Complexities of collapse: the evidence of Maya obsidian as revealed by social network graphical analysis

Gary M. Feinman, Field Museum of Natural History
Mark Golitko
James Meierhoff
Patrick Ryan Williams

Available at: https://works.bepress.com/gary_feinman/2/
Complexities of collapse: the evidence of Maya obsidian as revealed by social network graphical analysis

Mark Golitko¹, James Meierhoff², Gary M. Feinman¹ & Patrick Ryan Williams¹

The authors use a social network analysis to map the changing patterns of obsidian supply among the Maya during the period of Classic to Postclassic transition. The quantity of obsidian received from different sources was calculated for 121 sites and the network analysis showed how the relative abundance of material from different sources shifted over time. A shift from inland to coastal supply routes appears to have contributed to the collapse of inland Maya urban centres. The methods employed clearly have a high potential to reveal changing economic networks in cases of major societal transitions elsewhere in the world.

Keywords: Mesoamerica, Maya, Classic, Postclassic, third–fifteenth century AD, obsidian, social network graphical analysis, urbanism, systems collapse

Supplementary material can be found online at: http://www.antiquity.ac.uk/projgall/golitko332/.

Introduction

Explanations for the florescence and subsequent decline of large urban societies have generated persistent archaeological interest worldwide, for instance the collapse of Minoan urban centres on Crete during the Bronze Age, the decline of urbanism and political integration in the post-Roman period in Europe, and the rise and fall of major urban centres such as Teotihuacan in central Mexico. The decline of urban centres and the depopulation of particular regions in eastern Mesoamerica beginning around AD 800, sometimes termed the Classic Maya ‘collapse’, has served as an important case for more

¹ Department of Anthropology, Field Museum of Natural History, 1400 South Lakeshore Drive, Chicago, IL 60605, USA (Author for correspondence, email: mgolitko@fieldmuseum.org)
² Department of Anthropology, University of Illinois at Chicago, 1007 West Harrison Street, Chicago, IL 60607, USA

© Antiquity Publications Ltd.
Complexities of collapse

general models of the rise and decline of urbanism and political integration in the past (e.g. Tainter 1988) and continues to generate new debate (e.g. Webster 2002; Aimers 2007). Models of Maya political reorganisation, as for other global regions, propose causes both environmental (drought, catastrophic volcanic eruptions, hurricanes, anthropogenic environmental degradation) and socio-economic (warfare and invasion, peasant revolt, overpopulation, changing exchange routes) (Webster 2002; Demarest 2004; Chase & Chase 2006; Aimers 2007).

The role of changing trade networks has also been recognised by Maya scholars as a factor that contributed to the transition that characterised the Terminal Classic. Rathje (1973) argued that sites in the Classic ‘core’ (southern lowlands) were out-competed by settlements on the periphery (for example in the northern Yucatán and eastern Maya area), leading to inland collapse. Webb (1973), in contrast, argued that Maya polities were secondary states that arose in response to an influx of Mexican goods (including obsidian), and that emergence of commercial trade at the end of the Classic period caused a rapid loss of economic viability at inland centres.

Here we examine pan-regional exchange networks by applying graphical techniques from social network analysis (SNA) to chronicle variations in the supply of obsidian to inland and coastal centres. The resulting trends allow us to argue that increasing reliance on coastal trade networks played a key role in the decline of Maya settlements in the western lowlands and contributed to the fluorescence of coastal centres during the Terminal and Postclassic periods.

Maya obsidian exchange

Obsidian is an ideal material to use in reconstructing ancient trade relations. The chemical composition of obsidian recovered in archaeological contexts allows for the original source to be determined with high confidence, provided the regional sources are well understood. This is particularly the case in Mesoamerica, where over four decades of research have resulted in a comprehensive knowledge of the distinctive chemical signatures. In the Maya area of Mexico, Belize, Guatemala, Honduras and El Salvador, obsidian was primarily obtained from three sources located in the highlands of Guatemala, San Martín Jilotepeque (also referred to as Río Pixcaya), El Chayal and Ixtepeque (Figure 1).

Our regional analysis draws on earlier compilations, particularly Braswell’s (2003) synthesis of Terminal (~AD 800–1050), Early Postclassic (~AD 1050–1300) and Late Postclassic (~AD 1300–1520) obsidian for the broader Mesoamerican region. For the Classic period (~AD 250/300–800), data were drawn from earlier summaries as well as primary sources (see supplemental digital material for a complete listing). We have also included new sourcing data (see online supplement) for 70 pieces of obsidian from the Classic and Terminal Classic settlement of San José, Belize, excavated by Field Museum curator J. Eric Thompson during the early 1930s. San José is geographically situated between settlements in the Petén Lakes region to the west and Chetumal Bay to the north-east, both important nodes on routes of transport for obsidian and other goods at contact (e.g. Hammond 1972). Although most of the data included in our analysis were collected by chemical analysis (by XRF, INAA or ICP-MS), we have included visually sourced materials published by other scholars (see Braswell et al. 2000).

© Antiquity Publications Ltd.
In total, obsidian assemblages from 121 archaeological sites were analysed, including 50 that have components dating to the Classic period, 47 to the Terminal Classic, 19 to the Early Postclassic, and 44 to the Late Postclassic. Braswell combined all non-major sources from Guatemala and Honduras into an ‘other’ category; we have recoded all data in the same way and, for ease of viewing and analysis, pooled all central Mexican sources into a single category. The chances of identifying minority obsidian types in an assemblage decline with decreasing sample size (McKillop 1996), and as such we removed from analysis all sites with less than ten analysed pieces. For the Classic period, we included those assemblages with eight or more analysed pieces so as to include the San José assemblage. For visual display purposes and to assist in the geographical positioning of sites, all data points have been coded by regional ‘zone’ after Adams and Culbert (1977) (see Figure 1).

Social network analysis

SNA was developed in the social sciences to examine the functioning of active social networks (e.g. friendship networks, corporations, government or scientific collaboration.
Complexities of collapse

networks) in which all network ties can be quantified (Hage & Harary 1991; Newman 2001; Hanneman & Riddle 2005; Borgatti et al. 2009). In archaeology it has proved useful as a means of ordering data, even where all network actors and connections between them cannot be comprehensively quantified. SNA techniques have, for instance, been utilised to study regional patterning in ceramic style (Cochrane & Lipo 2010), relationships between geography and the patterning of genes, language and material culture (Terrell 2010a, 2010b), the development of ancient centres and states (Knappett et al. 2008; Mizoguchi 2009) and obsidian exchange networks (Phillips 2011). SNA has been previously applied to Maya Classic and Terminal Classic period political organisation by Munson and Macri (2009), who used measures of centrality derived from glyphic evidence to examine the degree to which Maya political networks were centralised during the Classic and Terminal Classic periods.

SNA is performed on sets of relational data consisting of ‘nodes’ (sites, individuals, objects, etc. . . .) connected by ties or ‘edges’ (friendship ties, trade connections, etc. . . .) (Hanneman & Riddle 2005; Mizoguchi 2009; Terrell 2010a). Although edges typically represent the presence or absence of documented connections between nodes, as in the approach to Maya glyphic evidence used by Munson and Macri, measures of similarity between node characteristics (e.g. archaeological assemblage data such as frequency of ceramic attributes, presence or absence of classes of material or frequency of raw material source types) also may be used to determine the strength of connection.

Here, we employ SNA on matrices of pair-wise Brainerd-Robinson coefficients of similarity between frequencies of source types for Maya obsidian assemblages spanning the Classic to Late Postclassic periods (Cowgill 1990). All analysis was performed using the network software packages Ucinet 6.289 and Netdraw 2.097 (Borgatti 2002; Borgatti et al. 2002). We utilise a method known as ‘spring embedding’ to position nodes—as DeJordy et al. (2007: 247) explain,

the (spring-embedding) algorithm works by modeling a network of social ties as a system of springs stretched between posts. If a pair of posts with a spring between them is placed too closely together, the spring is compressed and tries to push the posts apart (a property called node repulsion). If the posts are too far apart, the spring is stretched and tries to pull the posts together (a property called node-attraction).

The density of linkages utilised is generated by what is known as a ‘mini-max’ graph (Cochrane & Lipo 2010), one in which nodes are connected by the minimum number of edges necessary to connect the maximum number of nodes (typically all nodes, although some may be excluded if data quality or sample size is inadequate) into a single network. Whereas techniques such as multidimensional scaling, principal components analysis and contour plots display major trends in data at the expense of more ‘local’ variability, spring-embedded network graphs maintain an accurate representation of all nodal relationships across different scales of similarity (DeJordy et al. 2007).

Additionally, we utilise the ‘factions’ method (Hanneman & Riddle 2005: 189–92) to further explore ‘neighbourhood’ structure in Maya obsidian networks—clusters of nodes that are substantially more connected to each other than they are to other network nodes. The goodness of fit for different numbers of factions can be numerically assessed to find the most natural partitioning of nodes. Factions or groupings in this case do not imply an underlying
Method

Mark Golitko et al.

assumption of political connectedness or acquisition of obsidian through identical and exclusive network connections; SNA network graphs instead represent a flexible means of examining assemblage similarity against which varying hypotheses can be compared to explain aspects of network structure.

Networks were constructed for four periods: the Classic (Figures 2 & 3), the Terminal Classic (Figures 4 & 5), the Early Postclassic (Figures 7 & 8) and the Late Postclassic (Figures 9 & 10). On these figures, the geographical affinities of sites are shown by a symbol (as in Figure 1) and the groups having a similar pattern of supply (factions) by a colour. The data used in the analysis will be found in the online supplement.

Results by period

Classic period

Classic period obsidian assemblages are generally dominated by El Chayal obsidian (Figure 2), which in many parts of the lowlands replaced San Martín Jilotepeque obsidian, the dominant source during the preceding Preclassic period and earlier (Nelson 1985). San Martín obsidian remained in circulation, but is frequent only at sites in Soconusco and is present in small amounts near Palenque and in northern Guatemala. Ixtepeque obsidian is present in very high frequencies at Copán and other sites near its source but also at sites in the vicinity of Chetumal Bay, a point of entry for goods transported along the coast into inland waterways. Mexican obsidian, while generally infrequent during the Classic, is present at frequencies of greater than 1 per cent only in Soconusco, Yoxiha, and several sites in northern Guatemala. Mexican obsidian is also present at frequencies of less than 1 per cent in western Belize and at Copán. This distribution is in accord with a reliance on inland routes of transport in the Maya area.

The spring-embedded network mapping (Figure 3) divides the sites into three groups, with the Soconusco sites constituting one such faction, Copán and a handful of sites along the east coast a second, and the remaining sites making up a third faction in which El Chayal is the predominant obsidian variety present. The Copán group, characterised in particular by a dominance of Ixtepeque obsidian, also includes Quirigua, likewise positioned near the Ixtepeque source, but also Ek Luum, a coastal settlement at the entrance to Chetumal Bay. San José is more closely linked to inland sites such as Trinidad de Nosotros and Uxbenka than to those near Chetumal Bay.

Terminal Classic

Terminal Classic obsidian assemblages (Figure 4) are distinguished by much higher frequencies of Mexican obsidian, the distribution of which indicates the opening of a clear northern Yucatán route. This material falls off in frequency to the south, but even at Copán 13 per cent of all sourced obsidian derives from Mexican sources. Ucareo and Pachuca are relatively equally represented and constitute the majority of Mexican obsidian in the Maya region at that time, but almost all important Mexican sources are present in lower frequencies. Although Ixtepeque obsidian is more abundant at most sites than during the preceding Classic period, sites in the northern Yucatán generally are dominated by El

© Antiquity Publications Ltd.
Complexities of collapse

Figure 2. Classic period (∼AD 250/300–800) obsidian frequencies. Pie charts represent assemblages analysed from individual sites, sized on a logarithmic scale based on analysed sample size. Lines link pie charts to real geographic locations in densely sampled areas. × = minor sources in Guatemala and Honduras which were utilised in low frequencies in the pre-Hispanic period.

Chayal obsidian. This is particularly the case at sites farther inland, and it would appear that obsidian from El Chayal was still moving primarily through inland networks.

Terminal Classic network mapping (Figure 5) illustrates several trends—Soconusco sites still form an outlying group, but several new factions appeared. First, San Gervasio on Cozumel is linked into a network faction containing Copán and other Ixtepeque-dominated assemblages, but also a larger number of Belizean coastal and near-coastal sites are now divided into a nearby faction also characterised by high frequencies of Ixtepeque obsidian. This group includes San José but also sites farther west such as Tipu. There is a distinct faction that includes the emergent northern Yucatecan centre of Chichén Itzá, its affiliated trade port of Isla Cerritos (Andrews et al. 1989), and several other northern Yucatán sites.

© Antiquity Publications Ltd.
characterised in particular by high frequencies of Mexican obsidian, particularly Ucareo and Pachuca. Most other northern Yucatán sites are most closely linked to sites in the central Petén and highlands, including Kaminaljuyú, the centre sometimes argued to have controlled access to the El Chayal source (Braswell 2003). The exception to this pattern is Uxmal, which is linked most closely to Chetumal Bay sites, particularly because of the high frequencies of Ixtepeque found there.

San José is proximate to inland settlements and centres such as Xunantunich, yet the linkage with sites farther north-east in Belize and along the eastern Yucatán coast (such as Colha and Wild Cane Caye) is clearly revealed.

The frequency of Ixtepeque obsidian, as both the mapping and spring-embedded network graph illustrate, falls off as a function of distance from the eastern coast of the Yucatán Peninsula. This can be seen on a graph (Figure 6). Frequencies of Ixtepeque obsidian increase significantly at sites that were occupied during both the Classic and Terminal Classic. At San José, for instance, Ixtepeque frequency increased from 13 per cent to 27 per cent, and at sites in the central Petén Lakes region (~150m from the coast), frequencies of Ixtepeque obsidian similarly doubled between the Classic and Terminal Classic. At San Juan, McKillop (1995) notes a nearly eight-fold increase in the amount of obsidian recovered in Terminal Classic deposits, strongly suggesting that the volume of material transported...
Complexities of collapse

through coastal routes, including Ixtepeque obsidian, increased substantially, and that the relative gain in frequency of Ixtepeque was not simply the result of erosion of inland trade volume. Conversely, evidence for intensive curation of obsidian at lowland sites (Braswell 2003) and the declining volume recovered in the Petén Lakes region (Rice 1987) suggests that obsidian was increasingly hard to come by through inland routes.

Early Postclassic

Although San José, or at least its central sector, was apparently abandoned sometime before the beginning of the Early Postclassic period (EPC), many parts of eastern Mesoamerica remained densely settled during that time, actively participating in obsidian exchange. Examination of EPC obsidian exchange networks is constrained by the relatively small

© Antiquity Publications Ltd.
number of sites dating to this period from which obsidian has been sourced. Yet Ixtepeque obsidian constitutes a large percentage of most assemblages dated to this period (Figure 7). In the central Petén Lakes region, the frequency of Ixtepeque obsidian increased again from ~20 per cent during the Terminal Classic to nearly 60 per cent of the EPC assemblages. A few assemblages were dominated by Mexican obsidian (principally Pachuca), most of which are small, so this apparent feature of EPC obsidian distribution may be an artefact of sample size. Network mapping (Figure 8) results in a two-faction structure that principally divides sites with high frequencies of Ixtepeque obsidian in their assemblages from those with either very high frequencies of Mexican obsidian (Isla Cerritos) or those with very high frequencies of San Martín obsidian (Chuisac and Izapa). There is, however, again a coastal/inland divide in the Ixtepeque-dominated faction; near coastal settlements (San Gervasio, Colha, Xelha and Wild Cane Caye) are more proximate to each other and to Chihuautan, a site near the Ixtepeque source in the eastern highlands of Guatemala, than they are to sites such as Chan and the Petén Lakes assemblages, which are positioned closer to Izapa in the network mapping, which continues to show that assemblage structure was influenced by distance from coastal exchange networks.
Complexities of collapse

Figure 6. Classic (AD 250/300–800) and Terminal classic (AD 800–1050) period frequencies of Ixtepeque obsidian by distance from the eastern coast for sites north of 16°N at which ten or more samples were sourced.

Late Postclassic

A distributional mapping of Late Postclassic (LPC) obsidian frequencies (Figure 9) illustrates that the increase in frequencies of Ixtepeque obsidian evident in the Terminal Classic continued through the LPC, so that it became the predominant variety in all analysed assemblages except in Soconusco and at sites in the immediate vicinity of the San Martín Jilotepeque source. Network mapping of the LPC assemblages (Figure 10) yielded five factions strongly structured by geographical location. Site assemblages from Belize and the northern Yucatán are dominated by Ixtepeque obsidian, with lesser amounts of El Chayal and only minor amounts of Mexican obsidian. The northern Yucatán sea route through which Mexican obsidian was transported during the Terminal Classic (and possibly EPC) appears to have been less active at that time, although Mexican sources do appear in some assemblages around Chetumal Bay, and they form an extreme minority component of the assemblage at Mayapán, the primary LPC political power in the northern Yucatán (Braswell 2003; Sabloff 2007). The proximal positioning and linkage between Sarteneja, San Gervasio and Xelha shows a continued connection between Chetumal Bay and sites along the coast of the northern Yucatán, a network structure that also may include Mayapán.

Sites near the San Martín obsidian source primarily utilised that raw material and constitute a network faction, whereas three sites closest to the El Chayal source, Chitaqtzazq, Finca El Pilar and Aldea Chimuch, are linked into a network faction characterised by majority El Chayal acquisition. El Chayal obsidian is present in almost all assemblages.

© Antiquity Publications Ltd.
during the LPC, however, and the fall of Kaminaljuyu apparently did not entirely sever the networks through which this material moved. Media Cuesta, located roughly between the El Chayal and Ixtepeque sources, forms an outlier faction reflecting the relatively high frequency of ‘unspecified’ obsidian(s) there—possibly from Honduran sources.

As in prior time periods, Soconusco assemblages form a fourth distinct faction, but during the LPC these assemblages are particularly distinguished by very high frequencies of Mexican obsidian, primarily from the Pico de Orizaba and Pachuca sources. Soconusco was under the political influence of the Aztec empire (Gasco & Voorhies 1989) and/or its associated pochteca traders during the LPC (Blanton et al. 1993: 213), the patterns of obsidian acquisition reflecting this new political arrangement.

**Discussion**

The shifting exchange networks, and particularly the growing role of coastally focused trade, provide the basis for an explanatory model that corresponds spatially and temporally
Complexities of collapse

Figure 8. Spring-embedded network map calculated from Brainerd-Robinson coefficients for Early Postclassic period (~AD 1050–1300) obsidian assemblages, with assemblages with less than ten pieces omitted and threshold distance set to 62, the minimum value to connect all points into a single network. Nodes are coded by zone (shape: see legend to Figure 1) and faction (colour: coded by majority obsidian type, best fit achieved with two factions).

to political reorganisation and shifts in the geographic balance of power. Inland Maya centres that were important nodes in Preclassic and Classic period exchange networks have revealed the earliest evidence for decline, whereas sites near the coast in Belize, and particularly those around Chetumal Bay (Houston & Inomata 2009: 294–310), with easy access to coastal trade routes, are in general those that experienced least disruption prior to the Spanish incursion.

The increasing importance of coastal supply routes has been documented for other commodities as well. Kepecs (2004), McKillop (1996, 2004) and others have persuasively documented the importance of salt in coastal exchange, and other important coastal products and exotic commodities likely travelled through similar routes, including ceramics, shells and other goods of value to the Maya. For instance at San José, almost all Ixtepeque and Mexican obsidian identified, including a superb monolithic axe (Figure 11), was recovered from two caches also containing important marine products such as *Spondylus* shells, porcupine fish spines, and pearl (Thompson 1939). If this interpretation is correct, then the distributional data we have compiled indicate a significant increase in the importance of coastal trade routes and decline of inland routes beginning already during the Classic period, a trend that continued through the Terminal and Postclassic periods, when Ixtepeque dominated the sourced obsidian from Maya sites.

Current network approaches stress the critical role that access, centrality and connectivity play in determining the relative political and economic success of settlements, including © Antiquity Publications Ltd.
the elites resident there (e.g. Knappett et al. 2008; Mizoguchi 2009). Kepecs and colleagues (1994) for instance stress the role of access to trade routes in the rise of centres such as Chichén Itzá during the Terminal Classic. Consequently, the growing importance of Ixtepeque obsidian and the sea trade through which it was primarily acquired may signal a shift in the balances of power and access routes to obsidian (and other exotic goods) that occurred from inland to coastal sites. Although obsidian was a material available to and utilised by all segments of Maya society, it was particularly associated with elite segments of society during the Classic period (Rice 1987). The collapse of inland networks and network connectivity may therefore have severely impacted elite segments of Maya society, who were by the Late Classic period increasingly reliant on network power strategies (Blanton et al. 1996; Feinman 2001), whereby access to valuable exotics (e.g. Mexican obsidian, shell, metals), many derived from coastal and marine sources, were essential for the maintenance of socioeconomic power and status.
Most archaeologists today eschew unicausal models of complex phenomena such as the Maya collapse (e.g. Demarest et al. 2004: 565), and we do not suggest that changes in trade routes caused political collapse. An explanation of the collapse of Maya centres resulting solely by loss of trade route access would ignore other significant variables (Culbert 1988: 78). Our model is at present coarse-grained and addresses the collapse at the broadest level. Intraregional differences in the relative success of particular Maya urban centres have been noted (e.g. Pyburn 2008; Hutson et al. 2010; Braswell 2011) and Braswell (2010) argues that political cycling in many cases occurred on a shorter time scale than fundamental changes in economic structure. Environmental, demographic, subsistence economic, and internal political factors certainly also played an important role in weakening the underpinnings and legitimacy of Maya political hierarchy; warfare accompanied and in turn exacerbated the decline (Demarest et al. 2004: 567–68). Nevertheless, our findings cast doubt on recent arguments (e.g. Haug et al. 2003) that climatic changes alone were responsible for these demographic declines.

Conclusion

Social network analysis graphical techniques, focused on sourced Maya obsidian assemblages, have been utilised to examine changes in eastern Mesoamerican obsidian
exchange networks spanning the Classic through Late Postclassic periods (AD 200–1520), including the site of San José, Belize. Our analysis indicates that San José initially was connected into inland exchange networks through which El Chayal obsidian was primarily moved. Later, during the Terminal Classic, the site inhabitants relied increasingly on waterborne networks that followed the eastern coast of the Yucatán Peninsula, through which Ixtepeque obsidian was principally transported. San José mirrors a broader regional pattern that continued into the Late Postclassic, when regionalisation of obsidian distribution and the primary presence of Ixtepeque obsidian at remaining sites in the lowlands indicate that inland routes had largely collapsed.

Importantly, the growth of coastal trade at the expense of inland routes began prior to the collapse of both urbanism and population in the Maya lowlands. Rather than being the result of collapse and abandonment, the decline in the volume of inland trade may have been an important contributing factor that led to a shift in the demographic and political balance of power from the landlocked rainforest centres to the northern Yucatán and eastern coastal regions. Over this period, access to critical resources and vestments of elite authority were more readily obtained through these emerging coastal networks of transport that moved not only obsidian but also formed the starting point and source of important coastal goods such as salt and sea products. Although we have focused on only one material type—obsidian—other materials that carry potential provenance information, including jade, ceramics and chert, could also in principal be included in future SNA analysis of Maya economic interaction to provide a multidimensional understanding of patterning beyond that presented here. As Munson and Macri (2009) have similarly demonstrated, a network approach provides useful methodological and theoretical tools for examining shifts
Complexities of collapse

in Maya political, social and economic structure over time, opening a new path of inquiry into the factors that contributed to the relative success of different urban centres and political formations over time in eastern Mesoamerica as well as other regions of the world.

Acknowledgements

We would like to thank Jeffrey Buechler, Linda Nicholas and John Edward Terrell for comments on earlier drafts of this paper. Marilyn Masson provided access to unpublished data for which we are grateful. The equipment at the Field Museum Elemental Analysis Facility utilised to analyse the obsidian from San José (project EAF004) was acquired with grants from the National Science Foundation (BCS-0320903), The Museum’s Anthropology Alliance and Grainger Foundation Fund for Scientific Research, and an anonymous donation. All remaining errors are the sole responsibility of the authors.

References


© Antiquity Publications Ltd.


MARK GOLITKO ET AL.