eTopoi Journal for Ancient Studies

Special Volume 7 (2020): Political and Economic Interaction on the Edge of Early Empires, ed. by David A. Warburton, pp. 74–86.

DOI: 10.17169/refubium-28211

Helen Dawson

Networks in Archaeology: An Introduction

Edited by Gerd Graßhoff and Michael Meyer,
Excellence Cluster Topoi, Berlin

eTopoi ISSN 2192-2608
http://journal.topoi.org

Helen Dawson

Networks in Archaeology: An Introduction

This paper introduces key concepts of network theory and analysis, and their relevance to archaeological research. The framework is compared to alternative approaches, in particular World-Systems Theory (WST) and its offshoot, World-Systems Analysis (WSA). After reviewing both strengths and weaknesses of a networks perspective through relevant examples, the discussion highlights potential developments for understanding cultural connectivity with particular reference to social complexity.

networks; connectivity; interaction; small-world networks; complexity; instability

Dieser Beitrag stellt zentrale Konzepte der Netzwerktheorie und -analyse vor sowie ihre Bedeutung für archäologische Forschung. Der Rahmen wird verglichen mit alternativen Ansätzen, vor allem der *World-Systems Theory* (WST) und ihrem Ableger, der *World-Systems Analysis* (WSA). Nach der Sichtung von Stärken und Schwächen einer Netzwerk-Perspektive anhand relevanter Beispiele zeigt die Diskussion mögliche Entwicklungen auf, um kulturelle Konnektivität mit besonderer Bezugnahme auf gesellschaftliche Komplexität zu verstehen.

Netzwerke; Konnektivität; Interaktion; Kleine-Welt-Netzwerke; Komplexität; Instabilität

Network studies focus on understanding links and what they can tell us about the individual nodes being connected, whatever they may be. This introduction will spell out the key concepts of a network perspective in archaeology, outlining its main strengths and weaknesses and highlighting where it may lead us.

1 Understanding connectivity

Understanding links between different cultures has been a long-term goal for archaeologists and remains a topic of considerable current interest as modern communities experience the effects of connectivity to the maximum (in terms of globalization and "small-world" networks).[1] The 20th century witnessed some major paradigm shifts in archaeological explanations of culture change: while Childean diffusionism[2] focused on population movement as a prime cause for culture change, Processual Archaeology viewed change as an adaptive response to external stimuli and internal feedbacks.[3] World-

I would like to thank David Warburton for inviting me to take part in the *Economic and Political Interaction on the Edges of the Ancient Empires* conference and for his feedback on the final paper. I am also grateful to the anonymous peer-reviewers and to Francesco Iacono for their precious comments and improvements to the text. This paper was written during my research fellowship at Topoi, which is generously funded by the Gerda Henkel Foundation. The text and bibliography were last updated in September 2018.

1 Watts and Strogatz 1988; Telesford et al. 2011.
2 Childe 1929.
3 Trigger 1989.

Systems Theory (WST)[4] and its offshoot, World-Systems Analysis (WSA),[5] emphasized the importance of understanding cultural flows and mutual "intersocietal interaction".[6]

In the last decade, network studies have emerged as the main arena for explaining inter- and intra-cultural connections.[7] Networks allow archaeologists to "explore the dynamics between relational and geographical space"[8] at the micro-, meso-, macro-, and global scale.[9] In comparison to approaches such as WSA, which take a 'top-down' view, explaining the rise of social complexity by focusing on the long-term and the macro scale (often at the expense of the local scale), network approaches adopt a 'bottom-up' view, building upon different scale dynamics.

2 Key concepts

The basic elements of a network in formal analysis derive from mathematical graph theory:[10] as a first step, 'nodes' (i.e. elements being connected) and 'edges' (i.e. their links) must be defined in order to reconstruct a network; edges may be directed or undirected, resulting in asymmetric or symmetric relations between neighbouring (i.e. connected) nodes. Features of a network include: "density" (the overall level of connection within a network), "distance" (the average distance to reach every node in the network), degree of "centrality" (number of incoming and outgoing ties),[11] and "betweenness" (extent to which a node lies on the shortest path between two other nodes).[12] Once the extent of interaction is defined, it is possible to explore also its causes and effects. In the case of settlement networks, for example, sites can gain importance on the basis on their centrality, defined in terms of the frequency, intensity and directionality of their connections.[13]

Networks fall into three main categories:[14] centralized (nodes cluster around a main 'hub'), decentralized (there are several centres or hubs) and distributed (random distribution of nodes with no clusters). Highly clustered networks with short paths between most pairs of nodes are referred to as "small world"[15] networks (fig. 1). This is a very common feature of social networks (resulting in the "six degrees of separation" phenomenon[16]) and is considered so efficient it can even be observed in human brain functional systems.[17] The 'short-cuts' between the nodes ensure connections across the network are maintained even if other nodes no longer exist, making the network more resilient. Interaction within small world networks can happen very fast; however, such close-knit networks may tend towards conservatism or "cliquishness" as the introduction of new ideas and practices tends to be restricted by their "strong ties". This effect is mitigated by "weak ties" (such as those connecting discrete clusters), which can provide significant openings for the

4 Wallerstein 1974; for a review of World-Systems Theory, see Flammini on World-Systems from the 'Theory' to 'a Perspective': On Social Interconnections in Bronze Age Afro-Eurasia, this volume.
5 Hall, Kardulias, and Chase-Dunn 2011, 238–240.
6 Hall, Kardulias, and Chase-Dunn 2011, 266.
7 See numerous papers in S. Evans and Felder 2014; Knappett 2013.
8 Brughmans 2014, 24.
9 Knappett 2011.
10 See Hanneman and Riddle 2005 and Collar et al. 2015 for useful glossaries and more extensive discussions of these key concepts.
11 The most commonly used measurements are "closeness centrality", "betweenness centrality" and "eigenvector centrality" (as defined by Bonacich 1972 and Freeman 1977; see Brughmans 2010 for a discussion).
12 All of these terms are defined in the glossary by Collar et al. 2015.
13 Rivers, Knappet, and T. Evans 2013.
14 Baran 1964.
15 Watts and Strogatz 1988.
16 Milgram 1967.
17 Smith Bassett and Bullmore 2006.

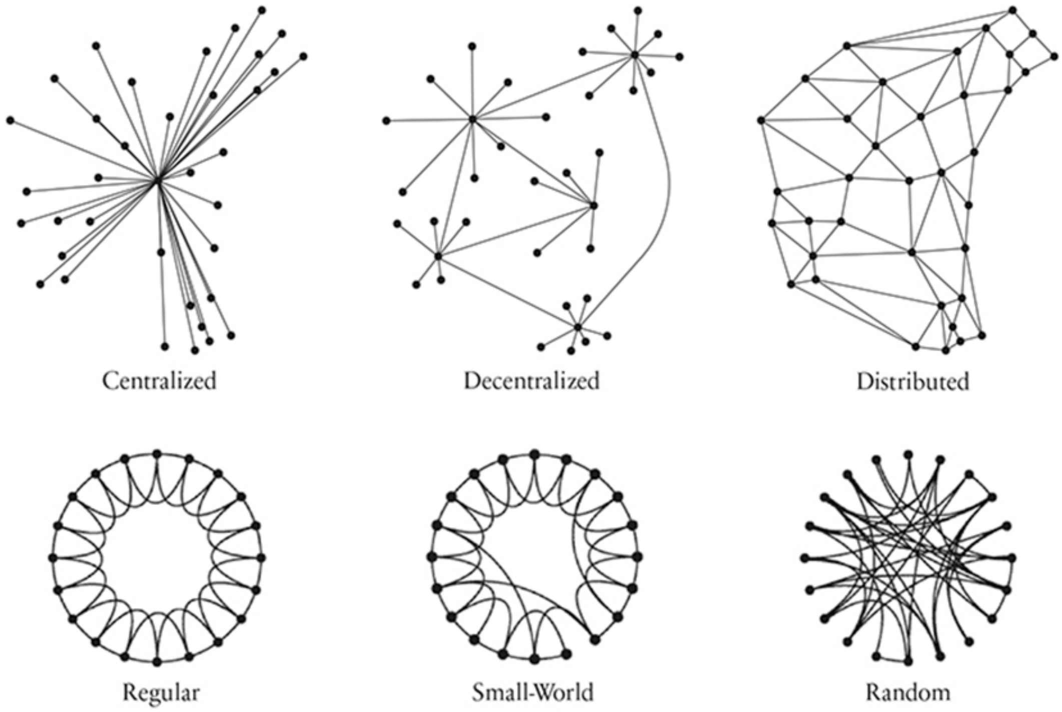

Fig. 1 | Different types of networks (adapted from Baran 1964, 2, fig.1 and Watts and Strogatz 1988, 441, fig.1).

spread of new ideas.[18] Nodes joining discrete clusters function as important 'gateways' for innovation.[19]

A network perspective may at first sight appear to offer a more neutral and more objective approach to understanding the past, free from earlier deterministic biases (e.g. migrationist and environmental). However, networks can be drawn on the basis of almost anything and carry the inherent biases of any research design.[20] Viewing cultures through network graphs highlights potentially significant patterns; however, a theoretical framework is required to interpret the meaning of such patterns and connections, to bring to life what are otherwise static representations of the past.[21] There is also the risk that connections identified in the archaeological record may in fact not have been significant to people in the past.[22] With this in mind, networks still offer a valid tool for advancing our understanding of possible modes of past interaction,[23] as will be argued in the following section (see Tab. 1).

18 Granovetter 1973; Mark Golitko and John Terrell. "Three Simple Geographical Network Models for the Holocene Bismarck Sea". In *Bridging social and geographical space through networks. Proceedings of the international workshop, Topoi Excellence Cluster, 2–3 December 2016*. Ed. by H. Dawson and F. Iacono. Leiden: Sidestone Press, forthcoming.

19 See Dawson and Nikolakopoulou, this volume, for a discussion of island gateways and hubs in interaction networks of the Bronze Age Mediterranean.

20 Leidwanger et al. 2014.

21 See Iacono 2016 for an application of Marxist social theory to Bronze Age networks in the central Mediterranean.

22 Brughmans 2014, 22.

23 Brughmans 2010, 298.

3 Networks in archaeology

Networks can be descriptive and exploratory.[24] Two parallel fields have emerged in recent times: one is a more conceptual school which explores the development and effects of interaction on a more qualitative level;[25] the other is a more analytical school which is developing formal methodologies for studying networks on a quantitative level.[26] The latter draws heavily on Social Network Analysis (SNA) and, to a lesser extent, Complex Network Analysis (CNA).

Irad Malkin is often quoted for his explicit use of networks as a conceptual framework, which he used to explain the emergence of Greek civilization as part of the process of westward expansion and colonization. His study is neither quantitative nor analytical; rather, he uses networks as "a descriptive and heuristic term"[27] and explores the potential implications of a network framework in order to explain the formation of a "small Greek world",[28] where relational distance, i.e. cultural connectivity, is more important than geographical distance.

Tartaron's study of Mycenaean maritime interaction during the Bronze Age provides another useful illustration of this approach. In his study, Tartaron identifies four levels of interaction: 1. "coastscape"; 2. "maritime small world"; 3. "regional/intra-cultural maritime sphere"; and 4. "interregional/inter-cultural maritime sphere". He goes on to explain that interaction in the form of seafaring was mostly short-range and that, as a result, Bronze Age communities were tied into "maritime small worlds".[29]

At the other end of the spectrum, the quantitative approach uses Social Network Analysis (SNA), a field of research in sociology, to extract structures and patterns in social networks. Whereas in sociology the focus is primarily on (living) people, network analysis in archaeology is best equipped to study relations between places and objects.[30] Nonetheless, reconstructing networks allows one to reconstruct different practices and ultimately to gain insight into the communities responsible for those practices.[31]

Using a descriptive/analytical approach, archaeologists can draw links between nodes (usually sites) on the basis of the presence/absence of certain classes of material[32] and/or of their similarity (frequencies of certain classes of material), the latter can be used to determine the strength of the links.[33] This approach can be combined with a geographical model in an exploratory way. Point Proximal Analysis (PPA) was one of the first applications of SNA employed by archaeologists. In PPA, each node is linked to its nearest three neighbours (e.g. geographically nearest and/or sites which share certain archaeological features). Nodes may reflect either hypothetical locations or known sites and those with more connections are considered more central, i.e. 'hubs' (fig. 2). PPA can also adopt a 'fixed radius' model to simulate the creation of networks: in this case, all the nodes that lie within a certain distance are connected (e.g. within the range of travel of a canoe or sailing boat). Classic examples of PPA in archaeology include Irwin's study of Lapita expansion across the Pacific and Broodbank's study of interaction in the Bronze Age Cyclades.[34] In such ways, SNA can be used compare social and geographical space, and to test

24 Brughmans 2010; Brughmans 2014; Knappett 2013.
25 E.g. Malkin, Constantakopoulou, and Panagopoulou 2009; Malkin 2011.
26 E.g. Brughmans 2014; Knappett 2013.
27 Malkin 2011, 16.
28 From the title of Malkin 2011.
29 Cf. Tartaron 2013, 188–198; Tartaron 2018, 61–67.
30 Brughmans 2014, 22.
31 See applications in Collar 2013; Collar 2014.
32 Also known as "co-presence" (Brughmans 2010, 287); for an application, see for example Blake 2014.
33 Golitko et al. 2012, 510; for an application, see for example Freund 2018.
34 Irwin 1992; Broodbank 2000; for more recent applications, see Rivers, Knappet, and T. Evans 2013 and Knodell 2017.

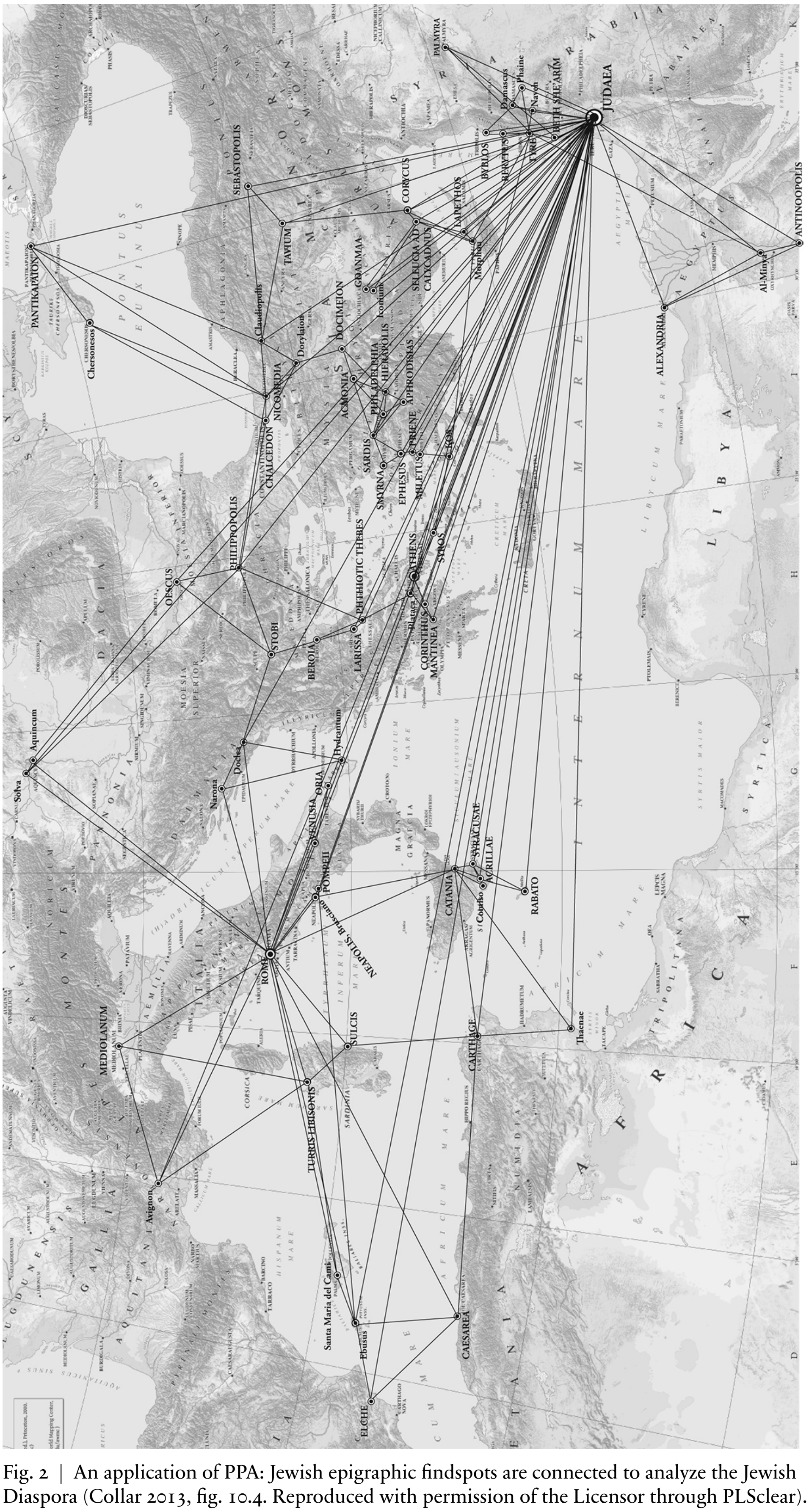

Fig. 2 | An application of PPA: Jewish epigraphic findspots are connected to analyze the Jewish Diaspora (Collar 2013, fig. 10.4. Reproduced with permission of the Licensor through PLSclear).

different hypotheses, such as those relating to centrality and marginality, continuity and innovation; and clarify processes of cultural, social, technological, political, and economic interaction in the past.[35]

Complex Network Analysis (CNA) uses algorithms to explore interaction by factoring in additional parameters. Knappett et al. have pioneered this approach in archaeology through a cost-benefit analysis of trade-based interaction in the Bronze Age Aegean (fig. 3).[36] Such an approach can help explain, for example, why certain nodes attract more links, such as sites emerging at seemingly marginal locations.[37] They also used CNA to explore the immediate and long-term effects of the catastrophic Thera eruption on the Minoan trading network in the mid-2nd millennium BC, their models indicating that while it was not initially detrimental to the system it led to its inevitable collapse in the long run.[38]

A number of software packages, which simplify the application of complex algorithms to archaeological data, are available on an open access basis and are free to download from the internet. This factor has in itself contributed considerably to the wide appeal of network analysis. The software is used to build and visualize the networks on the basis of a matrix (the data arranged by the archaeologist according to different parameters, such as presence/absence of a particular type of pottery) and to determine different features of the network (described above).

4 Ways ahead in Network Archaeology

The last two decades saw GIS becoming a mainstream tool in archaeological inquiry; this was in no small part thanks to technical progress in PCs which could handle and process growing bodies of data. Similarly, the last decade has seen a shift in focus from spatial to social analysis, again in part stemming from contemporary developments, especially the rise of social media.[39]

Networks can be spatial and/or relational, i.e. they can represent physical and/or social space.[40] They can be used to formalize theoretical discussions of connectivity, relations, and "entanglements"[41] between people, places, animals, and objects. Excessive polarization between the more theoretical and quantitative approach is likely to prove counterproductive; rather, archaeologists can ultimately benefit from a dialogue.[42] Archaeology as a discipline is ideally positioned to further the progress of network studies, through the effective integration of spatial and social approaches, which have traditionally developed along separate tracks.[43]

In considering potential applications of network studies to the theme of this special issue of e-Topoi, I think it will be interesting to explore their potential not only with regards to the emergence of societal complexity and the rise of empires, but also their concomitant instability, resulting in societal collapse.[44] Viewing instability in a network

35 See Collar et al. 2015 for different applications.
36 Knappett, T. Evans, and Rivers 2008.
37 Broodbank 2000, see also Dawson and Nikolakopoulou, this volume.
38 Knappett 2011.
39 Brughmans 2014, 35.
40 Brughmans 2014; Knappett 2013.
41 See Hodder 2012 for "Actor-Network Theory", a network perspective in which objects also have agency.
42 See Fulminante 2014.
43 Helen Dawson. "At the heart of Mare Nostrum. Islands and small world networks in the central Mediterranean Bronze Age". In *Bridging social and geographical space through networks. Proceedings of the international workshop, Topoi Excellence Cluster, 2–3 December 2016*. Ed. by H. Dawson and F. Iacono. Leiden: Sidestone Press, forthcoming.
44 For example Mills et al. 2013; Golitko et al. 2012.

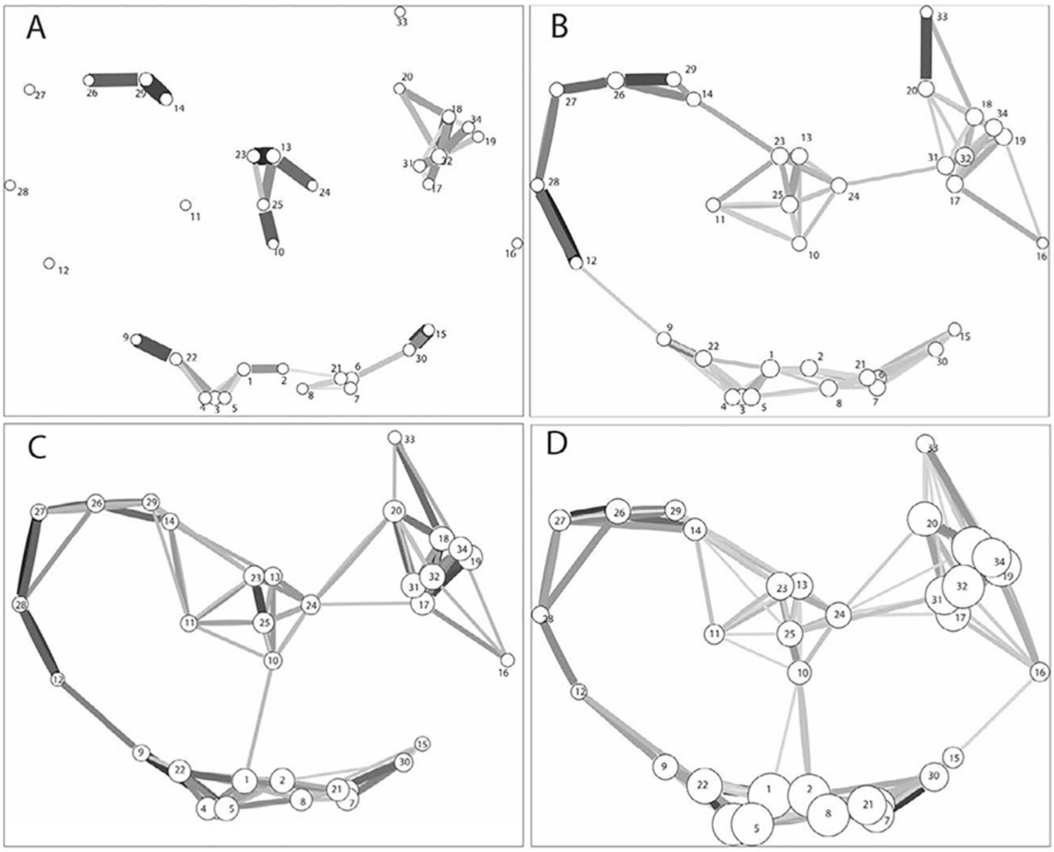

Fig. 3 | Complex Network Analysis of Bronze Age trade between the Aegean islands. The shape of the network changes as the benefits of trade increase from A to D (reproduced with permission by the publishers and authors).

Strengths	**Weaknesses**
Draws on many different fields (sociology, anthropology, geography, physics, mathematics)	Network analysis may appear objective but it is not immune from theoretical and methodological bias
Explores the dynamics between relational and geographical space	Networks can appear 'static' if data resolution is low[i]
Can help us think about different forms of interaction	The networks we analyze are not necessarily identical to the past networks we are trying to understand (different networks can lead to similar end results: equifinality)
Software packages facilitate multiple scales of analysis and comparison	Complex Network Analysis still requires understanding of complex algorithms; models must be accurately selected

[i] Brughmans 2010, 283.

Tab. 1 | Key strengths and weaknesses of a network perspective.

context can highlight a whole range of factors (environmental, climatic, demographic, social, cultural), which may have contributed to a society's vulnerability, providing answers that are ultimately more convincing than traditional, mono-causal, explanations of collapse.

References

Baran 1964
Paul Baran. “On Distributed Communication Networks”. *IEEE Transactions on Communications Systems* 12 (1964), 1–9.

Blake 2014
Emma Blake. *Social Networks and Regional Identity in Bronze Age Italy*. Cambridge and New York: Cambridge University Press, 2014.

Bonacich 1972
Phillip Bonacich. “Technique for Analyzing Overlapping Memberships”. *Sociological Methodology* 4 (1972), 176–185.

Broodbank 2000
Cyprian Broodbank. *An Island Archaeology of the Early Cyclades*. Cambridge: Cambridge University Press, 2000.

Brughmans 2010
Tom Brughmans. “Connecting the Dots. Towards Archaeological Network Analysis”. *Oxford Journal of Archaeology* 29 (2010), 277–303.

Brughmans 2014
Tom Brughmans. “The Roots and Shoots of Archaeological Network Analysis”. *Archaeological Review from Cambridge* 29 (2014), 18–41.

Childe 1929
Vere Gordon Childe. *The Danube in Prehistory*. Oxford and New York: Clarendon Press and Oxford University Press, 1929.

Collar 2013
Anna Collar. “Re-Thinking Jewish Ethnicity Through Social Network Analysis”. In *Network Analysis in Archaeology. New Approaches to Regional Interaction*. Ed. by C. Knappett. Oxford: Oxford University Press, 2013, 223–246.

Collar 2014
Anna Collar. “Networks and Ethnogenesis”. In *A Companion to Ethnicity in the Ancient Mediterranean*. Ed. by J. McInerney. Chichester: Wiley-Blackwell, 2014, 97–111.

Collar et al. 2015
Anna Collar, Fiona Coward, Tom Brughmans, and Barbara J. Mills. “Networks in Archaeology: Phenomena, Abstraction, Representation”. *Journal of Archaeological Method and Theory* 22 (2015), 1–32.

S. Evans and Felder 2014
Sarah Evans and Kathrin Felder. “Social Network Perspectives in Archaeology”. *Archaeological Review from Cambridge* 29 (2014).

Freeman 1977
Linton C. Freeman. “A Set of Measures of Centrality Based on Betweenness”. *Sociometry* 40 (1977), 35–41.

Freund 2018
Kyle P. Freund. “A Long-Term Perspective on the Exploitation of Lipari Obsidian in Central Mediterranean Prehistory”. *Quaternary International* 468 (2018), 109–120.

Fulminante 2014
Francesca Fulminante. “The Network Approach: Tool or Paradigm?” *Archaeological Review from Cambridge* 29 (2014), 167–178.

Golitko et al. 2012
Mark Golitko, James Meierhoff, Gary M. Feinman, and Patrick R. Williams. “Complexities of Collapse: the Evidence of Maya Obsidian as Revealed by Social Network Graphical Analysis”. *Antiquity* 86 (2012), 507–523.

Granovetter 1973
Mark S. Granovetter. “The Strength of Weak Ties”. *American Journal of Sociology* 78 (1973), 1360–1380.

Hall, Kardulias, and Chase-Dunn 2011
Thomas D. Hall, P. Nick Kardulias, and Christopher Chase-Dunn. “World-Systems Analysis and Archaeology: Continuing the Dialogue”. *Journal of Archaeologica lResearch* 19 (2011), 233–279.

Hanneman and Riddle 2005
Robert A. Hanneman and Mark Riddle. *Introduction to Social Network Methods*. Riverside: University of California, 2005.

Hodder 2012
Ian Hodder. *Entangled: An Archaeology of the Relationships Between Humans and Things*. Chichester: Wiley-Blackwell, 2012.

Iacono 2016
Francesco Iacono. “From Networks to Society: Pottery Style and Hegemony in Bronze Age Southern Italy”. *Cambridge Archaeological Journal* 26 (2016), 121–140.

Irwin 1992
Jeoff Irwin. *The Prehistoric Exploration and Colonisation of the Pacific*. Cambridge: Cambridge University Press, 1992.

Knappett 2011
Carl Knappett. *An Archaeology of Interaction: Network Perspectives on Material Culture and Society*. Oxford: Oxford University Press, 2011.

Knappett 2013
Carl Knappett, ed. *Network Analysis in Archaeology. New Approaches to Regional Interaction*. Oxford: Oxford University Press, 2013.

Knappett, T. Evans, and Rivers 2008
Carl Knappett, Tim Evans, and Ray Rivers. “Modelling Maritime Interaction in the Aegean Bronze Age”. *Antiquity* 82 (2008), 1009–1024. DOI: https://doi.org/10.1017/S0003598X0009774X.

Knodell 2017
Alex R. Knodell. “A Conduit Between Two Worlds: Geography and Connectivity in the Euboean Gulf”. In *An Island Between Two Worlds. The Archaeology of Euboea from Prehistoric to Byzantin Times*. Ed. by Ž. Tankosić, F. Mavridis, and M. Kosma. Papers and Monographs from the Norwegian Institute at Athens Volume 6. Athens: Norwegian Institute at Athens, 2017, 195–213.

Leidwanger et al. 2014
Justin Leidwanger, Carl Knappett, Pascal Arnaud, Paul Arthur, Emma Blake, Cyprian Broodbank, Tom Brughmans, Tim Evans, Shawn Graham, Elizabeth S. Greene, Barbara Kowalzig, Barbara Mills, Ray Rivers, Thomas F. Tartaron, and Van de Noort Robert. "A Manifesto for the Study of Ancient Mediterranean Maritime Networks". *Antiquity (Project Gallery)* 342 (2014).

Malkin 2011
Irad Malkin. *A Small Greek World: Networks in the Ancient Mediterranean*. Oxford: Oxford University Press, 2011.

Malkin, Constantakopoulou, and Panagopoulou 2009
Irad Malkin, Christy Constantakopoulou, and Katerina Panagopoulou, eds. *Greek and Roman Networks in the Mediterranean*. London: Routledge, 2009.

Milgram 1967
Stanley Milgram. "The Small World Problem". *Psychology Today* 2 (1967), 60–67.

Mills et al. 2013
Barbara J. Mills, Jeffery J. Clark, Matthew A. Peeples, Randal W. Haas, John M. Roberts, J. Brett Hill, Deborah L. Huntley, Lewis Borck, Ronald L. Breiger, Aaron Clauset, and M. Steven Shackley. "Transformation of Social Networks in the Late Pre-Hispanic US Southwest". *PNAS* 110 (2013), 5785–5790.

Rivers, Knappet, and T. Evans 2013
Ray Rivers, Carl Knappet, and Tim Evans. "Network Models and Archaeological Spaces". In *Computational Approaches to Archaeological Spaces*. Ed. by A. Bevan and M. Lake. Publications of the Institute of Archaeology, University College London. Walnut Creek, CA: Left Coast Press, 2013, 99–126.

Smith Bassett and Bullmore 2006
Danielle Smith Bassett and Ed Bullmore. "Small-World Brain Networks". *The Neuroscientist* 12(6) (2006), 512–523.

Tartaron 2013
Thomas F. Tartaron. *Maritime Networks in the Mycenaean World*. Cambridge: Cambridge University Press, 2013.

Tartaron 2018
Thomas F. Tartaron. "Geography Matters: Defining Maritime Small Worlds of the Aegean Bronze Age". In *Maritime Networks in the Ancient Mediterranean World*. Ed. by J. Leidwanger and C. Knappett. Cambridge: Cambridge University Press, 2018, 61–92. DOI: 10.1017/9781108555685.005.

Telesford et al. 2011
Qawi K. Telesford, Karen E. Joyce, Satoru Hayasaka, Jonathan H. Burdette, and Paul J. Laurienti. "The Ubiquity of Small-World Networks". *Brain Connect* 1.5 (2011), 367–375.

Trigger 1989
Bruce Trigger. *A History of Archaeological Thought*. New York: Cambridge University Press, 1989.

Wallerstein 1974
Immanuel Wallerstein. *The Modern World-System. Capitalist Agriculture and the Origins of the European World-Economy in the Sixteenth Century*. New York, San Francisco and London: Academic Press, 1974.

Watts and Strogatz 1988
Duncan J. Watts and Steven H. Strogatz. "Collective Dynamics of 'Small-World' Networks". *Nature* 393 (1988), 440–442.

Illustration and table credits

FIGURES: **1** Adapted from Baran 1964, 2, fig.1 and Watts and Strogatz 1988, 441, fig.1. **2** Collar 2013, fig. 10.4. Reproduced with permission of the Licensor through PLSclear. This figure is excluded from the Creative Commons license, or any other onward reuse. **3** Knappett, T. Evans, and Rivers 2008, 1016, fig. 4. Courtesy of the Author and Antiquity, DOI: https://doi.org/10.1017/S0003598X0009774X. TABLES: **1** H. Dawson.

Helen Dawson
Helen Dawson, PhD (London 2005), is an affiliate research fellow at the Institute of Prehistoric Archaeology, Freie Universität Berlin. The focus of her research is on comparative island archaeology.

Dr. Helen Dawson

E-Mail: h.dawson@fu-berlin.de