Assembling Çatalhöyük

Edited by Ian Hodder and Arkadiusz Marciniak

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Cover image(s): *Left*: Ochre hand prints on the north wall of Building 77; *Middle*: Bucrania and horned bench associated with the northeast platform of Building 77 (both taken from Taylor pp. 127–50, this volume); *Right*: The incised panel above burial 327 in TP Area (taken from Marciniak et al., pp. 151–66, this volume).

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CHAPTER 3

Networking the Teams and Texts of Archaeological Research at Çatalhöyük

ALLISON MICKEL AND ELIJAH MEEKS

INTRODUCTION

Assembling the diverse bodies of data collected over the twenty years of excavation at Çatalhöyük has required an equivalent assemblage of researchers representing wide-ranging disciplinary traditions. The team has in turn produced a large and varied body of documentation. Team members are linked to each other by participating in the research teams together, as well as by co-authoring excavation records and reports, and the network produced by these linkages enables the flow of data and the production of multidisciplinary knowledge about the past.

In 2013, the authors sought to map out the paths by which data flow through the collection of researchers and records at Çatalhöyük. To do so, we created a social network displaying Çatalhöyük research participants, archive reports, and teams as nodes, broken out by year. Authorship of an archive report connects individuals to documents, and membership in a team links people to teams. We analysed the structure of this social network, in order to investigate how groups form within the group of researchers at Çatalhöyük and to suggest how data and interpretations move through the project. We also applied topic modelling to the corpus of archive reports, as well as diaries, to identify the presence and movement of ideas and languages through the network of humans and texts that enable the production of knowledge at Çatalhöyük.

Through this analytical approach, we have been able to discover some individual researchers, teams, and reports especially productive at connecting different kinds of experts in the research process. We have been able to create a typology of collaboration, and to develop some measures by which to see which groups are most dominant and most consistently well-represented through the years of the project. Our analysis, furthermore, has emphasized the dynamic nature of the research network at Çatalhöyük through time, recognizing that it is constantly shifting and that these constant changes have an evident impact on how archaeologists draw conclusions from the data gathered.

The methods applied here add to a number of studies on the social interactions, politics, and production of knowledge of the Çatalhöyük Research Project (see Hodder, 1998; Shankland, 1999; Bartu, 2000; Hamilton, 2000; Tringham & Stevanović, 2000; Zak, 2004; Rountree, 2007), but offer a new insight into the linkages between research participants, and into how information flows through this assemblage. We describe its advantages below, as well as its limitations for understanding the full range of relationships underpinning the collection, circulation, and interpretation of data and the creation of facts from the archaeological record.

SOCIAL DYNAMICS AND NETWORKS IN ARCHAEOLOGICAL FIELDWORK

Unraveling the social complexity of archaeological projects is hardly a new pursuit. In 1955, Louis Dupree published a short, one-page commentary on his ideas about how archaeological projects create short-lived, insular 'cultures' among the labourers they hire (Dupree, 1955). More recently, intensive studies centred on the interactions that characterize archaeological research have emerged as their own discrete field of research. For example, Gero's (1996) assessment of the role of gender in fieldwork and the treatment of archaeological evidence represents a critical, early such study, based on participant observation of excavation at Arroyo Seco in Argentina. Several edited volumes have been published, compiling ethnographies of archaeological practice (e.g. Edgeworth, 2006; Castañeda & Matthews, 2008; Silliman, 2008; Mortensen & Hollowell, 2009). Edgeworth's (2006) volume, in particular, includes a number of studies with a goal similar to the one our network analysis was designed to achieve. Both Goodwin (2006) and Yarrow (2006) examine how objects and archaeologists work together to produce knowledge about the past; Edgeworth's own (2003) dissertation accomplishes a similar end, relating specific dialogues and practices that transform unseen, underground, unknown things into artefacts which convey information about the past.

Many of the ethnographic approaches focused on understanding the operation of archaeology, among other studies (e.g. McDavid, 2002; Moser et al., 2002; Gallivan et al., 2011; Atalay, 2012), often evaluate the degree of collaboration that has successfully occurred between archaeologists and non-archaeologists. In our network analysis of the team at Çatalhöyük, we do not take into account local residents or members of the public, but a chief priority of our analysis is to systematically identify the evidence for collaboration within the research project members. After all, collaboration has long been a priority of the research project at Çatalhöyük (Hodder, 2000). Many researchers on the team have conducted related ethnographies of the work at the site and the individuals engaged in it. Hodder (1998), Bartu (2000), Rountree (2007), Shankland (1999) as well as Tringham & Stevanovic (2000) have written on the multiple versions of Çatalhöyük that different groups construct, based on their varying perspectives and priorities. Balter's (2005) popular site biography can be considered alongside these academic publications, discussing in even further detail the particular histories, interests, and personalities of the people working at Çatalhöyük for the first half of the project. Other projects align even more closely with that of the authors, including Zak's (2005) report on observed collaboration between excavators and conservators, and Hamilton's (2000) ethnography of the project describing the 'fault line' dividing excavators from laboratory specialists.

The methodology and results presented here add to these previous assessments of the social dynamics on the Çatalhöyük Research Project by taking into account the impacts of the interactions not only between people, but also between people and documents. Within the field of science studies, Latour's influential ideas about how the networks of people and inscription devices in laboratories produce scientific knowledge (see Latour & Woolgar, 1979; Latour, 1987, 1999) pioneered the now-widespread recognition of the importance of examining equally the roles of humans and non-humans in the creation of scientific facts. Archaeologists (e.g. Lucas, 2001; Van Reybrouck & Jacobs, 2006; Martin, 2013) have engaged in similar analyses, casting objects, and people as equal agents in the production of archaeological knowledge. *Archaeology: The Discipline of Things* (Olsen et al., 2012) represents perhaps the most extensive mapping of people and tools mutually engaged in archaeological fieldwork, including even the networks created through digital recording technologies.

It is to this body of work on the social dynamics of archaeological research at Çatalhöyük and elsewhere, collaboration, and networks of scientists and documentation that our analysis contributes. We provide a novel technique, combining social network analysis (SNA) with topic modelling in order to provide a new, diachronic view of the web of actors implicated in archaeological research at Çatalhöyük. The result of this approach can be evaluated both qualitatively and statistically to understand the flow and influence of ideas on the project.

Methodology

In order to build the network, we made use of several bodies of data. To assemble the networks linking people to the teams they were members of in each year, we relied on the team lists given in the newsletters published online each year (http://www.catalhoyuk.com/newsletters/). Stanford undergraduate Margaret Tomaszczuk also manually created a list of the authors of each contribution to the archive report, per year, which would connect individuals to documents. These two edge lists were combined, and fed into the open source software Gephi, designed for network visualization and analysis. This allowed us to view and manipulate a map of the social network based on research team participation and co-authorship. Then, Allison Mickel and Ian Hodder together examined the interactive network and crafted a narrative interpreting the network, year-by-year, suggesting how and why groups were forming and how documents seemed to be created. Elijah Meeks created an online platform presenting this narrative alongside a visualization of the network it explains, accessible at http://catalhoyuk.stanford.edu/network/teams/ (see also Figure 1). Nodes are presented as larger or smaller depending on the relative centrality of the node. Visitors can filter out only the years of interest, as well as include only the node types they wish to see (e.g. people, documents, or teams). The timeline function of the network, wherein users can watch the network form over time and zone in on particular periods, is an especially innovative contribution to longitudinal network studies. The network is also searchable, so that one can easily locate a particular individual within the expansive and complex graph.

In order to examine the flow of knowledge through this network, we required a means of identifying, or marking, 'knowledges'. To do this, we looked at two corpora of documents that team members have produced. We wanted to focus both on formalized publications and more informal, less polished records, and to take into account as wide a range of perspectives as possible. For these reasons, we decided to analyse the archive reports generated at the end of each research season, along with the diaries produced during the course of excavation, meant to preserve the ongoing thought processes and larger context surrounding the production of other documentation at

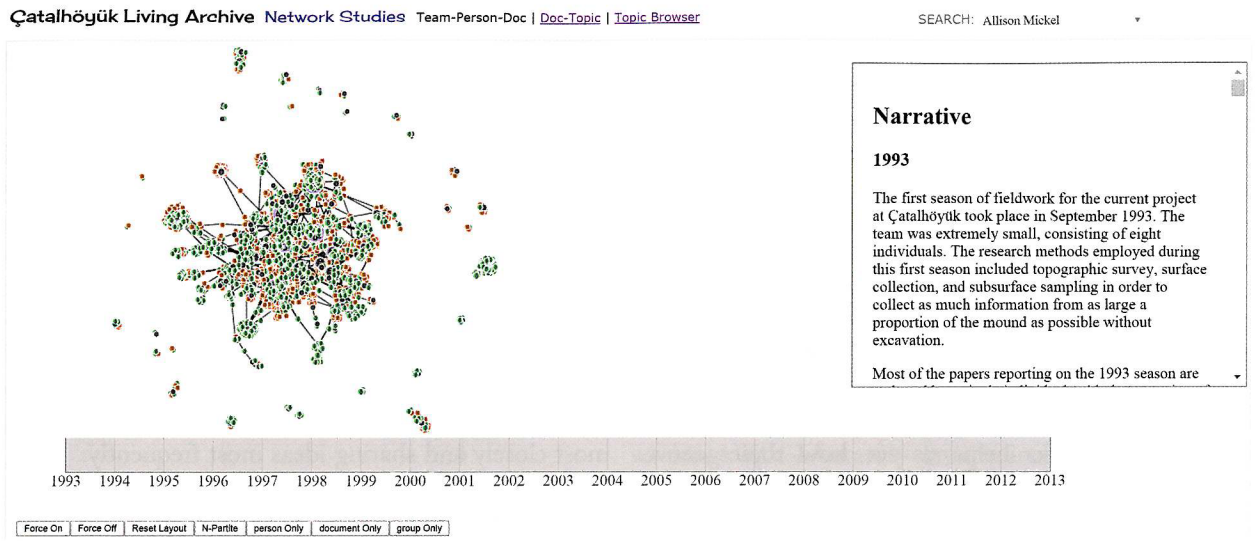

Figure 1. *Social Network of the Çatalhöyük Team, 1993–2013.*

Çatalhöyük. In order to prepare these records for comparable analysis, Stanford undergraduates Margaret Tomaszczuk and Soo Ji Lee manually segmented all twenty years of archive reports into three-paragraph-long text files—approximately the same length as the average diary entry. Meeks then fed these text files into MALLET, a platform for topic modelling, which yielded one hundred groupings of words found commonly in close association, called a 'topic' (see Figure 2; also available at http://catalhoyuk.stanford.edu/network/doc-topic/). Words which appear larger in a given grouping appear most frequently in the text. This method also showed the proportion of the documentation across the years in which a given topic was represented, allowing us to view when a particular topic became especially popular or particularly obscure.

Finally, we created a network mapping out shared language across the full range of documents included in the topic modelling. We theorized that if 10 per cent or more of a document could be characterized as a particular topic, we could say that it 'discussed' that

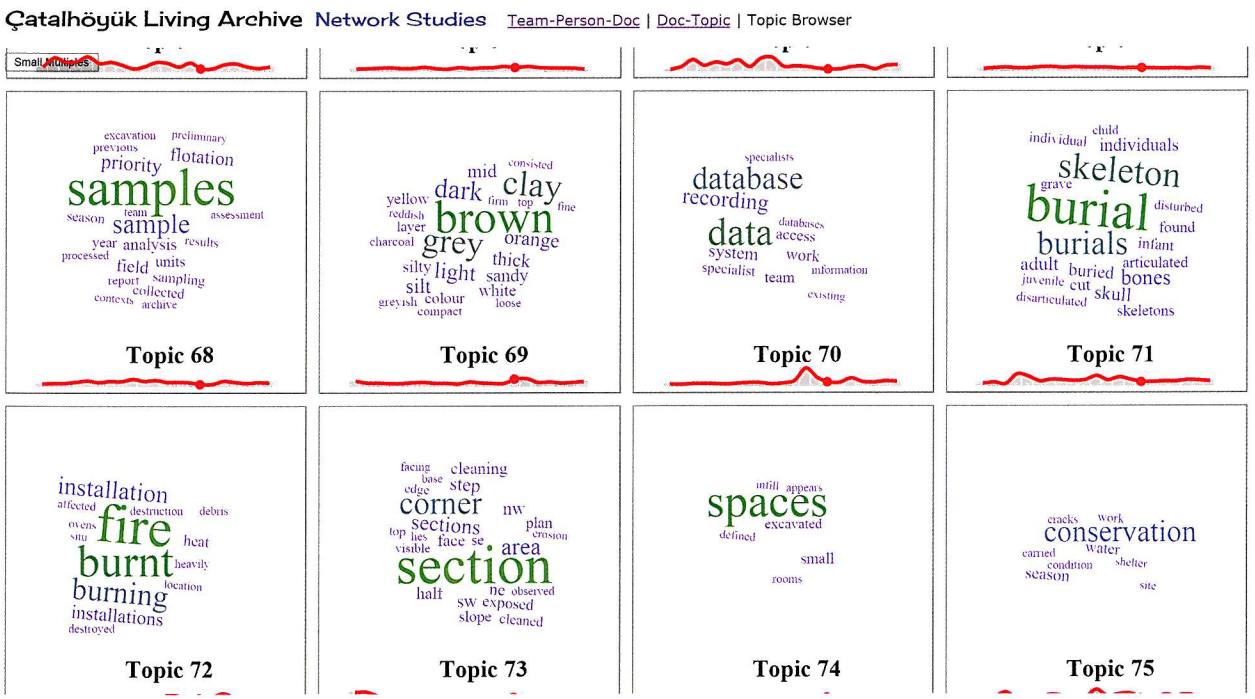

Figure 2. *Sample of topics modelled.*

topic. We then produced a network which links documents to the topics they discuss. Users can interact with this network at http://catalhoyuk.stanford.edu/network/topics/ (see also Figure 3). Diaries are marked in pink, archive reports in green, and topics in blue. Once again, the network is searchable for particular documents, and it can be filtered to show only topics which are discussed in the same documents, or documents which discuss the same topics. This network helps us to understand when, and in what records, some general concepts are being considered; when viewed alongside the first network, we can understand by whom. The unique temporal aspect of these two networks helps us see how topics move through the team over time, whether ideas cross between research groups, which ideas persist over time, and which team members are most critical in enabling the flow of knowledge through the project.

Insights from the Social Network

For the first three years of the renewed investigations at Çatalhöyük (1993–1995), the network appears extremely disconnected, as well as small (e.g. Figure 4). The team itself, was of course small (it grew to only twelve members in 1995), and intensive excavation had not yet begun. Accordingly, the list of project participants had not been broken down into subgroups, nor were there many examples of co-authorship in the archive reports. In this early stage of the project, individual researchers took responsibility for particular areas of research, from investigation to publication. The network accurately reflects the way that labour and expertise were spread over the site in these years.

In 1996 (Figure 5), the team grew by close to 1000 per cent, with over one hundred people suddenly working on site. Full-scale excavations began this season in three separate areas, along with several related research projects. This is the first year that teams within the overall project emerged and were formally labelled. Project participants are linked to each other in ways they have not been previously; for the first time, we can visualize who might be interacting most closely and sharing ideas most frequently.

In other ways, however, the 1996 network lacks opportunities for the flow of knowledge; in the terminology of SNA, it is not very cohesive at all. The excavation team shares no connections at all with any lab specialties, and each laboratory group is entirely disconnected from all others. Furthermore, there are many project members on the site who do not participate in the production of the archive report at the end of the season, a process which could involve a significant degree of discussion and collaboration if multiple people were involved. Instead, most teams have one or two individuals who author the report on behalf of the team—an authorship structure we have termed 'hierarchical'. Although the appearance of this structure, of course, does not preclude the possibility that the author has discussed the report contents with the team members before or even during the writing process, we can only hypothesize that this may have occurred unless someone is listed as a co-author,

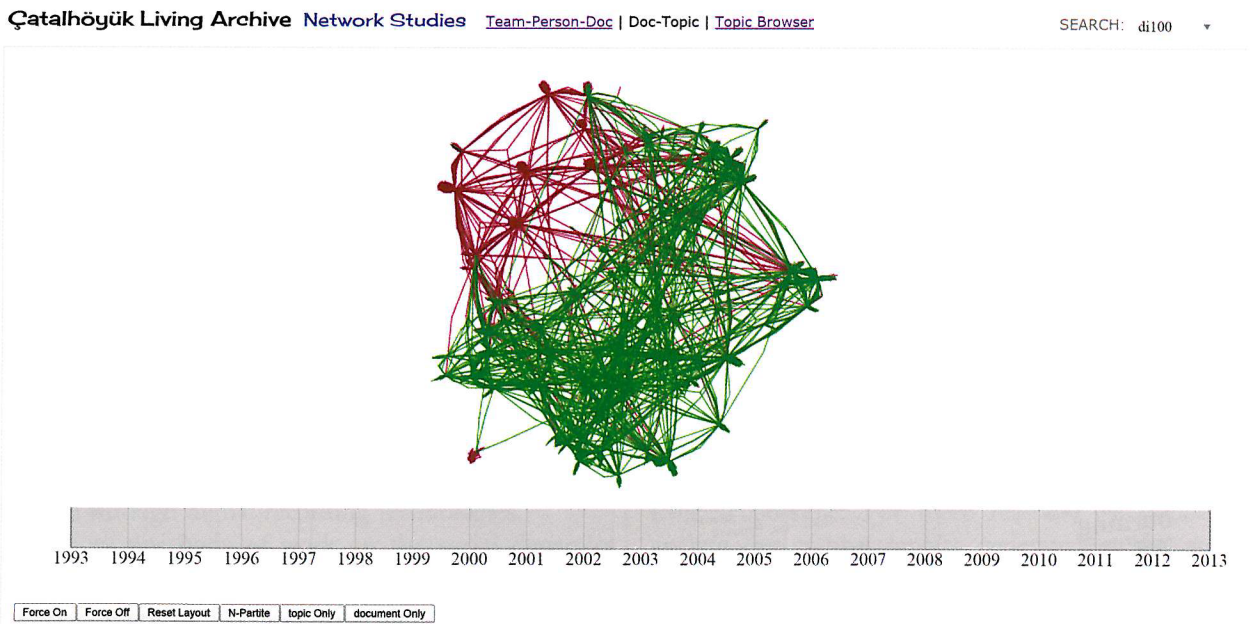

Figure 3. *Document and Topic Network.*

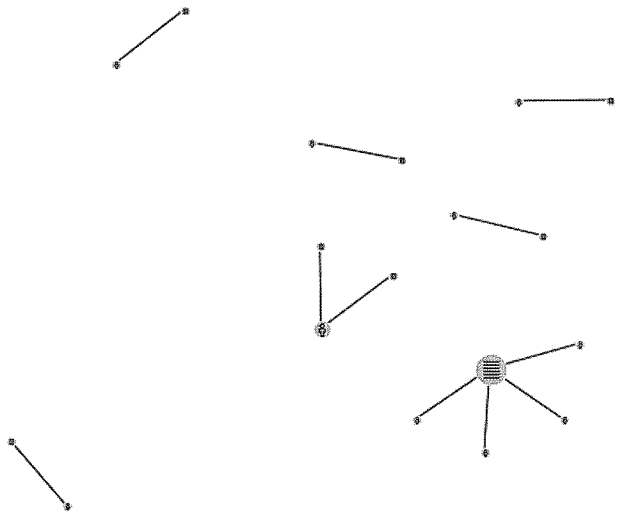

Figure 4. *Network in 1994, illustrating the small size of the team and a disconnected social structure.*

which certifies such co-operation. All members of the 1996 faunal team, for example, were named as authors on the 'Animal Bone Report'. We have called this authorship structure 'collaborative', and the faunal team's report is the only example in 1996.

Over the following two years (1997–1998; Figure 6), the network becomes significantly more cohesive, reflecting the conscious efforts of a new team arriving to the project. The Berkeley Archaeologists at Çatalhöyük (BACH) team actively encouraged integration across excavation teams and laboratory research groups. They therefore had team members who were not only excavating in the BACH area, but also working with laboratory groups including the faunal team, the finds lab, and the archaeobotanical team. This ethic of integration seems to have had a wider impact on the project too, as excavators from other teams were also participating in laboratory research.

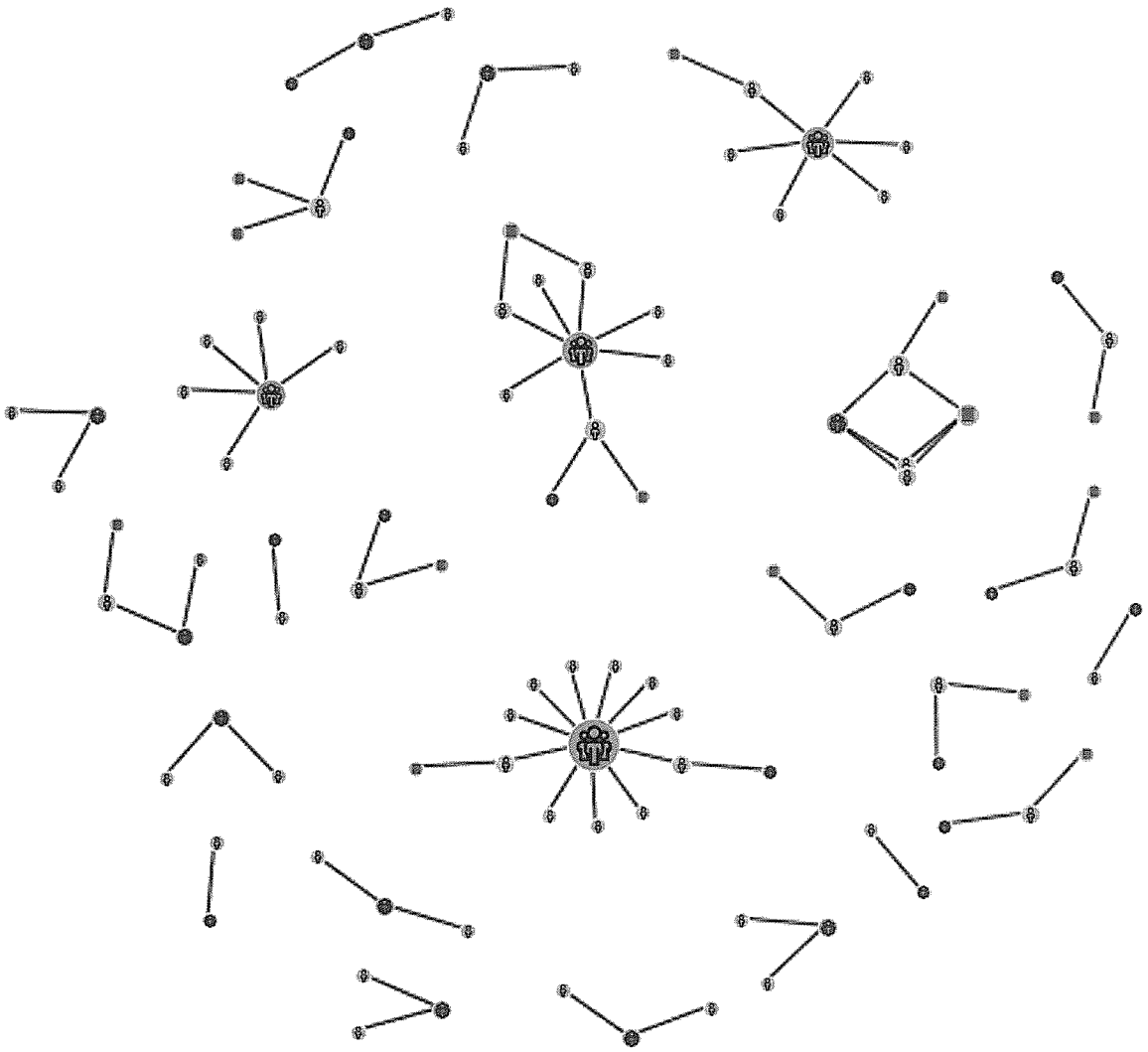

Figure 5. *Network in 1996, illustrating the growth of the project team but few opportunities for information flow.*

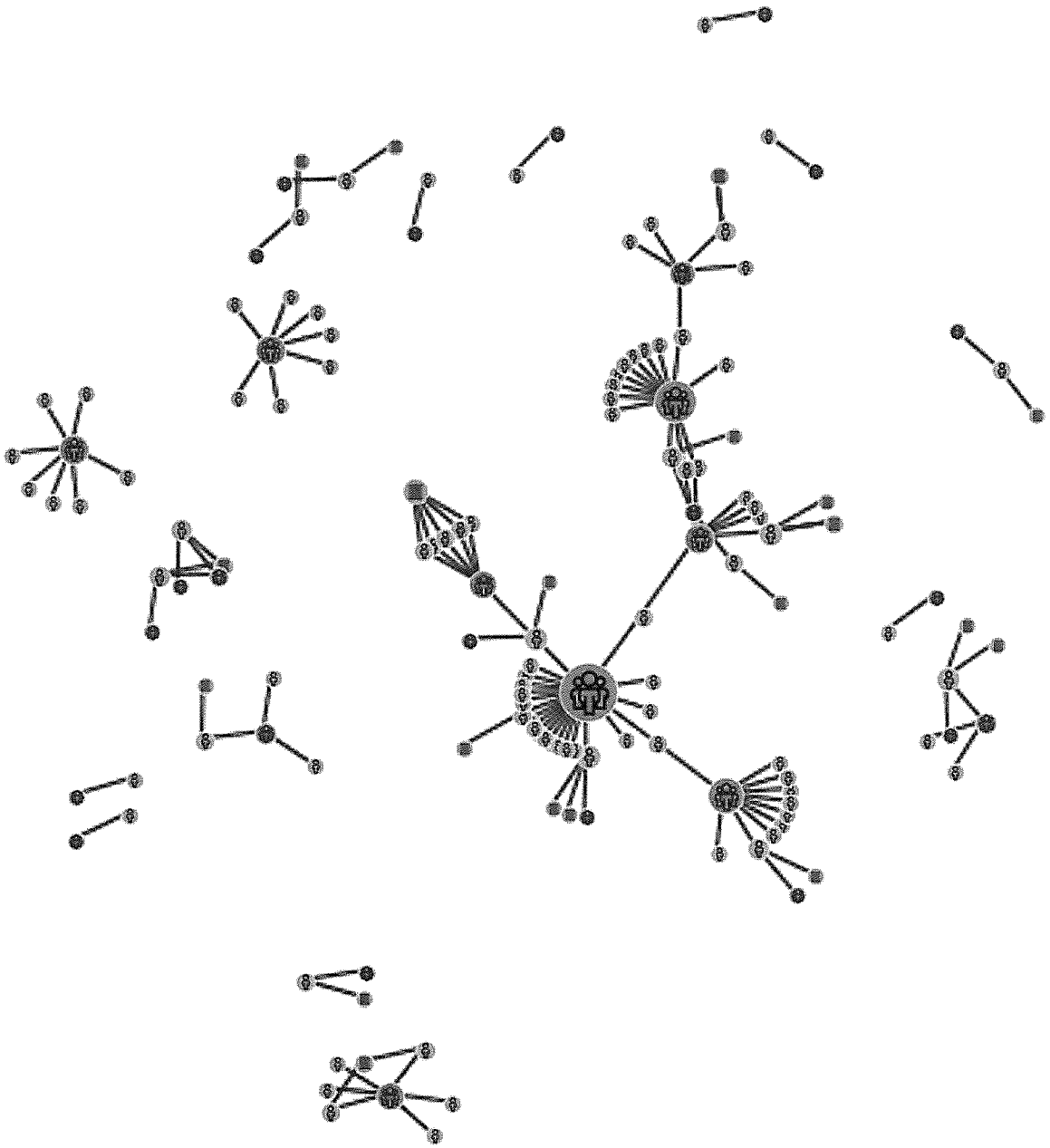

Figure 6. *Network in 1998, illustrating the increased integration of the team.*

Both the University of Thessaloniki and UK excavation groups had members participating in the faunal laboratory, and UK excavators were also working with the human remains, ceramics, groundstone, and survey subgroups. These individuals, engaging not only with two material types but also with all of the people working on those material types, represent crucial nexuses in the network where information generated in one area may pass to and influence another.

The network changes rather drastically in 1999, as did the programme of research (Figure 7). The British excavators worked onsite for six months, and appeared at the centre of the most populated structure in the total network. Members of this team are also members of the human remains, video documentation, survey, and paleoenvironment research groups. The BACH team, which dug for only a few weeks, is split off in the network, though is still connected to one laboratory—the faunal team. The network we have modelled therefore makes sense in terms of measuring the potential for information flow; surely those working on site for six months would have many opportunities to share data and theories, while those present for much less would have many fewer.

The project appears even more disconnected in 2000–2001, which were study seasons for the core UK team (Figure 8). Other excavation groups (e.g. BACH and the West Mound) share links with laboratory

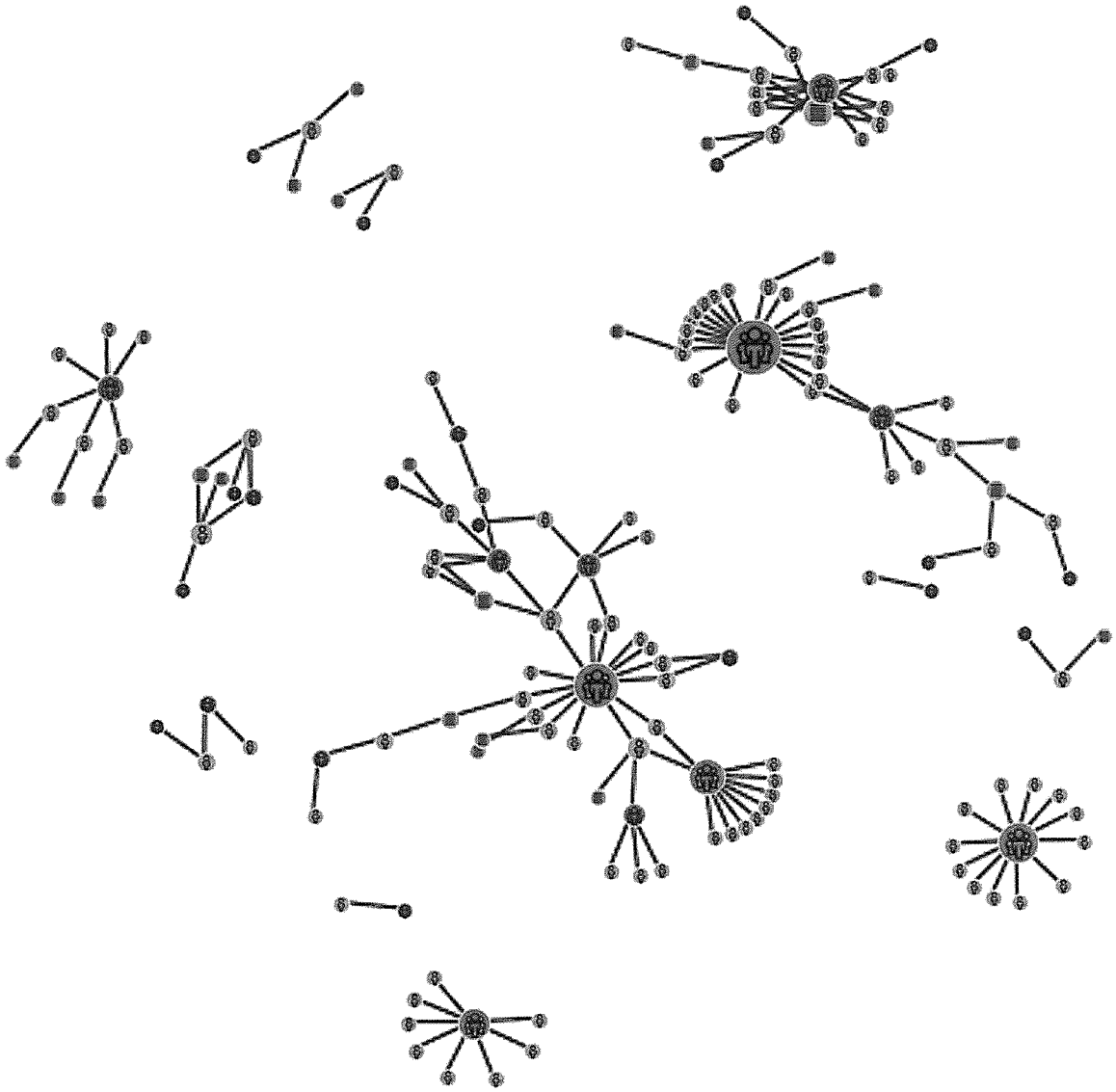

Figure 7. *Network in 1999, illustrating the effects of the six-month field season.*

research teams, but the groups participating in the interpretation and write-up process are isolated, reflecting a research process in which each laboratory was responsible for presenting its interpretations of a particular material to all others. Although in some ways, this procedure can be seen as promoting information flow, it is equally segregating, with each laboratory head responsible for representing exclusively 'their' body of data.

With intensive, site-wide excavations beginning again in 2002, the network is more cohesive than ever (Figure 9). All of the major excavation groups and laboratory teams are somehow connected to one another, perhaps because the BACH team's influence had reached its apex, or because the dig house had been expanded to accommodate many more project members—or simply because of strong friendships forged over the nine years of the project's existence. Still, however, the predominating mode of authorship is hierarchical, with a minority of individuals responsible for reporting on the work of the larger group.

Suddenly in 2003, the network breaks apart (Figure 10) and remains extremely fragmented until 2007. One might relate this to the teams being more physically spread out over the site (in 2003, the team returns to surface scraping in order to open up a larger area for digging), as well as the departure of the BACH team from the project. Instead of intentional placement of individuals in teams, however, some different forms of collaboration begin to emerge. Over time, an increasing number of excavators write their own archive reports, focused on only their portion of the excavation, an authorship structure we call 'dendritic', Also, in 2003, we see for the first time two examples of what we call 'cross-team collaboration', in which members of different research groups work

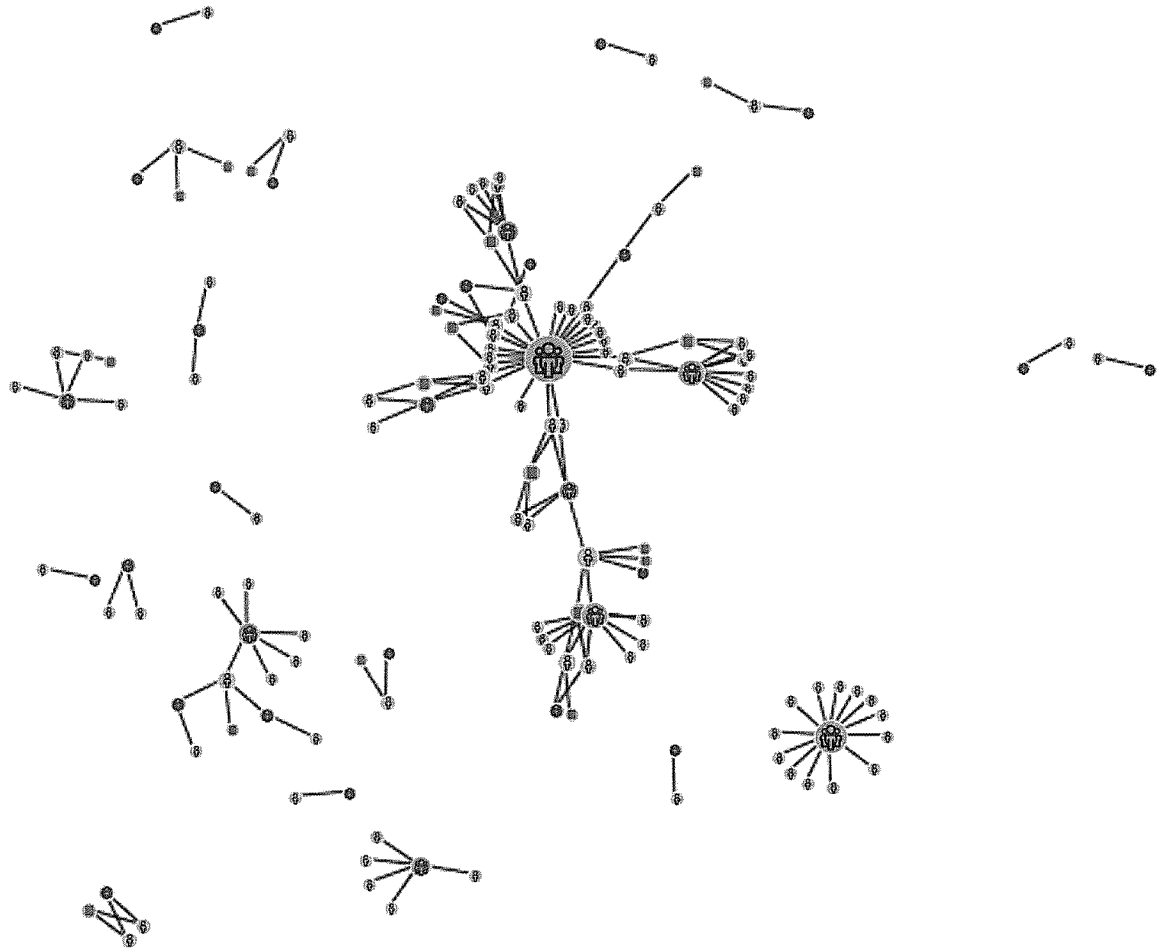

Figure 8. *Network in 2000, illustrating the disaggregation associated with this and other study seasons.*

together to produce a single archive report at the end of the season. In fact, as certain teams grow in number and membership remains consistent from year to year, these groups begin to inspire independent research projects that rely on bringing together data from multiple specialisms. There are several examples of this practice in 2007 and 2008.

In the study season spanning from 2009 to 2011, the network disintegrates again (Figure 11). As in 2000–2001, the research methodology is highly individualistic, with each team concentrating on representing its own results to date. The networks during the second study season unsurprisingly resemble those from the first. Then when excavations begin anew in 2012, teams again share members just as they did in 2002, and documents have multiple authors, mostly within but also across teams, representing once more the potential for data and interpretations to move through the project. The network remains essentially intact in 2013, the final year for which we have modelled the teams and co-authors.

Overall, several trends may be observed in the network over time. We can see that authorship is nearly exclusively hierarchical in the early years of the project, and that over time cross-team collaboration becomes increasingly common between research groups while dendritic authorship eventually predominates among excavators. As the project develops over time, then, two very different models of co-operative authorship take hold and largely replace the previous unitary practices.

Furthermore, the network generally disaggregates during study seasons and linkages proliferate when excavation begins anew. It is not clear, however, that intensity of excavation correlates perfectly with cohesiveness of the network; for example, the network is extremely fragmented in the six-month excavation season (1999) as well as during the excavations from 2003 to 2008. We must also consider other factors impacting the formation of linkages in the network. It appears that some of the years in which the network is most densely interconnected are also years in which the dig house accommodations were expanded, laboratories were built, and when the area of excavation was most concentrated. Developments such as these allowed project members to both live and work more closely together. The network therefore seems to reflect, to some degree, physical interactions occurring

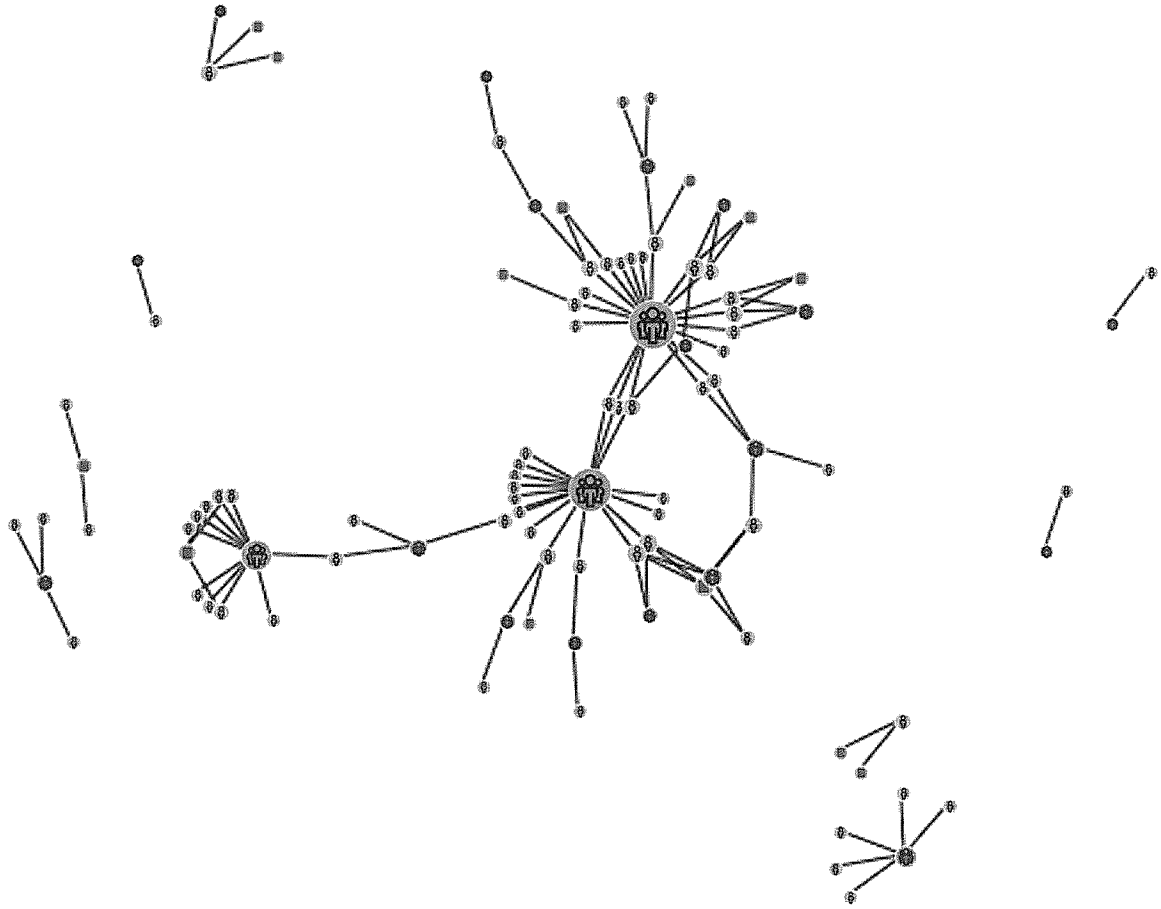

Figure 9. *Network in 2002, illustrating renewed cohesion in the team's social structure.*

onsite which would offer increased opportunities for the flow of information between research participants.

The network visualization described here maps out and hints at opportunities for shared participation in knowledge production at Çatalhöyük. It suggests which individuals and which teams might be the most influential in distributing information throughout the project. As mentioned above, however, this approach is not the only one that has attempted to examine the processes of interaction and teamwork on the site. In what follows, we will compare this analysis with previous studies based primarily on participant observation. Then, by putting together the social network with the topic network, we will describe the drawbacks of this methodology as well as its advantages in accurately representing the formation of facts about the past.

Comparison to Previous Analyses of the Social Structure at Çatalhöyük

The narrative we have constructed based on the social network of the team articulates and complements previous approaches to describe the social dynamics of the Çatalhöyük project. Although our network does not include many of the interlocutors whose participation has been most well-examined—for example, the local villagers and the Goddess community (Hodder, 1998; Shankland, 1999; Bartu, 2000; Rountree, 2007), it does serve to increase a reflexive understanding of how the team has formed and operated, and adds to previous studies in many ways. For one, we add a time dimension beyond previous reflexive analyses. Studies by Tringham & Stevanovic (2000) and Hamilton (2000) take into account the project to 1999, Balter's (2005) site biography narrates up to 2004, and Zak's (2005) participant observation only occurred during 2004 and 2005. Our network illustrates the linkages from 1993 to 2013.

The network analysis we have applied additionally extends the focus beyond one or two research groups (as in Tringham and Stevanovic's chapter, and Zak's report as well) or even beyond the range of characters constructed in Balter's book. He focuses intensively on particular researchers, humanizing the archaeological research process, and bringing to life the culture of the dig at Çatalhöyük. Our priority is instead to look at how the team as a whole arranges itself, and what

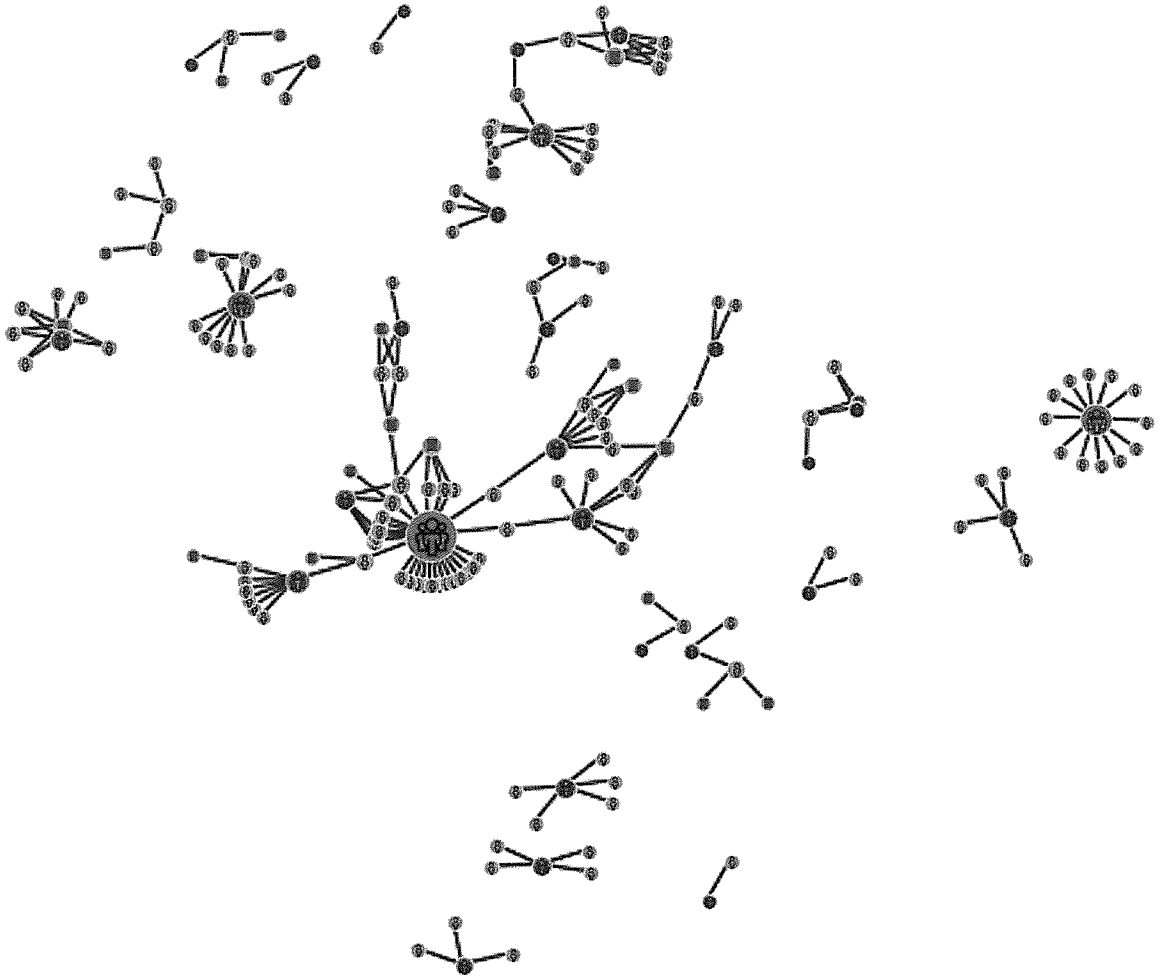

Figure 10. *Network in 2003, illustrating the network breaking apart and new forms of collaboration emerging.*

possibilities are opened or closed by these arrangements. We do not, moreover, take into account the content of conversations on site, methodologies employed, or peoples' physical interactions (though, as noted above, the network does seem to capture the latter in an indirect way). Instead, for this type of information, one should refer to Zak (2005) and Hamilton (2000) who have both used participant observation to collect this type of data.

Not only have we broadened the scale of analysis offered by these prior projects, however, we have been able to demonstrate some rather different processes than what has been described in the past. For example, Tringham & Stevanovic (2000) focus on the differences between their methodologies and those of the British excavation team. Indeed, our model illustrates that in 1999 and 2000, the British excavation group is completely disconnected from the BACH team. But in 1997 and 1998, the two teams are linked to each other, since they are both engaging in the same practice of sharing excavators with laboratories. We might argue, then, that there is a shift towards greater divergence over these four years—and the methodological differences could be either the cause *or* the result.

We can also add to Hamilton's (2000) description of the 'fault lines' between excavators and laboratory researchers at Çatalhöyük. In 1996, there is clear, visual evidence for such a divide. But by 2002, it is no longer present. One might attribute this to the active efforts of the BACH team to encourage integration through the team, but perhaps more significantly, this is two years after Hamilton's study is published. This gives enough time for the team to react and for the project leaders to make the necessary interventions to alleviate the tensions Hamilton describes. Our network maps out the reactions to particular developments in certain years, including studies conducted on the social structure itself.

Similarly, Zak's (2005) study of collaboration centres on two groups—excavators and conservationists—who are almost never connected in this network. The conservation group, in general, is entirely isolated, except for three years—2002, when one individual (Brigid Gallagher—discussed below) both digs and works in the conservation lab, and 2004–2005. Jackie

Zak is herself someone who forms a bridge between the conservation group (she was, after all, a *participant* observer) and other groups. It is a truism in ethnography that one's very presence in a particular situation alters it, but we are able to identify exactly how—to show which specific teams are more likely to communicate and collaborate with the conservation team (and others) based upon Zak's membership in the team.

Studying the social linkages in the team, then, provides perspectives on the social dynamics of archaeological research that add to the pictures derived through other techniques. It does not, however, offer an entirely complete picture, and it is important to be aware of its deficiencies before delving further into what this analysis suggests about knowledge production at Çatalhöyük and other archaeological sites.

Addressing Shortcomings in the Network of the Çatalhöyük Research Project

The aspect of this analysis which deserves perhaps the closest critical scrutiny is the nature of the data itself. We have tried to be clear that the visualization we have created does not provide a perfect approximation of who is actually speaking to each other the most on the site. It does not take into account who is living in the same rooms, sitting near each other at meals, or, importantly, socializing after hours. Eddisford & Morgan (2011) have pointed to the importance of recreational spaces at Çatalhöyük for inspiring creative collaborations, but we do not have the data to suggest who spends time together after working hours. It is conceivable that mapping out the Facebook friendships or Twitter followers within the site—or the twice-weekly lists tallying the number of beers each team member has enjoyed—would provide a better perspective on informal relationships which are equally important for the transmission of information through the project. Our network, instead, focuses on more formal relationships. Shared membership in a team as well as co-authorship of reports certainly entails undeniable communication and teamwork. But mapping only these sorts of relationships does leave us with some results worth investigating further.

One concern is the number of isolates present in the network—nodes disconnected from any other nodes. We have several instances of individuals who are a one-person team, or a sole author, or both—as well as groups that never link to any other groups (conservation, as stated earlier, is disconnected from the rest of the social structure in 18/21 years). It is easy to recognize that this phenomenon stems directly from the data we are employing. But how are we to interpret it? In some cases, the isolates are individual, small-scale research projects, and it is possible to imagine that they had little influence on the rest of the team members and the overall record produced during that year at the site. The Geophysical Survey group (present in 2010 and 2012) represents one potential example of this. Although the results of these subsurface surveys are undeniably important, this team came for one week in 2010, and for ten days in 2012. The same is true for the groups associated with the public presentation of the site. They appear relatively disconnected from the wider social structure—but these groups tend to come for short time periods, often late in the season when many others have left, and to work together on specific projects without depending on ongoing input from other research team members. The isolation in these two cases, then, seems to accurately reflect intensity of interaction.

Site workers, as well, are disconnected completely across all years of the research project—despite the project's wide-ranging attempts to engage local community members and research participants in all dimensions of the project (Bartu, 2000; Hodder, 2000, 2006; Atalay, 2012). Ethnoarchaeology and ethnography have been conducted in the local villages (Shankland, 1999; Matthews et al., 2000), signifying ways in which residents of the area could contribute to ongoing research and direct quotes from local villagers from group discussions at the site were published within synthetic chapters in the sixth Çatalhöyük volume (Hodder, 2006). These ways that local community members have been included in the publication of the site have been, in many ways, quite peripheral, featuring as minor elements buried in larger articles by archaeologists. Furthermore, although longtime site guard Dural (2007) has even published his memoirs, presenting his own perspective on the site, Hodder expresses ambivalence within the book about his own role in making the book legible to potential readers. In the field, the problem of language barriers, the physical (rather than intellectual) nature of the jobs site workers are hired to complete, the frequent changes to workers' positions on site, and the fact that workers do not contribute directly to either the informal documentary record or the archive reports have all contributed to the workers' isolation. It is indeed unlikely that the site workers' ideas have historically had a great deal of impact on the published archaeological consensus about Çatalhöyük.

The most surprisingly and consistently dissociated individual in the network, however, is Ian Hodder. As the project director, should not Hodder have the *greatest* influence on the flow of knowledge through the project? In the language of SNA, however, Hodder as a node in this network is neither prominent nor central—the two key measures by which we might calculate a particular node's importance to the

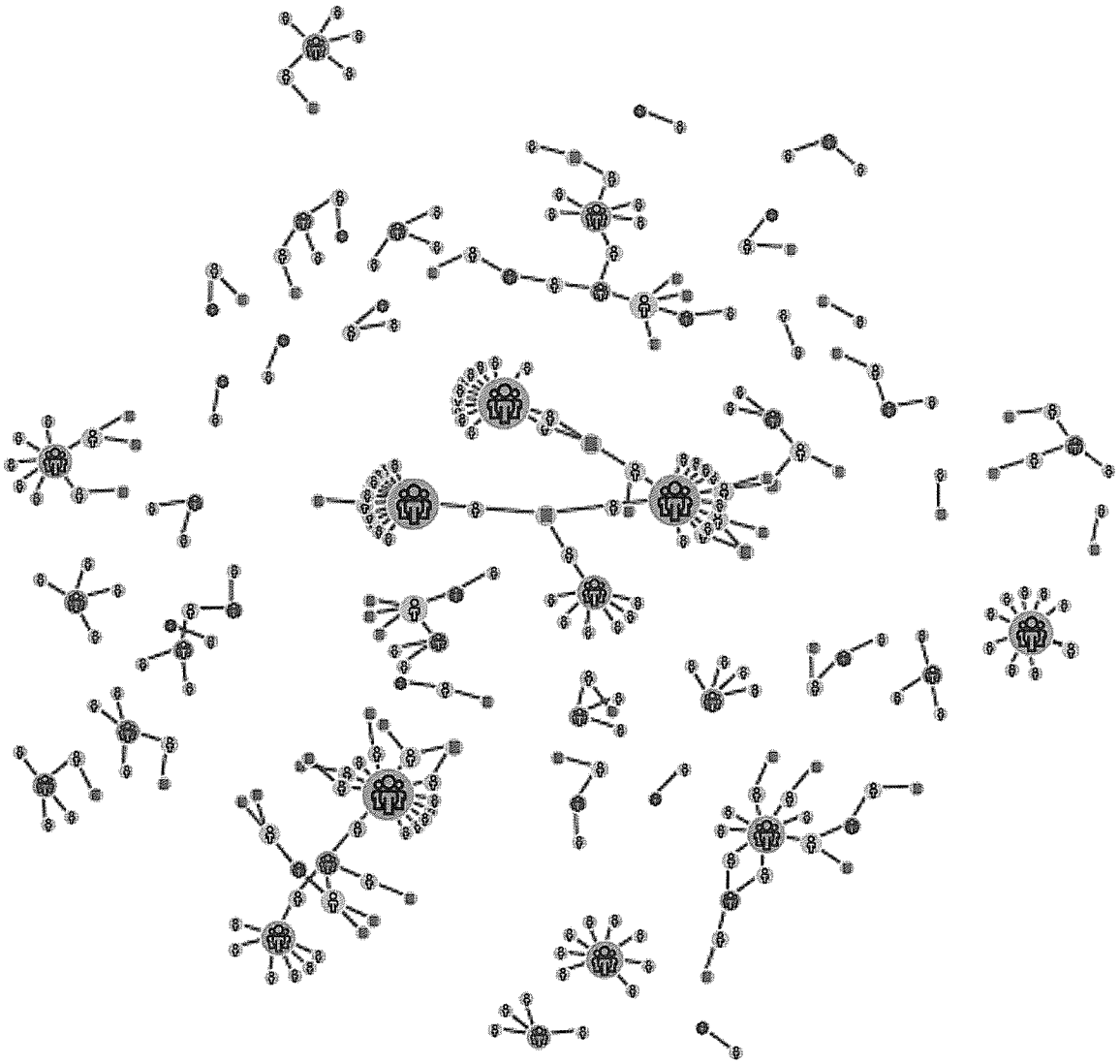

Figure 11. *Network in 2009, illustrating the disintegration of the network during a study season.*

flow of resources through a given network. His only links to the rest of the project team are through co-authoring the introduction to the 1993 archive report with Roger Matthews, and co-authoring one additional report with Shahina Farid in 2007. Although both of these figures are themselves well-connected, Hodder remains liminal with regard to the rest of the social complex.

In some ways, however, this is not completely inaccurate. Hodder may actually not be the most responsible for transferring knowledge through the network, especially when compared to area supervisors and laboratory heads. Certainly, he has an enormous amount of control over who actually comes to the site, and must himself keep apprised of ongoing research. Hodder's position as project director means that he is exceptionally well-positioned to know instantly about new findings and results, and to influence what team members are writing or how they are interpreting the site. And our network is not very good at modelling this. In terms of formal team hierarchy, SNA—especially given the data we have used here—often falls flat, so to speak. We do not have a good way of representing, in our model, differences in degrees of power and authority at the site.

At the same time, however, it is important to recognize that this type of power is not equivalent to being a crucial figure for enabling the flow of knowledge. This latter notion, which can be approached using different network measures and which we explored using what is known as 'betweenness centrality', suggests one's ability to act as a broker—to promote or thwart the movement of resources through the system. Area supervisors, lab heads, and those who practise cross-team collaborative authorship—these researchers are not only engaging with their own data, but necessarily consulting with others in order to understand their own particular material evidence and

potentially conveying this information to those whom they supervise. They form a bridge between those who are digging, washing, and analysing the deposits and artefacts and those who operate at the administrative and synthetic level, the project leadership. Hodder is at one pole of this bridge; likewise, he is on the periphery of the network. Interestingly, similar analysis has been applied to terrorist organizations, with similar results. Krebs (2002) has made the influential argument that in the prevention of terrorism, it is not the regime leaders who are most crucial for homeland security to suppress. Instead, it is the people with unique skills and the highest degree of betweenness who are most crucial for co-ordinating terrorist activities (the 9/11 hijackers, for example, had high betweenness quotients within the al-Qaeda network). Though of course the content is dramatically different, our network possesses the same ability to demonstrate that information moves through the Çatalhöyük project in a rather different way than one might predict by looking only at the project hierarchy. Knowledge flows; it does not simply 'trickle down' from the top.

The foregoing discussion serves to underscore the importance of knowing precisely what the network and the data are able to show. Our network does not draw out the informal friendships which might initiate collaboration, nor does it illustrate the hierarchies underpinning individuals' presence and positions on the project. Instead, it points to areas where productive and serious research collaborations may occur, based solely on individuals' memberships in project subgroups and their co-operation in producing technical reports. Once one acknowledges what such a network cannot describe with regard to epistemology at Çatalhöyük, it is possibly to reflect on the significant level of potential insight that can be gained on the topic by employing such a network analysis.

Applying Social Network Analysis to Knowledge Production in Archaeology

Network analysis contributes a novel perspective to understanding how the team at Çatalhöyük functions. It has been used extensively in other fields to examine how groups form, and has been especially effective in elucidating commonalities and nearly universal rules across social systems because of the statistical capabilities inherent in this approach (Wasserman & Faust, 1994; Barabasi, 2002; Otte & Rousseau, 2002; Friemel, 2008; Borgatti et al., 2009). For instance, SNA has led to the recognition that all kinds of networks possess *connectors,* or nodes with an anomalously high degree of centrality (a large number of links) (Barabasi, 2002). These nodes, over time, increase the number of linkages they have at a much higher rate relative to other nodes in the network. For instance, in the Çatalhöyük network, we have calculated that the average degree of a node is approximately thirty-five; that is to say that the average project participant, over the course of their membership on the team, will either share membership in a subgroup or co-author with a total of thirty-five individuals. But there are individuals like Serdar Cengiz, who has connected with 137 individuals over the course of six years—or Aslı Kutsal, who has connected with 155 people over only five years. Both of these researchers worked as excavators on many different excavation teams, which tend to comprise many more members than the average lab group or particular research project. Therefore, when Kutsal joined the project in 1998 and immediately worked as a member of a nineteen-person team (the British excavation team), using SNA we can easily identify him as a connector—someone who will continue to link to many more nodes in the network relative to others. In contrast, Daniela Cottica represents an 'average' project participant in terms of degree centrality. She connects to exactly thirty-five individuals through shared membership on various teams over her three years on the project, and when she joins the project in 1998, there are only seven other individuals on her team.

Identifying the connectors of a network, like Kutsal and Cengiz, helps to comprehend how the network aggregates over time, how concentrated subgroups form, and how individuals who participate in small ways or for short times often get drawn into the larger structure. As Barabasi (2002) suggests, there are individuals in any network who are especially good at amassing groups around themselves, whether because of how they position themselves, or their personalities, or the type of work they do. In our case, we can see that participating in many sectors of excavation over several years is an especially productive means of forging linkages with many people, in terms of sheer numbers. Connectors are most likely to be found excavating.

But this alone does not help to discern who is most responsible for moving information through the network. For this, we also need to bring in the notion of *brokerage,* which is measured by betweenness centrality. Brokers are the ones who bridge otherwise largely disparate regions of the network. At Çatalhöyük, there are individuals like Brigid Gallagher, Shahina Farid, and Burcu Tung who fulfil this role. Calculating their betweenness centralities helps us to identify them; when we try to interpret why, it becomes clear that indeed these women are positioned to act as potential gatekeepers on information passing through the system. Gallagher, for example, participates in both the conservation and excavation teams in

2002, and is in fact the only direct link between these two teams. Conservation in general, as discussed above, is a relatively isolated subgroup, so Gallagher's extremely high betweenness centrality derives from the fact that theoretically, she should always be the conduit for any information travelling efficiently from conservators to excavators or vice versa. Tung's participation on the project moved from excavation to individual researcher to field supervisor. Especially as a member of groups like 'research projects' and 'architectural analysis', whose members were each pursuing their own questions and methodologies, Tung's various stages of participation have meant that she is often the sole connection between certain project members and the rest of the group.

Farid also links between groups and individuals that are relatively cut off from the rest of the social structure at Çatalhöyük. Having co-authored a report with Rachel King in 2007, Farid creates a link between the Stanford Field Team and the rest of the project participants to whom she is connected. She also helped to carry out the Summer School that Gülay Sert has run for many years, thereby drawing in this otherwise disparate subgroup. Importantly, Farid also co-authored a report with Ian Hodder, who is only linked to the rest of the network by one other linkage; this suggests that Farid, during her long tenure on the project, filled the critical role of ensuring information made its way from the project director to the rest of the team, as well as the other way round.

Fundamentally, the most productive aspect of the perspective shift that comes with applying SNA methodologies to the Çatalhöyük team is the underlying notion that the relations in networks are channels for some type of resource to flow through them (Wasserman & Faust, 1994; Haythornthwaite, 1996; Borgatti et al., 2009). This resource can be anything from currency to pathogens to friendship to—in this case, as in many others—information. Operating under the assumption that information is flowing through the archaeological research project helps to visualize not only the very constancy of data transmission but also precisely the conduits available to this flow. Being able to identify how knowledge production relies upon interpersonal relationships also resonates with contemporary science and technology studies. We can demonstrate, as others have shown (e.g. Lynch, 1985; Pickering, 1992; Kuhn, 1996; Knorr-Cetina, 1999) that independent inspiration in science is more of an attractive mythology than a phenomenon in reality. Instead, science and technology studies have argued that knowledge is produced by groups of experts coalescing, engaging in specific forms of dialogue, and reaching a particular kind of consensus (Shapin & Schaffer, 1985; Kuhn, 1996; Shwed & Bearman, 2010). SNA has given us here a longitudinal vision of the structural changes underpinning these conversations at Çatalhöyük and the formation of sufficient consensus for the publication of technical reports each year.

This approach furthermore helps us to see how different sets of data, collected at different times, in different areas of the site—by different people—may come together to produce coherent conclusions about the past. In order to do this, it finally becomes necessary to examine the language used in the documents produced at Çatalhöyük.

Combining Social Network Analysis and Topic Modelling at Çatalhöyük

Topic modelling has proved an effective means of tracking the types of data used and ideas considered to produce the record of this site. Furthermore, by creating a network connecting archive reports and diaries to topics represented by 10 per cent or more of a given document, we can view which documents—as well as which authors—have been most effective at carrying ideas between disparate subgroups within the social network of the research team.

To begin with, we can ask what topics dominate the documentation in the project over time. In order to assess this, we can calculate each topic's PageRank, an algorithm originally developed by Google to measure the importance of webpages for the purposes of ordering search results. PageRank evaluates the likelihood that a random path through the network will arrive at a particular node. In our network, the topics with the highest PageRank represent those that are perhaps most likely to be discussed. Here, we will only examine topics in the network with a PageRank higher than the arbitrary threshold of 0.01. These are the topics which are theoretically the most significant to the overall body of both informal and formal documents produced at Çatalhöyük.

Topic 59, for example, with a PageRank of 0.0101, primarily involves discussion of 'obsidian', 'blades', and 'flakes', but also keywords associated with lithic production such as 'debitage', 'pieces', 'projectile', 'pressure', 'flakes', and 'core'. This topic first appears in the network of documents in 1993, in an archive report by James Conolly. In fact, Conolly is the only one extensively discussing this topic until 1999, when Tristan Carter and Heidi Underbjerg write about it in their respective archive reports, and Tristan Carter even writes two diary entries that discuss this topic. Neither Carter nor Underbjerg had ever worked on a team with Conolly, nor had they co-authored a paper with him previously. This suggests that the topic is present in their reports not only because of shared research interests, but also potentially because they had read the

previous reports written by Conolly. In this case, it seems to be the document itself that is advancing ideas through the project. Carter and Underbjerg continue to dominate discussions of this topic until 2001 when there are three separate reports discussing this topic—one by a fellow member of the Chipped Stone team and two by members of the West Mound team. It is interesting that such a widening of discussion on this topic should happen at precisely this point in time; only one year before, in 2000, the West Mound teams and Chipped Stone teams were connected—albeit tenuously—by sharing members with the linked-together Human Remains and BACH teams, respectively. We suggest that this may represent evidence of the social network working to convey ways of thinking and talking about archaeological data down the line.

Further evidence is provided by closely following topic 71 (with PageRank 0.0113). This is one of the key modes of discussing human burials, marked by words including 'burial', 'skeleton', 'adult', 'infant', 'disturbed', and 'articulated'. The topic first appears in 1996, primarily in some archive reports by Peter Moyers and Theya Molleson, as well as in the archive report by Naomi Hamilton—all three of whom are, unsurprisingly, members of the 1996 Human Remains Team. In 1997, however, Gavin Lucas takes up this topic in his archive report as well. Lucas is not a member of the Human Remains team, he is part of the British excavation team. However, in 1997, so is Hamilton. In 1998, Farid discusses this topic as well; she too has previously participated in the British excavation team. By 1999, the topic characterizes not only the archive reports of excavators and Human Remains team members, but also the informal diary entries of multiple British excavators and the archive reports of BACH team members (who have been linked via social connections to the human remains team for the past two years at this point). We can trace this topic, as well, moving from team to team at Çatalhöyük.

One might argue that both Topic 59 and Topic 71 are so intently focused on particular materials that their uptake in the network is highly predictable. Of course, those who study those materials would be most likely to use that particular language; it is unlikely, however, for a ceramicist to be discussing 'obsidian', 'blade', and 'core' all at once in their paper. To better comprehend the influence of the social network on the flow of knowledge through the system, we can instead look at Topic 9 (with a PageRank of 0.0121—the highest of any topic in the network), which features words like 'today', 'day', 'afternoon', 'morning', 'trench', 'working', and 'cleaning'. This might be interpreted as a narrative topic, characteristic of the kind of language used to tell the story of one's workday, and with the exception of 'trench', any of these words could be used by anyone on the team. It first appears in 1996, in two diary entries by Farid. In 1999, it appears in three separate diary entries by three different UK excavators—a team which has enjoyed a great deal of continuity since Farid's participation in 1996. By 2004, it appears in a diary entry by Ulrike Krotschek, a member of the Stanford Field Team—a subgroup which appears extremely peripheral to the overall network. Krotscheck, however, has previously participated in the 4040 excavation team, along with many former UK excavators who worked alongside Farid. Krotscheck is only one 'degree of separation' away from Farid, the originator of the narrative reflective trope at Çatalhöyük, and we can see exactly when the trope passed through the intermediary team.

As these three examples indicate, SNA helps us to see how particular kinds of language travel through the project. We can see how a specific way of discussing lithic material or human remains moves from one team to another, and how one documentation strategy —the re-examination of one's daily progress—persists through time within a single team due to continuity in team membership. It does not seem that co-authorship is an especially productive means of transmitting knowledge; shared participation in a subgroup of the project is a much more effective predictor of whether one is likely to use the same language markers as another individual.

There remains one topic to examine, however, because it does not seem to conform to the same general rules. That is Topic 18—another narrative set of words, though one more focused on excavation, with words like 'digging', and 'find' as well as words such as 'thought', 'pretty', 'good', 'nice', and 'big', suggesting a process of judgement and assessment. These descriptive, evaluative words are absent from Topic 9, described above—which also seems to represent recounting the process of excavation, but takes a more procedural approach, without the same language of valuation. The PageRank of this topic is calculated as 0.0113, making it tied for the second most likely topic to be hit on by someone travelling through the network of documents linked by shared topic. This topic is first discussed in 1996, by project director Ian Hodder—who is, as we have said, nearly entirely disconnected from the overall social structure in the project. And yet, only two years later in 1998, it characterizes diary entries by members of teams as diverse as UK Excavators, Human Remains, and Figurines and Miniature Clay Objects. Over the course of the project, it appears in diaries by team members in Field Supervisors, Project Administration, Paleoethnobotany, Paleoenvironmental Research, Faunal Analysis, Architectural Analysis, Image and Media, Computing, Database Development, Finds, KOPAL, South Area Excavation, North Area Excavation, West Mound Excavation, the Stanford Field Team, the

Berkeley Field School, and Independent Researchers. Bit by bit, it diffuses throughout essentially the entire project. But how do we explain such a pervasive spread of a language initiated by someone so apparently peripheral to the social network?

First, it is important to notice that Hodder, despite having very few connections to the overall network, has two connections which both have very high betweenness centralities. That is, they both theoretically possess a significant ability to act as gatekeepers on the overall flow of information through the network. Both Farid and Matthews are ideally situated to enable precisely this kind of process to occur, where an innovation begun in a seemingly tangential segment of the network disseminates through the entire structure. On the other hand, we must recognize who the innovator is. The fact that Hodder originated this language pattern—and has published in support of this kind of situated reflection on the archaeological process (Hodder, 2000, 2003, 2012)—is a likely reason for this topic's pervasiveness and persistence over time. As social network analysts have suggested, any given innovation has a defined 'spreading rate'—a likelihood to be adopted, and each individual has a 'threshold'—the likelihood that they will adopt any given innovation; combining these metrics helps to predict how quickly any innovation will die out—or just the opposite (Barabasi, 2002). In this case, we might hypothesize that Hodder initiating this particular language signature has invested it with a higher spreading rate than other topics in the network—revealing power dynamics inherent in the system that were not calculable with network analysis alone.

Conclusion

Taking the approach of combining diverse methodologies is in line with recent critiques of network analysis in archaeology. Network science has been applied in archaeology to understand large and complex datasets, often operating at a regional or diachronic scale (Knappett, 2013), to study the archaeological evidence for ancient transportation, communication, and cultural transmission (Jenkins, 2001; Bentley and Shennan, 2003; Graham, 2006; Sindbaek, 2007), and to foreground the properties of material culture—archaeologists' direct evidence of the past (Brughmans, 2013; Knappett, 2013). Ironically, however, these applications often do not make use of the particular advantages of SNA (Brughmans, 2013; Knappett, 2013). Time and space have long been theoretical debates in SNA (Marsden, 2005; Snijders, 2005; Kossinets & Watts, 2006), and the conventional SNA theory and methods have been forged on the study of interpersonal relationships, rather than shared traits between artefacts.

Instead, Knappett (2013) recommends a balance between utilizing the computing capabilities of network science while also retaining social questions as the foremost analytical motivation; Brughmans (2013) also suggests that archaeologists demonstrate a greater awareness of the powerful diversity of approaches encapsulated within network science. Our analysis here responds to both of these calls. Rather than focusing on the physical tools and spatial organization of fieldwork (e.g. Goodwin, 2006; Van Reybrouck & Jacobs, 2006; Olsen et al., 2012), we have concentrated instead on social relationships engendered by working together on research projects and technical reports and applied mathematical calculations to better understand the influence of these relationships. But we do not stop there, hoping to avoid the 'routinized explanatory process' Brughmans (2013) criticizes and says is the result of deploying only the most popular models and techniques of SNA. We also apply topic modelling, and argue that these topics themselves work to link documents, creating as well a network of texts. We cannot ignore the importance of the texts themselves for the production of archaeological knowledge, thereby joining the inherent strength of SNA for understanding social relationships with the archaeological necessity to equally consider non-human objects.

The SNA and topic modelling, combined here, have allowed us to identify particular ways of discussing specific parts of the archaeological process and materials, and to see how these approaches move through the system. Our study has shown that social relationships—specifically, shared team membership—play an essential role in determining how influential a given mode of discussing the archaeological record will be on the system overall, governing whether it will pass between teams and at what rate. Significantly, by looking in depth at exactly what a given interpretive approach entails and who its first or most visible proponent is, we have also been able to tease apart the specific social roles and types of power that SNA is especially good at capturing, as well as those that seem to slip past. In particular, combining topic modelling with network analysis allows us to trace the movement of categories of knowledge and data as they are conveyed between individuals and teams, and to quantify the ability of specific individuals to act as local brokers, encouraging or hindering the movement of information through the project. Some types of information or means of discussing the past, furthermore, are inherently more likely to pervade the network, often because of the conditions under which they originated. By retaining a focus on the specific social conditions structuring how ideas, evidence, and analyses are communicated and combined.

In our experience, using SNA to its fullest potential required the direct experience of having been on the site and participated on the team—an approach more in line with the ethnographic approach to understanding the production of archaeological knowledge (e.g. Edgeworth, 2006; Castañeda & Matthews, 2008; Silliman, 2008; Mortensen & Hollowell, 2009). Our analysis relies on linking together the quantitative and visual strengths of network science, the ethos of first-hand experience, and the archaeological emphases on time and objects. In doing so, we have been able to map out the individuals, texts, and overarching structural factors underpinning the process of successfully assembling diverse sets of data in order to produce archaeological knowledge at Çatalhöyük.

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