clapp, Heidi, and Katie Kirakosian
2017 Archaeologists and Archives: Revisiting an Old Challenge. *Advances in Archaeological Practice* 5:220–226.
Birch, Jennifer
2012 Coalescent Communities: Settlement Aggregation and Social Integration in Iroquoian Ontario. *American Antiquity* 77:646–670.
Birch, Jennifer (editor)
2014 *From Prehistoric Villages to Cities: Settlement Aggregation and Community Transformation*. Routledge, New York.
Blanton, Richard E., Jill Appel, Laura Finsten, Steve A. Kowalewski, Gary M. Feinman, and Eva Fisch
1979 Regional Evolution in the Valley of Oaxaca, Mexico. *Journal of Field Archaeology* 6:369–390.
Blanton, Richard E., Steve A. Kowalewski, Gary M. Feinman, and Jill Appel
1982 *Monte Alban's Hinterland, Part I: The Prehispanic Settlement Patterns of Central and Southern Parts of the Valley of Oaxaca, Mexico*. University of Michigan Museum of Anthropology, Ann Arbor.
Brughmans, Tom
2010 Connecting the Dots: Towards Archaeological Network Analysis. *Oxford Journal of Archaeology* 29:277–303.
2013 Thinking through Networks: A Review of Formal Network Methods in Archaeology. *Journal of Archaeological Method and Theory* 20:623–662.
Casarotto, Anita, Jeremia Pelgrom, and Tesse D. Stek
2016 Testing Settlement Models in the Early Roman Colonial Landscapes of Venusia (291 B.C.), Cosa (273 B.C.) and Aesernia (263 B.C.). *Journal of Field Archaeology* 41:568–586.
2019 A Systematic GIS-based Analysis of Settlement Developments in the Landscape of Venusia in the Hellenistic-Roman Period. *Archaeological and Anthropological Sciences* 11:735–753.
Ciugudean, Horia
2011 Mounds and Mountains: Burial Rituals in Early Bronze Age Transylvania. In *Bronze Age Rites and Rituals in the Carpathian Basin*, edited by Sandor Berecki, Rita E. Németh, and Botond Rezi, pp. 21–57. Mega, Târgu Mureș, Romania.
Ciugudean, Horia, and Colin P. Quinn
2015 The End of the Wietenberg Culture in the Light of New ^{14}C dates and its Chronological Relation Towards the Noua Culture. In *Bronze Age Chronology in the Carpathian Basin*, edited by Rita Németh, Botond Rezi, and Sandor Berecki, pp. 147–178. Bibliotheca Mvsei Marisiensis, Târgu Mureș, Romania.
Cook, Katherine, Canan Çakirlar, Timothy Goddard, Robert Carl DeMuth, and Joshua Wells
2018 Teaching Open Science: Published Data and Digital Literacy in

https://doi.org/10.1017/aap.2019.37 Published online by Cambridge University Press

Archaeological Classrooms. *Advances in Archaeological Practice* 6:141–156.
Drennan, Robert D., Bryan K. Hanks, Adriana Maguiña-Ugarte, and Alexander J. Martín
2019 Comparative Archaeology Database. University of Pittsburgh, Center for Comparative Archaeology. Electronic document, http://www.cadb.pitt.edu/, accessed March 24, 2019.
Duffy, Paul R.
2014 *Complexity and Autonomy in Bronze Age Europe: Assessing Cultural Developments in Eastern Hungary. Prehistoric Research in the Körös Region*, Vol. 1. Archaeolingua, Budapest.
2015 Site Size Hierarchy in Middle-Range Societies. *Journal of Anthropological Archaeology* 37:85–99.
Duffy, Paul R., László Paja, Györgyi M. Parditka, and Julia I. Giblin
2019 Modelling Mortuary Populations at Local and Regional Levels. *Journal of Anthropological Archaeology* 53:240–261.
Duffy, Paul R., Györgyi M. Parditka, Julia I. Giblin, and László Paja
2019 The Problem with Tells: Lessons Learned from Absolute Dating of Bronze Age Mortuary Ceramics in Hungary. *Antiquity* 93:63–79.
Duffy, Paul R., William A. Parkinson, Attila Gyucha, and Richard W. Yerkes
2013 Coming Together, Falling Apart: A Multiscalar Approach to Prehistoric Aggregation and Interaction on the Great Hungarian Plain. In *From Prehistoric Villages to Cities: Settlement Aggregation and Community Transformation*, edited by Jennifer Birch, pp. 44–62. Routledge, New York.
Earle, Timothy K.
2002 *Bronze Age Economics: The Beginnings of Political Economies.* Westview, Cambridge.
Earle, Timothy K., and Kristian Kristiansen (editors)
2010 *Organizing Bronze Age Societies: The Mediterranean, Central Europe, and Scandinavia Compared*. Cambridge University Press, Cambridge.
Earle, Timothy K., Johan Ling, Claes Uhnér, Zofia Stos-Gale, and Lene Melheim
2015 The Political Economy and Metal Trade in Bronze Age Europe: Understanding Regional Variability in Terms of Comparative Advantages and Articulations. *European Journal of Archaeology* 18:633–657.
Ebert, Claire E., Julie A. Hoggarth, and Jamie J. Awe
2016 Integrating Quantitative Lidar Analysis and Settlement Survey in the Belize River Valley. *Advances in Archaeological Practice* 4:284–300.
Flannery, Kent V.
1976 *The Early Mesoamerican Village*. Studies in Archeology. Academic Press, New York.
Galaty, Michael L.
2005 European Regional Studies: A Coming of Ages? *Journal of Archaeological Research* 13:291–336.
Gogâltan, Florin, and Victor Sava
2010 *Sântana-Cetatea Veche: O Fortificație de Pământ a Epocii Bronzului la Mureșul de Jos*. Complexul Muzeul Arad, Arad, Romania.
Goldstein, Lynne
1981 One-Dimensional Archaeology and Multi-Dimensional People: Spatial Organisation and Mortuary Analysis. In *The Archaeology of Death*, edited by Robert Chapman, Ian A. Kinnes, and Klavs Randsborg, pp. 53–69. Cambridge University Press, Cambridge.
Gyucha, Attila
2019 *Coming Together: Comparative Approaches to Population Aggregation and Early Urbanization*. Institute for European and Mediterranean Archaeology Distinguished Monograph Series. State University of New York Press, Albany.
Hill, J. Brett, Matthew A. Peeples, Deborah L. Huntley, and H. Jane Carmack
2015 Spatializing Social Network Analysis in the Late Contact U.S. Southwest. *Advances in Archaeological Practice* 3:63–77.
Howey, Meghan C. L.
2007 Using Multi-Criteria Cost Surface Analysis to Explore Past Regional Landscapes: A Case Study of Ritual Activity and Social Interaction in Michigan, AD 1200–1600. *Journal of Archaeological Science* 34:1830–1846.
2011 Multiple Pathways Across Past Landscapes: Circuit Theory as a Complementary Geospatial Method to Least Cost Path for Modeling Past Movement. *Journal of Archaeological Science* 38:2523–2535.
Kansa, Eric C.
2010 Open Context in Context: Cyberinfrastructure and Distributed Approaches to Publish and Preserve Archaeological Data. *SAA Archaeological Record* 10(5):12–16.
Kansa, Sarah Whitcher, and Eric C. Kansa
2018 Data Beyond the Archive in Digital Archaeology: An Introduction to the Special Section. *Advances in Archaeological Practice* 6:89–92.
Kintigh, Keith W.
2006 The Promise and Challenge of Archaeological Data Integration. *American Antiquity* 71:567–578.
Kintigh, Keith W., Jeffrey H. Altschul, Ann P. Kinzig, W. Fredrick Limp, William K. Michener, Jeremy A. Sabloff, Edward J. Hackett, Timothy A. Kohler, Bertram Ludäscher, and Clifford A. Lynch
2015 Cultural Dynamics, Deep Time, and Data: Planning Cyberinfrastructure Investments for Archaeology. *Advances in Archaeological Practice* 3:1–15.
Kintigh, Keith W., Katherine A. Spielmann, Adam Brin, K. Selçuk Candan, Tiffany C. Clark, and Matthew Peeples
2018 Data Integration in the Service of Synthetic Research. *Advances in Archaeological Practice* 6:30–41.
Knappett, Carl
2011 *An Archaeology of Interaction: Network Perspectives on Material Culture and Society*. Oxford University Press, Oxford.
2012 A Regional Network Approach to Protopalatial Complexity. In *Back to the Beginning: Reassessing Social and Political Complexity on Crete During the Early and Middle Bronze Age*, edited by Ilse Schoep, Peter Tomkins, and Jan Driessen, pp. 384–402. Oxbow, Oxford.
Knappett, Carl (editor)
2013 *Network Analysis in Archaeology: New Approaches to Regional Interaction*. Oxford University Press, Oxford.
Livingood, Patrick
2012 No Crows Made Mounds: Do Cost-Distance Calculations of Travel Time Improve Our Understanding of Southern Appalachian Polity Size? In *Least Cost Analysis of Social Landscapes: Archaeological Case Studies*, edited by Devin A. White and Sarah L. Surface-Evans, pp. 174–187. University of Utah Press, Salt Lake City.
Luca, Sabin A.
2008 *Reperetoriul archeologic al județului Hunedoara*. 2nd ed. Altip, Alba Iulia, Romania.
Martindale, Andrew, Richard Morlan, Matthew Betts, Michael Blake, Konrad Gajewski, Michelle Chaput, Andrew Mason, and Pierre Vermeersch
2016 *Canadian Archaeological Radiocarbon Database* (CARD 2.0). Electronic document, https://www.canadianarchaeology.ca, accessed March 25, 2019.
McManamon, Francis P., Keith W. Kintigh, Leigh Anne Ellison, and Adam Brin
2017 tDAR: A Cultural Heritage Archive for Twenty-First-Century Public Outreach, Research, and Resource Management. *Advances in Archaeological Practice* 5:238–249.
Mills, Barbara J., Matthew A. Peeples, W. Randall Haas, Lewis Borck, Jeffery J. Clark, and John M. Roberts
2015 Multiscalar Perspectives on Social Networks in the Late Prehispanic Southwest. *American Antiquity* 80:3–24.
Nicodemus, Amy J.
2014 Bronze Age Economies of the Carpathian Basin: Trade, Craft Production, and Agro-Pastoral Intensification. PhD dissertation, Department of Anthropology, University of Michigan, Ann Arbor.
Olson, Kyle G., and Lynne M. Rouse
2018 A Beginner's Guide to Mesoscale Survey with Quadrotor-UAV Systems. *Advances in Archaeological Practice* 6:357–371.
O'Shea, John M.
1996 *Villagers of the Maros: Portrait of an Early Bronze Age Society*. Plenum Press, New York.
2011 A River Runs through It: Landscape and the Evolution of Bronze Age Networks in the Carpathian Basin. *Journal of World Prehistory* 24:161–174.
O'Shea, John M., and Amy J. Nicodemus
2019 ". . . The Nearest Run Thing . . ." The Genesis and Collapse of a Bronze Age Polity in the Maros Valley of Southeastern Europe. In *Coming Together: Comparative Approaches to Population Aggregation and Early Urbanization*, edited by Attila Gyucha, pp. 61–80. Institute for European

and Mediterranean Archaeology Distinguished Monograph Series. State University of New York Press, Albany.

O'Shea, John M., Györgyi Parditka, Amy Nicodemus, Kristian Kristiansen, Karl-Göran Sjögren, László Paja, Györgyi Pálfi, and Lidija Milašinović
2019 Social Formation and Collapse in the Tisza-Maros Region: Dating the Maros Group and its Late Bronze Age Successors. *Antiquity* 93:604–623.

Peeples, Matthew, Barbara J. Mills, W. Randall Haas Jr., Jeffery J. Clark, and John M. Roberts Jr.
2016 Analytical Challenges for the Application of Social Network Analysis in Archaeology. In *The Connected Past: Challenges to Network Studies in Archaeology and History*, edited by Tom Brughmans, Anna Collar, and Fiona Coward, pp. 59–84. Oxford University Press, Oxford.

Quinn, Colin P.
2017 The Crucible of Complexity: Community Organization and Social Change in Bronze Age Transylvania (2700–1320 BC). PhD dissertation, Department of Anthropology, University of Michigan, Ann Arbor.
2018 The Potential of Network Approaches to Understand Connectivity and Complexity in Bronze Age Transylvania and Carpathian Basin. In *Bronze Age Connectivity in the Carpathian Basin*, edited by Rita Németh, Botond Rezi, and Sandor Berecki, pp. 9–18. Bibliotheca Mvsei Marisiensis, Târgu Mureș, Romania.

Quinn, Colin P., and Horia Ciugudean
2018 Settlement Placement and Socio-Economic Priorities: Dynamic Landscapes in Bronze Age Transylvania. *Journal of Archaeological Science: Reports* 19:936–948.

Quinn, Colin P., Horia Ciugudean, Gabriel Bălan, and Gregory Hodgins
2019 Rethinking Time, Culture, and Socioeconomic Organisation in Bronze Age Transylvania. *Antiquity*, in press.

Seubers, Jorn
2016 Many Rivers to Cross: Revisiting the Territory of Ancient Crustumerium with a Cost Surface Based Site Catchment Analysis. In *Early States, Territories, and Settlements in Protohistoric Central Italy*, edited by Peter Attema, Jorn Seubers, and Sarah Willemsen, pp. 51–65. Barkhuis Publishing, Kooiweg, Netherlands.

Spencer, Charles S.
1990 On the Tempo and Mode of State Formation: Neoevolutionism Reconsidered. *Journal of Anthropological Archaeology* 9:1–30.

Spencer, Christine, and Andrew Bevan
2018 Settlement Location Models, Archaeological Survey Data and Social Change in Bronze Age Crete. *Journal of Anthropological Archaeology* 52:71–86.

Stos-Gale, Zofia A.
2014 Silver Vessels in the Mycenaean Shaft Graves and their Origin in the Context of the Metal Supply in the Bronze Age Aegean. In *Metalle der Macht: Frühers Gold und Silber. Proceedings of the 6. Mitteldeutcher Archäologentag in Halle (Saale), October 2013*, edited by Harald Meller, Roberto Risch, and Ernst Pernicka, pp. 183–208. Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, Landesmuseum für Vorgeschichte, Halle, Germany.

Szentmiklosi, Alexandru, Bernhard S. Heeb, Julia Heeb, Anthony Harding, Rüdiger Krause, and Helmut Becker
2011 Cornești-Iarcuri—a Bronze Age Town in the Romanian Banat? *Antiquity* 85:819–838.

Tobler, Waldo
1993 *Three Presentations on Geographical Analysis and Modeling: Non-isotropic Modeling Speculations on the Geometry of Geography Global Spatial Analysis*. Technical Report 93-1. National Center for Geographic Information and Analysis. Electronic document, https://escholarship.org/uc/item/05r820mz, accessed September 30, 2019.

Uhnér, Claes, Horia Ciugudean, Gabriel Bălan, Raluca Burlacu-Timofte, Svend Hansen, and Gabriel Rustoiu
2018 Settlement Structure and Demography in Teleac: A Late Bronze Age-Early Iron Age Hillfort in Transylvania. In *Bronze Age Hillforts between Taunus and Carpathian Mountains*, edited by Svend Hansen and Rüdiger Krause, pp. 371–394. Verlag Dr. Rudolf Habelt GmbH, Bonn, Germany.

Ullah, Isaac I. T.
2015 Integrating Older Survey Data into Modern Research Paradigms: Identifying and Correcting Spatial Error in "Legacy Datasets." *Advances in Archaeological Practice* 3:331–350.

Valente, Thomas W., Kathryn Coronges, Cynthia Lakon, and Elizabeth Costenbader
2008 How Correlated Are Network Centrality Measures? *Connect* 28(1):16–26.

Wells, Joshua J. Eric C. Kansa, Sarah W. Kansa, Stephen J. Yerka, David G. Anderson, Thaddeus G. Bissett, Kelsey Noack Myers, and R. Carl DeMuth
2014 Web-Based Discovery and Integration of Archaeological Historic Properties Inventory Data: The Digital Index of North American Archaeology (DINAA). *Literary and Linguistic Computing* 29:349–360.

White, Devin A., and Sarah L. Surface-Evans (editors)
2012 *Least Cost Analysis of Social Landscapes: Archaeological Case Studies*. University of Utah Press, Salt Lake City.

Wilkinson, Tony J.
2000 Regional Approaches to Mesopotamian Archaeology: The Contribution of Archaeological Surveys. *Journal of Archaeological Research* 8:219–267.

Willey, Gordon R.
1953 *Prehistoric Settlement Patterns in the Viru Valley, Peru*. U.S. Government Printing Office, Washington, DC.

Witcher, Robert
2008 (Re)surveying Mediterranean Rural Landscapes: GIS and Legacy Survey Data. *Internet Archaeology* 24. DOI:10.11141/ia.24.2.

Wright, Alice P.
2014 History, Monumentality, and Interaction in the Appalachian Summit Middle Woodland. *American Antiquity* 78:277–294.

Wright, Alice P., and Edward R. Henry (editors)
2013 *Early and Middle Woodland Landscapes of the Southeast*. University Press of Florida, Gainesville.

AUTHOR INFORMATION

Colin P. Quinn ■ Anthropology Department, Hamilton College, 198 College Hill Rd., Clinton, NY 13323, USA (cpquinn@hamilton.edu, corresponding author)

Daniel Fivenson ■ Department of Anthropology, University of Michigan, 1085 S. University Ave, Ann Arbor, MI 48109, USA

https://doi.org/10.1017/aap.2019.37 Published online by Cambridge University Press