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The Role of Road Networks in Social Definition and Integration of Angamuco, Michoacán (250–1530 CE)

Rodrigo Solinis-Casparius

A dissertation

submitted in partial fulfillment of the

requirements for the degree of

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Abstract

The Role of Road Networks in Social Definition and Integration of Angamuco, Michoacán (250–1530 CE)

Rodrigo Solinis-Casparius

Chair of the Supervisory Committee:
Marcos Llobera, DPhil
Department of Anthropology

Road networks can be defined as the movement infrastructure of a city. They are both the resource that guides inhabitants within a settlement, and that defines different levels of social interaction and social organization. This dissertation research explores the development of the urban layout by studying the composition and configuration of the road network of the ancient city of Angamuco (250-1530 CE), located in the core-area of the Purépecha Empire (Lake Pátzcuaro Basin), in Michoacán.

I used a combination of traditional archaeological investigation methods, such as survey and excavation, as well as remote sensing, GIS, and spatial analysis to investigate how pedestrian roads were created, maintained, modified, and used in this site. This research is divided in three

main sections: 1) The use of lidar and image analyses to identify over 6000 road segments, pathways, and intersections within this +6 km^2 urban center; 2) Excavation of a sample of roads, and ceramic analysis for determining the relative temporal sequencing and configuration of roads; and 3) A classification of roads according to their morphology, construction, configuration, experiential properties, and centrality (network analysis) indices.

The results of this research indicate that inhabitants of Angamuco were actively engaged in the construction and modification of the intra-site road infrastructure. Particularly, that massive road transformation events occurred around the Middle Postclassic period (1000 CE), right before the emergence of the Purépecha Empire. Changes in the road network also suggest that access to, and configuration of the space responded to socio-spatial settlement and occupation processes. This study provides field and computational techniques to better identify ancient urban roads by their manufacture technology, morphology, connectivity, and accessibility. Further, it provides a detailed typology of Mesoamerican urban roads and a conceptual scope to explore the intra-site mobility, social organization, and the urbanization process of Angamuco within the context and the impact of the Purépecha Empire's influence in the Lake Pátzcuaro Basin area.

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ACKNOWLEDGEMENTS

The following pages describe the process and results of my dissertation research. Throughout this process I benefited from the help, guidance, and support of many colleagues, friends, and family. This work is the culmination of eight years of education, experiences, training, and growth during my life as a graduate student at the University of Washington, Seattle.

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DEDICATION

For my mother Maria Casparius† who inspired me to be passionate about the past.

CHAPTER ONE: Ancient pedestrian road networks
An introduction

1.1. Thinking on roads

Walking is a fundamental form of travel, a way of getting to places, and a way of being in places. When we walk, we not only engage and interact with our surroundings, with the objects and buildings, and the ground-surface on top of which we walk, we also interact with the other pedestrians and people along our trip. To some extent, our walking is influenced by those interactions as well as our speed, our stroll, and the turns we take.

Several years ago, I moved to the city of Salamanca in Spain for my graduate studies and walking was my only means of transportation. Like most western European cities, Salamanca is not a place where having a car is indispensable to get by. Unlike many other cities of the world, the entire core center of Salamanca is pedestrian only. After only my first few weeks there, my daily trips to school, the library, the grocery store, or the coffee shop became very important ritual of my day. First, as a means to explore different parts of the city, I started choosing different routes. Eventually, I had created a repertoire to choose from —including the fastest way to school if I was running late for class, the most pleasant route for the days I needed to escape from stress, or the better lit paths for the darker winter evenings. There was something very liberating and relaxing, yet powerful, in having the opportunity and control to choose from the many combinations of route sections I could take.

When I moved to Salamanca, I didn't know anyone. But it was through this daily walking that I met my neighbors and I started recognizing a few other people. After weeks and then months of these daily encounters, I felt like I had created a community of pedestrians. We were all residents of our city. I didn't necessarily run into them in the same locations consistently but have engaged in long and recurring conversations with some of them.

Several years later, before starting this research, a friend told me she was visiting Salamanca. I excitedly created a tour plan for her. I drew a map, remembering my walking routes and the people that I met or usually encountered at some locations. When I finished drawing, my map of Salamanca was actually a diagram of streets and interactions.

I thought about that map when I first visited Angamuco. Like Salamanca, Angamuco, Michoacán is an intricate labyrinth of pedestrian roads. Instead of medieval sandstone buildings, there are partially-collapsed, prehispanic basalt buildings and lush vegetation. Anna Cohen, Chris Fisher, and I traversed this ancient, now abandoned city, for a few hours using ancient roads that are still visible. I couldn't stop thinking about the many encounters that Angamuco residents might have had in their daily trips through their everyday lives.

My first visit to Angamuco captivated me because it was the first archaeological site I had worked at that clearly resembled a city in modern terms. Kilometers of trails and ancient buildings including houses, sunken pyramids, plazas, and open flat areas seem all connected through these trails. As an archaeologist, I think of the traces of human action and I tend to imagine how objects and buildings were created and used originally and how that changed over time. So, in the next few years as I collaborated as part of the LORE-LPB project at Angamuco, I kept thinking how this city looked and how it functioned over a thousand years ago. But more and more, I thought how its residents moved around during their daily trips, who they interacted with, and how over time they also created communities of pedestrians like those I created in Salamanca.

I began thinking of Angamuco as a city, but not as a landscape of buildings and structures, and more as a system of connections and networks. My interest developed into learning how to explore if there was a correspondence between those social connections and the intricate system of pedestrian roads.

The literature on urbanism studies and sociology covers topics related to socialization and movement within urban settings, particularly those related to space configuration and interaction. Works like that of Bourdieu (1977), de Certeau (1988), Gehl, (1987; 1989; 2010), Hillier & Hanson (1996; 1984), Jacobs (1961), Lynch (1960; 1984), Moore (2005), Mehta (2013b), and Scheer (2010), inspired me into thinking of cities as places where the configuration of spaces has an effect on how we act. On the other hand, archaeologists who have explored the material evidence of human movement within large landscapes and in urban settings such as Bekker-Nielsen (2004), Blanton & Fargher (2016), Cobos & Winemiller (2001), Fisher (2009), Folan et al., (2001), Frederiksen & Perkins (2013), Kaiser (2011), Keller (2006), Laurence & Newsome (2011), Matteazzi (2017), Osborne (1991), Pugh (2018), Reynolds (2011), and Monica Smith (2003; 2005) helped me think how we transform our cities while we move around them. And finally, innovative studies that have incorporated computational modeling, statistics, and the use of GIS to investigate pedestrian interaction, mobility and road configuration like Branting (2004), Crucitti et al. (2006), Ewing & Handy (2009), Hoogendoorn & Bovy (2004), Kondo & Seino (2010), Polla & Verhagen (2014), and Sevtsuk, et al. (2013, 2014), motivated me to consider less traditional approaches to carry on my research including innovative digital technologies.

I decided to explore how ancient roads like those of Angamuco could help us better understand the urban layout of a city, and with it, the relationship between social organization and spatial configuration. Focusing on roads as a complete network has an enormous potential to help us understand many aspects of urban life. This includes, but is not limited to accessibility within the city, distribution of space for different activities, a sense of traffic or transportation modes, how central or visited different areas of the city are, levels of interaction, etc.

The biggest challenge for such analysis is identifying what methods and approaches are more suitable to study urban road networks within the archaeological assemblage. So, my research included the evaluation of previous work on ancient roads, from identifying the best analytical units, to the better excavation, survey, and mapping techniques on roads and associated features of the movement infrastructure.

My doctoral dissertation, here, centers on an exploratory study of the road network of the ancient city of Angamuco, a city that emerged 1800 years ago —approximately 1000 years before the consolidation of the Purépecha Empire— that changed both spatially and socially until its abandonment at the time of the European conquest in 1530 CE.

1.1. Dissertation organization

This dissertation is organized following traditional archaeological research work.

In the second chapter, I introduce the main topics or urbanization, city form, and social organization as it has been seen in both urban studies and archaeology. In the second part of that chapter I concentrate on several archaeological case studies that have investigated some social aspect of roads in ancient settings. Next, I present the difference between studies of regional and urban roads and the three main models of road network configurations. I finish chapter two with a discussion of how I treat roads as artifacts in this investigation.

In chapter three, I present the cultural and chronological background of the Lake Patzcuaro basin and the site of Angamuco, including the most recent archaeological work in Michoacán.

Chapter four is devoted to the goals and expectations, and concepts that guided this work and data collection methods. The chapter is divided into two sections both focusing on the identification of roads in the field and digitally. Stage 1 describes the survey and excavation methods used to conduct fieldwork on the roads of Angamuco. Stage 2 describes the use of lidar-derived data and image analyses employed to obtain the complete network of roads for the site (at least, the area that was uncovered at the time of this research).

In chapter five, I present the laboratory data analysis that guided the interpretation of the construction and chronology of roads in both relative and absolute dating methods. Here I describe the stratigraphy, architecture, and sequence of construction events associated with roads, the results of the ceramic analysis, and the radiocarbon determinations.

Next, chapter six is centered on the computer analysis methods used to study the road network of Angamuco (Urban Network Analysis). I first present the main assumptions and limitations of the data and other considerations while conducting this research. The chapter is divided into four sections, each discussing an aspect of the network, for example, the level of integration and accessibility present in the network, the evidence for urban planning, and so on.

Finally, in chapter seven, I focus on the interpretation of the results obtained for various case studies within this research. Based on these results, I propose a classification of roads and road-intersections. I discuss general patterns and characteristics of the network, and how these might be related to questions of social configuration within the city. In the last section of chapter seven, I discuss a proposal on future research that might study socialization using roads as evidence of interaction spaces.

The final chapter is devoted to the general conclusions of this work, its contributions to the understanding of the cultural development of Angamuco, and the area, and the study of road networks in archaeology.

CHAPTER TWO: Urbanism, city form, and road networks

The social roles of roads explored in Archaeology

Cities are human constructions and complex social landscapes. They don't emerge without people adapting to and transforming their natural landscapes. The origin of a city is not only explained by the order in which buildings were constructed, but also by understanding how its residents organized to share the space and resources.

We shape our cities to accommodate our needs, fit in the landscape, and reflect our views of the world. As we do that, we are in turn shaped by these new spaces. For example, intimate locations and open public areas influence our daily actions, our behavior, or the way we interact (Gehl, 2010:9).

These city-shaping processes have their unique temporalities and motivations. They are different for every city, time period, or even area within a city, but they all ultimately help reinforce a relationship between space and social organization. For example, it takes time to build a residential project in the outskirts of an American modern city, but it also takes time —and certain cultural conditions— for it to seem normal to residents of that city that those spaces should be inhabited by new middle-class young families. The areas of the cities, shapes of the buildings, and sizes of roads all carry implicit and explicit norms about who and how they should be used. These norms, however, are not static and do change (de Certeau, 1988:96).

Understanding how a city works and how it has transformed has been the focus of sociologists, urbanists, and historians who have provided an extensive body of theories and methods to better understand the dynamic life of cities (for example, Gehl, 1987; Hillier & Hanson, 1984; Jacobs, 1961). Archaeologists have also studied such questions, but by providing long-term diachronic, and material-based perspectives (Arnauld et al., 2012; Harris & Lewis, 1998; Hirth, 2003; Smith, 2010b; 2003).

In this chapter, I will introduce the concept of the city, concentrating on how archaeologists have applied the urban layout to understand social organization. I will then focus on the relevance of studying the movement infrastructure of a city to understand its layout, and to interpret interaction as a mechanism for social construction.

Lastly, I will present several case studies of archaeology that have focused on the analysis of ancient roads. I move from examples of regional roads to urban road networks in an attempt to show the challenges and contributions, of focusing this research on a unique feature that has often been ignored in archaeological investigations: the road infrastructure.

2.1. City form and social organization

There is not really a consensus on how to define a city —e.g. minimum number of structures, area size, total population, etc.— (Mumford, 1937). Archaeologists have struggled with the definition of sites in terms of their material deposits and area sizes for a long time (Dunnell, 1992; Parsons, 1972). How or when a human settlement can be considered a city and not just a large settlement is still not clear today[1], but perhaps it is not really that important as long as we take cities as one type of human settlement where several systems of political, economic, social, or religious institutions coexist and are organized spatially (regardless their size or shape).

Put simply, cities are social formations placed within a dynamic physical space (Smith, 2010a). Urban centers —cities, small settlements, group of neighboring settlements— are spatial

[1] There is of course a long-standing discussion of what constitutes an urban center in archaeology starting from G. Childe (1957). More recently, other scholars offer different perspectives on this topic (e.g. Marcus & Sabloff, 2008), however, what specific cultural conditions and their material manifestations distinguish a city from a large settlement (or, what is the difference between a city any other settlement) is still being debated in archaeology.

units that change in size and configuration over time. As social hubs, they are also constantly changing with cultural or political processes that allow for social relationships to both develop and consolidate (Smith, 2003).

Our current understanding of city formation is heavily informed by the work of urbanism scholars from two distinct moments in the 20th century —the first around the 1920s and the second after the postwar period in the 1950s. Their work propelled new perspectives that helped identify the many elements that form a city and explain the social composition of cities. The scholars in both of these unique time periods were responding to significant and abrupt transformations of major urban centers in the western world, economic boom, and technology advancements (LeGates & Stout, 2011). As a result, new methods and analytical approaches that centered on the design, origin, composition, and function of cities appeared from a wide range of fields, from sociology to architecture.

Archaeologists have contributed uniquely to urban studies in at least two ways. One of them is by focusing on ancient cities, which has provided a wider sample of examples of urban transformations over time, borrowing concepts and methods from the field of urbanism (Smith, 2010c). Some of the most influential theories in urbanism employed by archaeologists are *urban morphology* (e.g. Conzen, 2001; Moudon, 1997), *urban ecology* (e.g. Inomata, 2006; Moore, 2005), and *space syntax* (e.g. Cutting, 2003; Laurence, 1995). The second one is by centering the study of cities on the materiality of urban life and on the complex analytical goals that include inferring sociological processes from changes in a site's spatial layout through time.

Regarding the latter point, archaeologists consider the material elements (e.g. buildings, ceramic scatters, etc.) in terms of spatial variables (e.g. discontinuity, density, structure, centrality, etc.) that together might point to the social mechanisms that stimulated how people settled.

A very good example of this are domestic venues like households and neighborhoods that indicate that those areas and then the cities at large, are the result of both "top down" and "bottom up" processes (Marcus & Sabloff, 2008). Organizational units result from the combination of multiple social categories —e.g. ethnicity, kinship, race, wealth, religion, occupation, etc.— and their spatial expression can vary across cities, regions, and time periods. These units include considerable face-to-face interaction where social contracts, norms, and identities are established, often reflecting how space is configured (Arnauld et al., 2012). These processes are made possible through the revisiting of places and constant interaction with other individuals and material features, which help generate dispositions that guide behavior and thinking (Bourdieu, 1977). Since this is a social process shaped by past events and structures, it is created and reproduced unconsciously and constantly (ibid).

Examples of how social norms are intrinsically connected to the landscape are pointed out in Erickson's (2009) and Thomas' (1998) studies of quotidian spaces in Bolivia and the UK, and Moore's (2005) work on community creation in the Andes. In this sense, the urban layout is the spatial manifestation of social structuring by means of socialization processes that include daily interaction, religious ceremonies, production and consumption practices, and movement behaviors (Hillier, 1996; Hirth, 2003; Hutson, 2004; Monnet, 2003).

Although, there are examples of different levels of organization in ancient cities for complex societies in all parts of the world, specifically in Mesoamerican cities. Three levels of social organization have been observed: a) state-directed, such as autocratic regimes; b) community-negotiated, such as decentralized neighborhoods; and c) family-based, similar to individual residential units (Carballo, 2010; Hirth, 1992; McAnany, 1995; Rodríguez, 2006). Many spatial expressions of these social organizations co-exist within the same urban settlement, and each one has its own set of social norms and organizational principles. These have been observed in complex polities like Teotihuacan, Cantona, Calixcahuaca, Tula, Chunchucmil, Mayapan, and several other sites (Arnauld et al., 2012; Cowgill, 2004; Garcia Cook, 2003; Hirth, 2003; Hutson, 2004; Mastache & Cobean, 2003; Smith, 2004; York et al., 2010).

Studies in Mesoamerican urbanism (through surface ceramic distributions, settlement pattern, as well as other approaches) therefore suggest a significant variability of urban configuration (Smith, 2005). Despite this diversity however, all cities in prehispanic Mesoamerica —and in the rest of the modern world as well— can be considered as being the result of the same three basic components that supplement each other (Gehl, 2010; Lynch, 1960; 1984):

a) Architecture: spaces associated with functions and activities

b) Landscape: topography and natural resources

c) The movement network that allowed access through these spaces.

Thus, studying ancient cities has to necessarily consider these three components. In general, archaeological studies of urbanism has prioritized the first two —architecture and landscape— and roads have been relegated or ignored. However, I argue, that the movement network might actually be very useful to answer questions of social organization.

Human settlements represent distinct and complex sociocultural systems expressed at many scales of organization, production, distribution, and consumer practices (Cowgill, 2004) and roads are a spatial expression of these systems because they define access to, and transit through architecture, resources, and the natural landscape (Blanton & Fargher, 2011).

In archaeology, roads have most often been seen as the byproduct of the movement of people and goods which on occasion are conceived as spatial divisions within the city (Kaiser, 2011). Because roads are structures where individual decisions —influenced by social norms—

occur daily, their use, construction, and maintenance responds to a combination of complex cultural, economic, and political factors that have to be determined in community (Bourdieu, 1977; Cobos & Winemiller, 2001; Edmonds, 1993; Erickson, 2009; Pred, 1986; Ur, 2009).

Studying how roads are created and used, and the potential activities these may have afforded offers the possibility to better understand fundamental dimensions of human socialization and urban development (see several examples in Snead et al., 2009).

2.2. Social roles of roads

Road networks can be defined as the movement infrastructure of a city. A road network acts as an agent in confining and preserving social identities. Roads, intersections, and entrances guide and generate interactions that occur at different scales: personal, community, and state (Gibson, 2006; Wood et al., 2010). Consequently, road networks are both the material manifestation of human movement and, the resources that guide inhabitants within a settlement, and define different levels of social interaction and social organization (Blanton & Fargher, 2016; Hillier & Hanson, 1984; Richards-Rissetto & Landau, 2013). In this way, roads are an important geographic anchor for social interaction and a fundamental unit of research for understanding a city's configuration (Jacobs, 1961:29).

Roads have an impact in solidifying social structures. The following four archaeological case studies I discuss will demonstrate this impact, which I will refer to as the *social roles of roads*.

The first case study shows how roads turn the physical act of moving into a mechanism of consolidation of social norms. In his study of Neolithic causeway enclosures in Britain, Mark Edmonds (1993) suggests that movement ("the timing and spacing of human action traversing through the landscape") played a fundamental role in social reproduction. He observed a series of causeways that were easily identifiable to its users 3000 years ago because they were built using materials that would have contrasted visually with the natural landscape. These causeways connect to ritual locations within settlements and were most likely used for meaningful trips to such places (e.g. mortuary processions, ritual commemorations, etc.). Excavation revealed distinct episodes of modification and cleaning, although leaving the general structure and shape of causeways intact. These reconstruction events would have been carried out in community but often enough that more than one occurred within one person's lifetime. The act of restoring would have constituted a process through which traditional values and associations would be enhanced and meaningful for a person. Edmonds concluded that the repeated patterns or cycles of movement, like those created by daily transit to and from common places through the causeways, constituted routines through which people reaffirmed and manipulated traditions and meanings.

This is a similar idea to the concept of *city legibility* proposed by Kevin Lynch (1961). As an urbanist studying modern cities, he suggested that all city residents create cognitive (mental) maps of the urban layout by two means: revisiting and remembering places, and by decoding a certain "coherent" or "logical" pattern of the city.

Both examples —modern cities and Neolithic settlements— show how the physical bodily experience of moving through space is a significant act that connects the physical walking infrastructure (the roads) with traditions and memories. Thus, the roads serve as a device to understand or remember external elements like historical events, meanings, or social class.

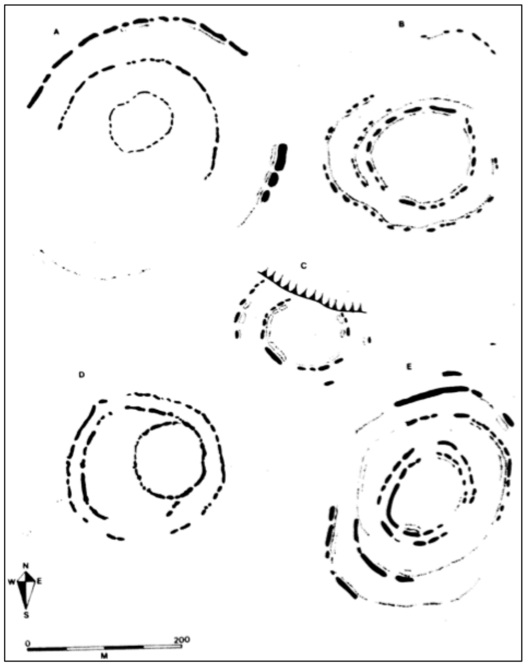

Figure 2.1. Plans of selected causeways or interrupted ditch enclosures, in Southern Britain.
Image taken from Edmonds, 1993.

A second case study suggests how roads can be manifestations of political instability and help reinforce cultural identities. Scott Hutson et al. (2012) explore the construction of an elevated long-distance causeway in the terminal classic period (250–900 CE) Yucatán. This particular road might have been planned to connect two independent but contemporary city-states across the Mayan landscape. However, the causeway was not finished, resulting in one complete stretch departing from one of the destinations (Tzacauil) and several unconnected sections remaining in the other end (Yaxuná). The authors suggest that the road was not intended as a practical means for communication, but rather as a sign of power and political control from one location to the other. They further interpret the unfinished project as a resistance effort from Yaxuná, or a failed attempt for collaboration. Significantly, the two communities continued to live in the settled areas for several centuries after the failed project, and the road itself became a symbol of identity preservation for each community. This case study illustrates how road placement and connectivity may have helped define social order between two communities, and may have signaled decisions and dispositions of the ruling classes, a common practice through the configuration of spaces and monumental architecture in the Mayan area (Ashmore, 2002).

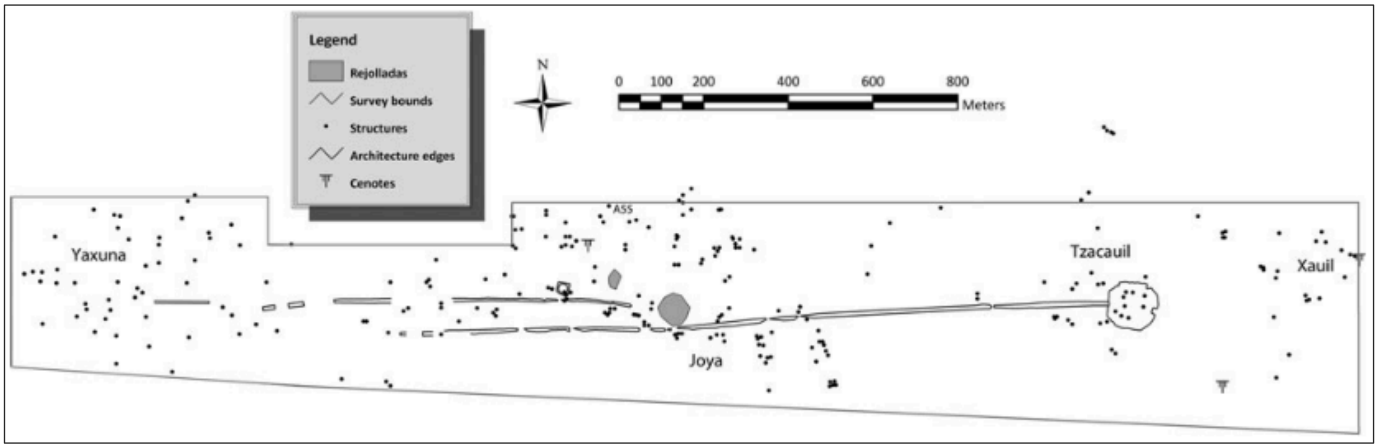

Figure 2.2. Planview of the causeway showing the unfinished or unconnected segments by Yaxuná in Western Yucatán. Image taken from Hutson et al, 2012.

A third investigation helps demonstrate how the shape of the road network can in fact impact the social cohesion of a settlement. Blanton & Fargher (2016) surveyed several pre-modern cities to help describe how urban layouts facilitated interaction and cooperation. One of their examples, the ancient city of Tokyo (*Edo*), Japan (15th century), actually shows the opposite: a system of deliberate obstructions in the network (through moats, walls, gates, etc.) that affected movement and intermingling, but also restricted social organization and neighborhood formation. In this case, the road network was specifically designed, built, and maintained by the state in order to impede residents from creating community and cooperation with the explicit intent of forcing neighborhoods to remain isolated, unable to organize, and dependent on the ruling class. This example illustrates how the structure of the network may constitute a determinant factor for the social integration of a city.

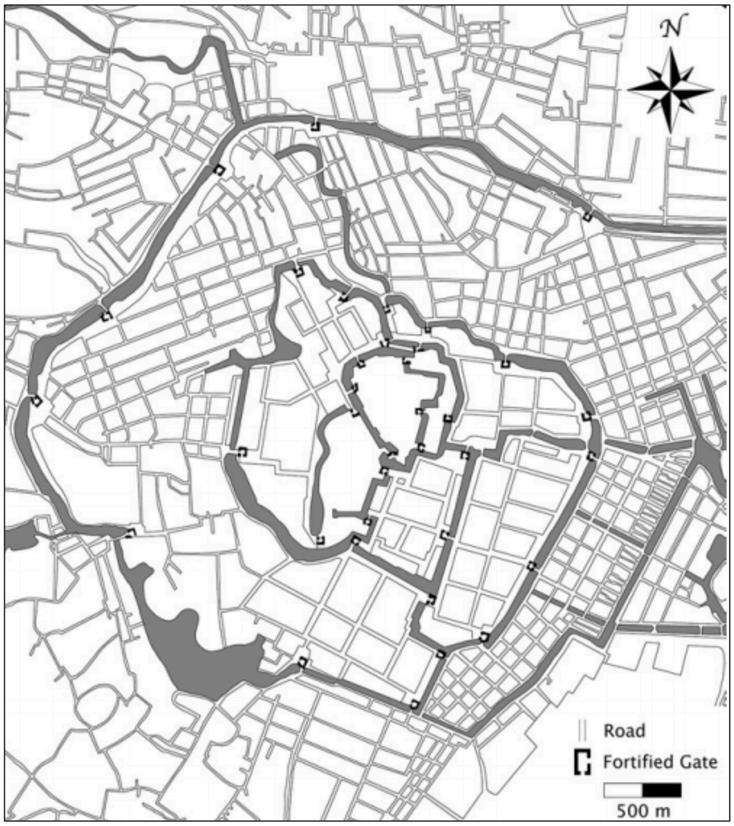

Figure 2.3. Central Tokugawa Edo showing the road network and the moats (dark).
Image taken from Blanton & Fargher, 2016.

Finally, a fourth case study from the Bolivian amazon demonstrates how intra-site movement infrastructure enhanced sociability and social alliances through practices of every-day life. Clark Erickson (2009) mapped the prehispanic canals and causeways of the Baures floodplains in Bolivia. He observed a series of man-made straight canal-causeways (navigable canals) that connected households and terraces. He suggests that these features were planned and engineered networks of social interaction as they do not follow the natural landscape. He observed two types of canals: minor or short canals most likely built by individuals with a strong desire to directly connect with neighbors, and major or large canals, characterized by their impressive number, length, width, volume, and straightness. The major canals were a visible form of monumentality and a means to show community labor, pride, and aesthetic. In sum, the entire network of canals probably facilitated and solidified social interaction. This case study clearly shows that it is possible to observe differences within a network of roads that result from differences in labor for their construction, and that perhaps more importantly, point towards different social impacts and motivations.

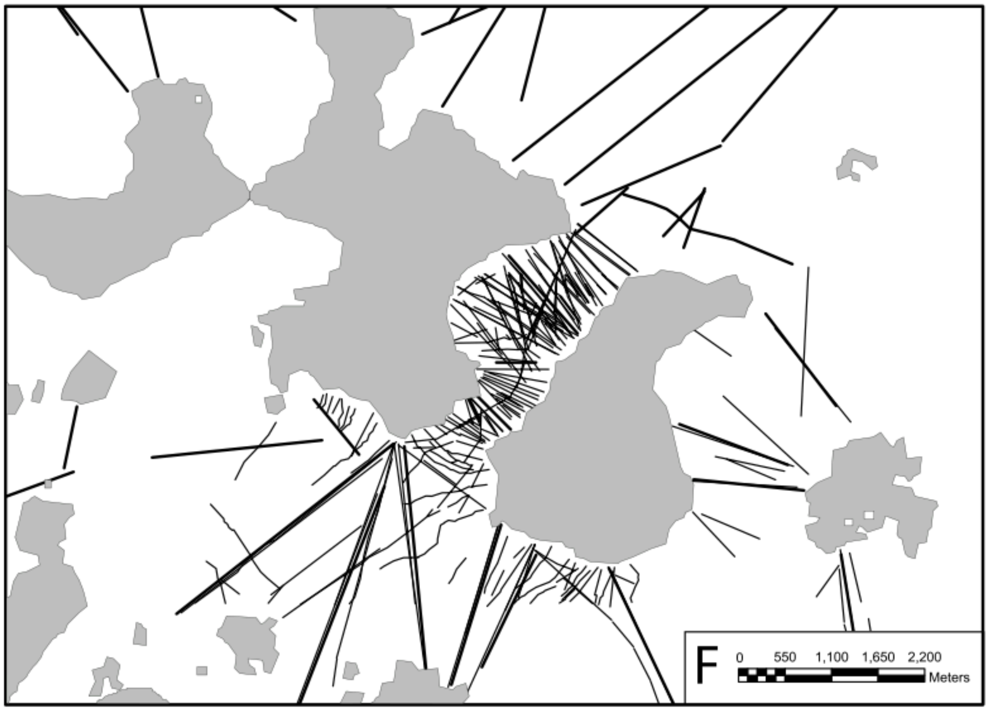

Figure 2.4. Major and Minor Causeways-Canals of the San Martin Forest Island Complex, and example of the work by Erickson. Image taken from Erickson, 2009.

The above investigations demonstrate how the urban plan —taken here as the result of the natural landscape, architecture, and road network together— is a key element for investigating how cities were internally structured and how social groups were defined in a settlement (Green & Perlman, 1985; Hirth, 2003; Stark, 1998). It is therefore clear that road networks merit in-depth exploration and examination.

Traditional work in archaeology has looked at the urban plan from the perspective of settlement patterns and architecture distribution (Parsons, 1972). Yet, I believe that an analysis centered on the road network has the potential to explain particular phenomena of moving around the city, but also, as I have explained here, to reveal social structures in urban life.

However, there are important challenges in the study of roads in archaeology. Two of the most evident challenges are the lack of comprehensive methodologies to study roads from an archaeological perspective (Kaiser, 2011), and the fragmentary state and low level of preservation of road networks in the archaeological assemblage (Trombold, 1991).

In the next section I discuss different archaeological approaches to investigating roads. I look at how previous investigations have collected data in the field (either by survey, mapping, excavation or through remote sensing), what data was used for their evaluation, and their general analytical methods.

2.3. Roads in Archaeology

Research on urban movement is not novel. As I mentioned earlier in this chapter, urban studies, economy (transportation systems), geography, and sociology are some of the scientific fields that have developed methods and ideas to study this process. While the main focus of these fields has centered around contemporary road networks, many of the methods and tools used in these can be readily applied to archaeological roads.

The body of work on movement in archaeology is relatively new and still developing, particularly the work centered on ancient roads. As a result, although there is interest in these features, especially for areas of the world with large ancient urban centers, there is a considerable need for standardized concepts, data collection systems, and analysis methods. Most of the work on ancient roads is highly descriptive and adds information, catalogues, and data, but lacks a set of clear core anthropological questions and methods.

There are isolated examples of research centered on roads, or where roads have been investigated in-depth —mostly at urban centers in the old world— that have introduced new perspectives on daily movement, use and transformation of urban layout, pedestrian interaction, and social organization for the construction of movement infrastructure. It is precisely these research projects that are motivating urban archaeologists to consider road networks as a fundamental focus of research.

2.3.1. Regional roads

The study of road networks in archaeology can be grouped into the analysis of regional roads that connect locations across vast extensions of the landscape and the analysis of urban roads within cities. While the study of roads in Mesoamerica, the Middle East, Asia, and the Mediterranean has been helpful in suggesting the existence of certain social structures —i.e., hierarchical classes and religious affiliation (Cobos & Winemiller, 2001; Gibson, 2006; Hutson, 2014; Keller, 2018; Lipo & Hunt, 2005; Maca, 2006)— the role that roads have played in defining social roles within a settlement has yet to be explored in depth, particularly in Mesoamerica. Archaeological investigations on roads offer valuable reference information on the material and construction aspects of road networks and have primarily focused on the interaction between settlements (Bekker-Nielsen, 2004; Hassing, 1991; Ur, 2003).

Regardless of the amount of transit regional roads supported, interaction in these road networks is likely to have been low and infrequent when compared to transit within an urban landscape. It is unlikely that these roads would have been used on a daily basis or by a large number of individuals —i.e., only those involved in trade (Luo et al., 2014; White & Barber, 2012).

Typically, the use and intensity of regional networks is closely dictated by economic practices or trade periods of the sites that they connected. This is made clear in Hendrickson's analysis of historic regional roads in Cambodia (2010, 2011) and in the analysis of regional scale trade networks in Mexico's central basin and Purépecha areas by Smith (2005) and Pollard (2003). Additionally, the chronology of these regional networks has been defined on the basis of the locations (e.g., settlements) that the roads connect (Saintenoy, 2016; Sheets & Server, 1991).

2.3.2. Urban roads

By contrast to regional roads, studies that have focused on characterizing intra-site road networks deal with everyday social practices and city-shaping phenomena. In general, these studies have explored the complexity of the road configuration within a settlement and have approached the study of roads as the outcome of habitual spaces of interaction, individual decision-making, and community involvement.

Cantona, in the eastern Basin of Mexico, is a large urban center from the Early postclassic period (700–1000 CE) that serves as one such example. Garcia Cook (2003) focuses on how urban roads allow access to most parts of the city of Cantona. Around 1,500 roads were identified and classified according to a typology based on their width, from which function (e.g., public causeways and private passages) was then derived. In the Maya region, Hutson (Hutson & Welch, 2010; Hutson, 2004) points out the contrast between the degrees of shape variation present in smaller roads at Chunchucmil. He suggests that these were most likely the result of an absence of urban planning, while other straighter roads were associated with formal causeways at the site.

Elsewhere, Kaiser (2011) and Laurence (1995) apply analytical principles of Space Syntax (Hillier, 1996; 2005; Hillier & Hanson, 1984) to explore questions regarding accessibility and individual negotiation of space in four Roman cities. Notably, Kaiser focused on the role that obstructions and impasses played in commoners' negotiation for access. Lastly, Branting's (2004) research developed a methodology that incorporates GIS, spatial analysis, and field interventions in order to study the roads at Kerkenes Dag, Turkey. In his study, Branting proposes models of traffic flow based on the urban layout, the topography, and the road network configuration that help explore how people settled in the city. In sum, while inter-site mobility studies provide helpful methodological and analytical tools for exploring road networks, intra-site perspectives have been more relevant for understanding localized social phenomena and their relationship to urban configuration.

Understanding urban configuration has perhaps been one of the greatest contributions to the analysis of ancient road networks. Particularly, archaeologists have confirmed that there are essentially three main archetypes of urban road networks:[2]

1) Rectangular or block pattern (orthogonal):

In this model, roads run to each other at right angles forming a uniform grid. This patterning has been explained as evidence of a strong state figure and explicit social norms that contributed to the planning of a city (Poulter, 2011). This model is generally seen as economically effective, facilitating movement and ordering the space, but it has also been explained as religiously motivated (Boeing, 2019). City sections with this pattern required extensive labor to modify the terrain.

[2] These three urban patterns coincide with what urbanists have observed for modern cities.

Roman cities are good examples of this model (e.g., Kaiser, 2011; Laurence, 1995; Stoger, 2011), although they have also been observed in Mesoamerica, such as in Teotihuacan (Manzanilla, 2001) and the Mayan region (Pugh, 2018).

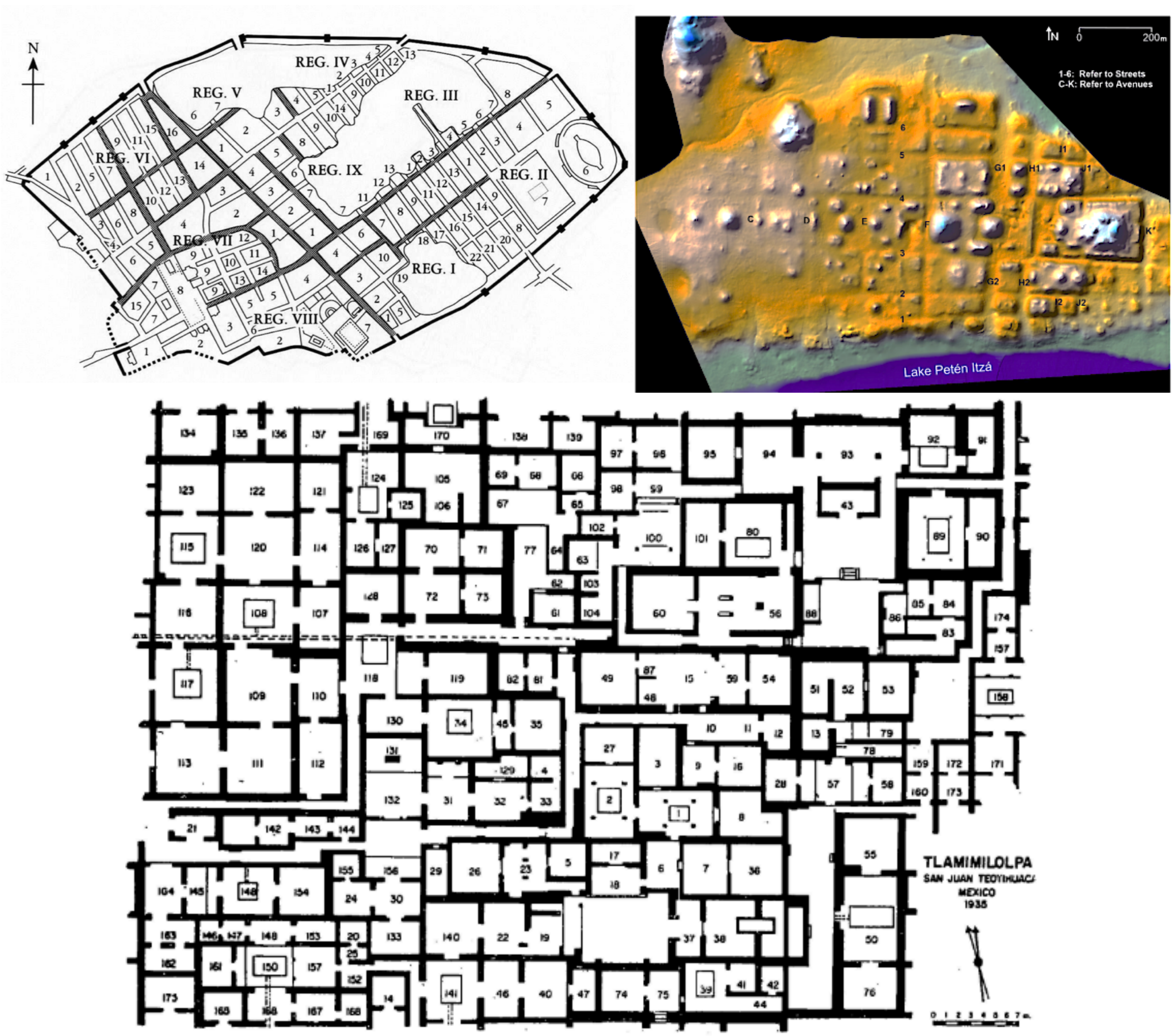

Figure 2.5. Above, left: streets with the highest occurrence of graffiti (messages of public display), in an orthogonal street pattern of Pompeii. Image taken from Laurence, 1995.
Above, right: plan of Nixtun-Ch'ich', Belize with orthogonal streets and avenues.
Image taken from Pugh, 2018.
Below: plan of residential complex of Tlamimilolpa, Teotihuacan. Image taken from Manzanilla, 2001.

2) <u>Radial network</u>:

This pattern is characterized by inner and outer ring-roads linked by radiating roads. Like orthogonal roads, the radial model can be explained as physical manifestations of socioreligious values. However, landscape may have been the more influential force in designing radial road networks. For example, few studies in the Middle East have interpreted radial roadways as the best strategy to connect farmers and draft animals from their city dwelling to their outer fields. Thus radial networks serve as indicators of autonomous and self-sufficient agricultural towns and villages, as opposed to roads designed by a strong ruling class (Ur, 2009; Wilkinson, 1993).

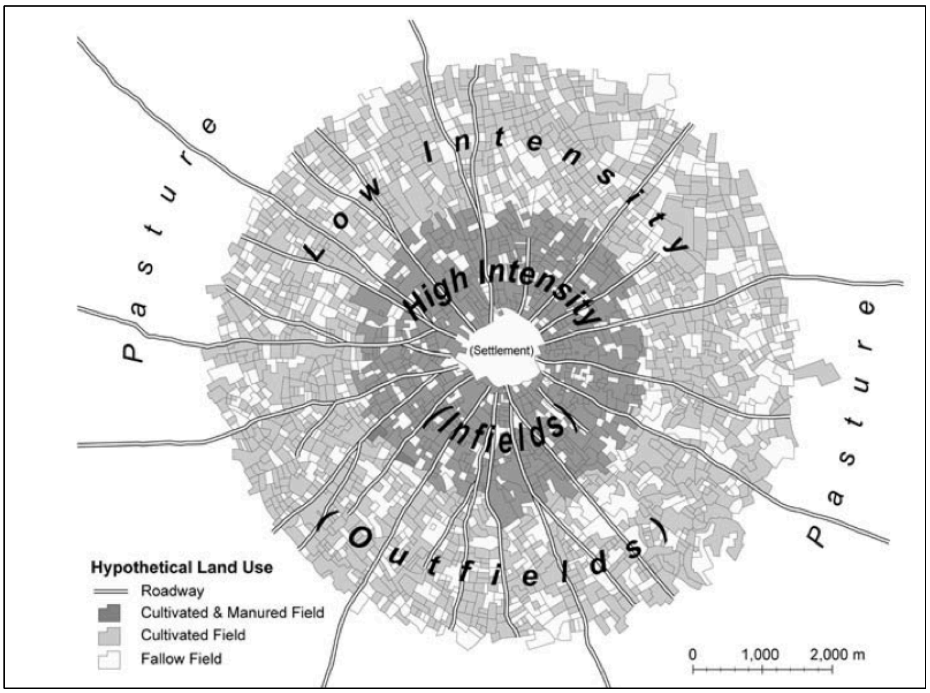

Figure 2.6. Schematic plan of settlement, roadways, and land-use zones in northern Mesopotamia. Image taken from Ur, 2009.

3) <u>Organic city layout (irregular pattern):</u>

In this model, roads are placed opportunistically, depending on social, economic, or religious needs and the characteristics of the terrain. Roads generally follow the topography and the network typically lacks a formal structure. The road sizes vary considerably, and it is common to find curved or sinuous segments. Cities or sections of cities with this pattern have been interpreted as *organic* (made with fewer governing constraints), indicating that the residents either had more agency in how to settle and connect to each other's dwellings, or they had weak economic and political structures (e.g., manpower, organization, etc.) that limited major engineering projects (Smith, 2010b).

Organic city layout is the most common road network pattern in the archaeological assemblage and is often ignored for being considered obvious and interpreted as "natural." I argue that this city layout has the highest potential to understand individual agency and community organization.

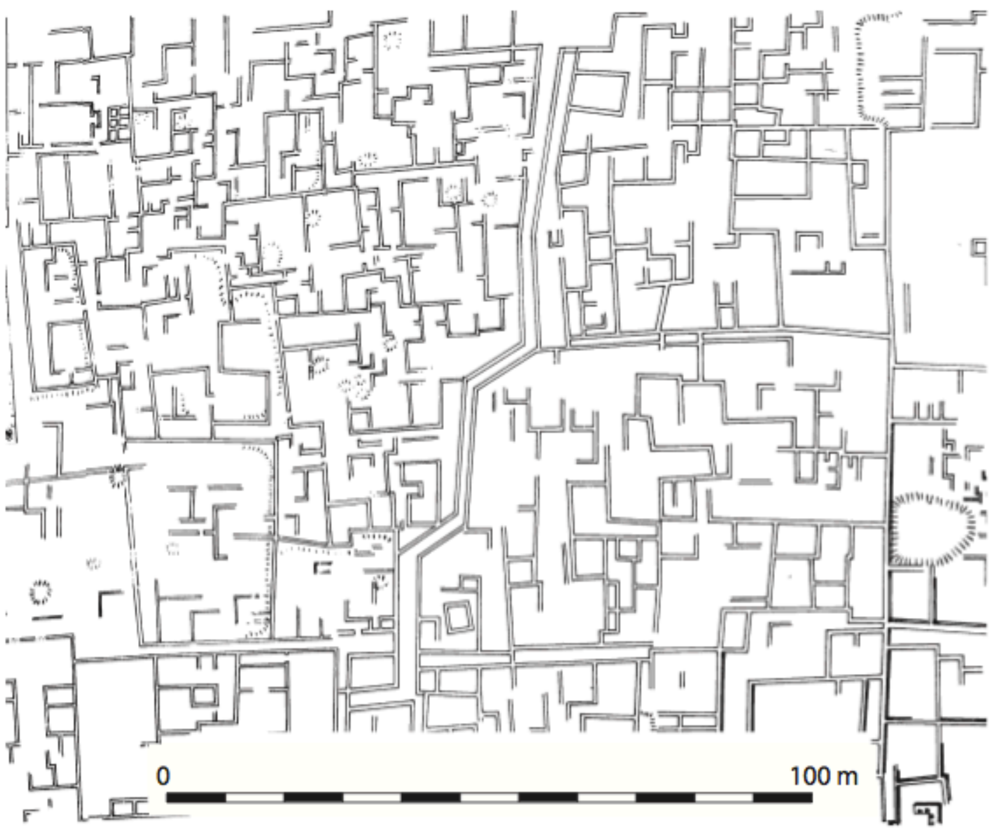

Figure 2.7. Informal urban settlement outside the *Laberinto* compound, Chan Chan, Peru. Image taken from Smith 2010 (who modified from Moseley & Mackey, 1974).

2.4 Roads as artifacts

Roads have functional lives, reflect cultural behavior, and have material and measurable attributes just like ceramic vessels or lithic tools. Exactly like other artifacts, they can be examined through their parts, sorted by their varied attributes —form, function, size, location, shape, time period, the material deposits they hold, etc.— and organized into typologies. They can be associated with trends of human activities —e.g., trading routes — or suggest a single event — e.g., ritual processions—, but just like an obsidian arrowhead from the Paleolithic might be the best indicator of human technology and hunting practices, roads are unique and the best evidence to explore human movement within a settlement. Their material attributes can be abstracted into metrics and shed some light onto their underlying social use and significance.

A systematic study of roads needs to consider what kind of data, or which of those physical attributes, are more relevant for such research. For example, a hierarchical study of commercial routes would consider data associated with the extension or dimension of these routes (Isaksen, 2008), a study of pedestrian traffic would focus on measuring sediment compaction or erosion of pavement (Lipo & Hunt, 2005), and a study of safest routes would evaluate more visible or less secluded roads (Štefanović, 1993).

A large proportion of archaeological studies done on roads, particularly in Europe, Africa and Asia has focused on regional roads, particular types of roads like the ceremonial Mayan sacbe (Hutson et al., 2012) or the ceremonial roads at Angkor (Hendrickson, 2010), and exceptional examples such as Calzada de los Muertos in Teotihuacan (Manzanilla, 2001).

However, those are not characteristics of the roads at Angamuco, Michoacán and would not help explore social phenomena beyond exceptionally unique trips. One of my goals in this research was to understand how roads influence the daily life of residents of Angamuco (and vice versa). In other words, how daily trips to and from common locations influence how residents of all classes might encounter and interact with others, engage with the landscape, create routines, or settle in the land.

Thus, narrowing the scope to study certain roads that would have been used only occasionally and by a selected group of people would be problematic and insufficient. For all these reasons I decided to approach the study of the road network as a whole, not by studying a few single roads, and this required me to identify all the 'parts' that form this global network. The main challenge of this approach lies in making sense of roads as parts of a network when the whole network is not fully preserved. For such, I identified the 'parts' or 'analytical units' of the urban network of Angamuco that would be recognizable in the field and the computer (trough Digital Elevation Models). These analytical units: *segments* and *nodes* are fully explained in chapter four and discussed in chapter seven.

2.5 Overview and objectives

In this chapter I discussed the relevance of focusing on the urban layout to understand how ancient cities were socially structured. Particularly, I described how intra-site road networks have the potential to answer questions about urban development, self-community organizing, and even individual interaction with the landscape. I believe this is fundamental and of great consequence in Mesoamerica, which witnessed the emergence of many large and complex urban centers.

Nevertheless, a significant challenge for archaeologists when studying road networks is identifying roads in the archaeological context. Archaeological features in general are disturbed and damaged from modern urbanization and land use. Roads are even more fragile because they are often made of less durable materials (e.g., trails on the surface) or extend away from concentrations of ancient architecture. In addition, and more significantly, the challenge of studying roads archaeologically is an analytical problem. Roads have been seen as disassociated from the role they play within a road network. Excavation and survey are essential to understanding the materiality and temporality of roads and to establishing parameters that identify when road segments begin, end, or are crossed —e.g., bends, abrupt changes in direction, breaks in the flow of traffic, dead ends, entries into household complexes, etc.—. More importantly, tools like GIS, spatial, and image analyses provide better approaches to studying road networks in their entirety.

This dissertation is centered on the analysis of the urban road network of a unique prehispanic settlement within its own temporal and cultural context in western Mexico: the city of Angamuco, Michoacán. Analytically, it is inspired by numerous studies on how to identify different levels of sociopolitical integration in a city (both from archaeology and urban studies). This work furthermore attempts to make methodological contributions to the identification, registration, and analysis of urban roads in the field.

CHAPTER THREE: Background and case study

Angamuco and Urban Development in the Lake Pátzcuaro Basin

In order to investigate a possible relationship between road network composition and social order using archaeological field and computational methods, I chose the prehispanic site of Angamuco in western Mexico. Its unique landscape and relatively high level of conservation make it a prime location for such comprehensive analysis.

The close relationship between urban layout (road network) and the social structure of a settlement is the result of many social processes (Smith, 2014). In this sense, this chapter attempts to situate the reader within the urban development of polities around Angamuco. The first part of this chapter presents a general review of the history of the Lake Pátzcuaro Basin in light of the archaeological work initiated in the first part of the 20th century. Particularly, this review will focus on the settlement processes and urban development for neighboring sites from the Formative period (1300 BCE) until European contact (1521 CE). Interpretation of the formation, configuration, and function of urban centers in the area from before the foundation of the Purépecha Empire is key for the analysis and discussion of the urban road network of Angamuco.

The chapter concludes with an introduction to Angamuco from the previous investigations performed through several field sessions, master's theses, and dissertations, that include the geomorphology, environment, and first interpretations of its urban layout.

3.1. Lake Pátzcuaro Basin's urban development

In western Mexico, most of the research on the development and urban configuration of polities is still drawn from the following two perspectives: a) the emergence and expansion of Purépecha governance (1250–1530 CE) from its core area around the Lake Pátzcuaro Basin (LBP) outwards (Figure 3.1) (Pollard, 2008), and b) the transformation of the political economy and elite activities after the formation of the Purépecha Empire (Gorenstein & Pollard, 1983; Hirshman, 2008; Maldonado & Rehren, 2009; Michelet, 2008; Pollard & Cahue, 1999; Pollard & Vogel, 1994; Rebnegger, 2010).

The Purépecha Empire covered over 75,000 km^2 of western Mexico and was the most politically and economically centralized polity during the Postclassic period (circa 1300–1530 CE) (Beekman, 2009; Pollard, 1993; Smith & Berdan, 2003). It was organized as a series of realms controlled from a capital located near the LPB (Pátzcuaro, Ihuatzio, and Tzintzuntzan). The Purépecha expanded southward beyond the Balsas River and northward towards the Lerma River in the two centuries following the Empire's foundation. Today, the dimensions of the largest expansion of the Empire cover most of the modern state of Michoacán as well as parts of Colima, Jalisco, Guanajuato, and Guerrero. As it grew, the Empire imposed a tributary system and influenced the social order, religion, and landscape modification of conquered territories (Espejel Carbajal, 2008; Gorenstein & Pollard, 1983; Pollard, 1993).

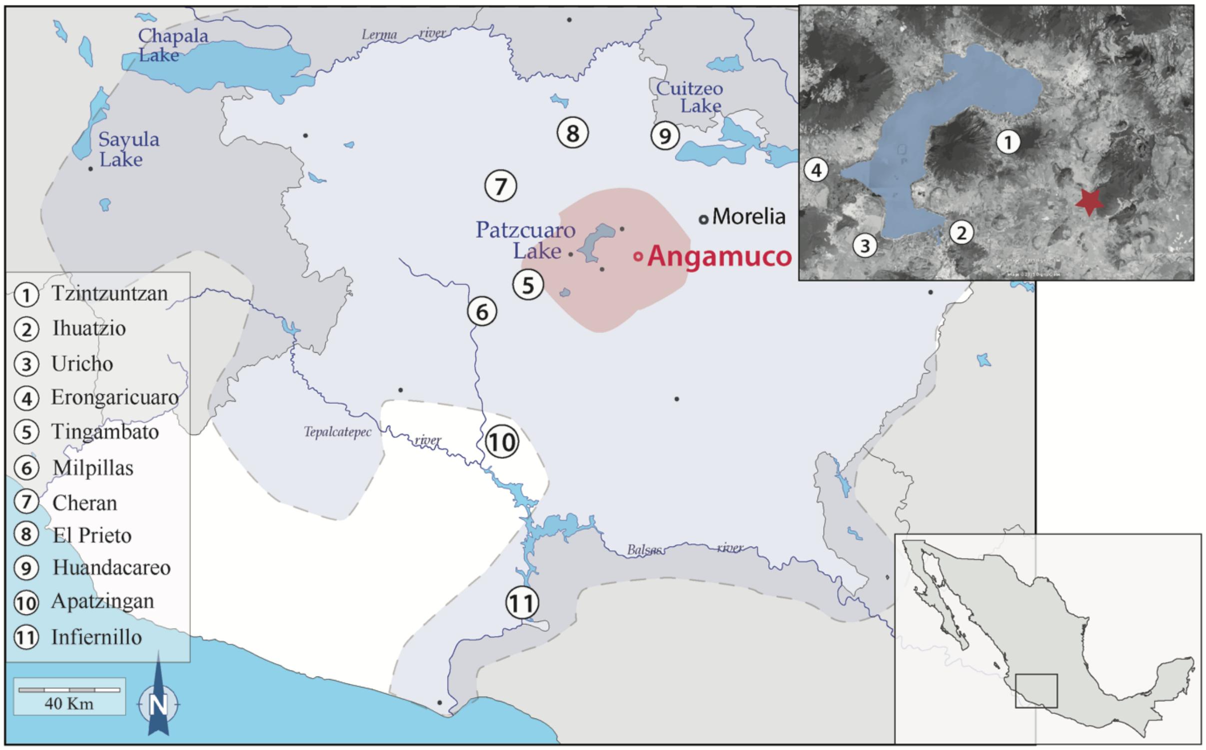

Figure 3.1. Extension of the Purépecha Empire (light blue) showing the location of Angamuco and other important Purépecha sites and the Lake Pátzcuaro Basin. Map modified from Pollard, 2008.

Nonetheless, there is a considerable history of independent urban centers that exhibited various models of social complexity for more than two millennia before the Purépecha Empire. Based on research in adjacent regions, it has been suggested that the first human settlements in the LPB were most likely small villages with few architectural structures and very localized cultures that continued developing until 250 BCE (Haskell & Stawski, 2017; Pollard, 1993; Pollard & Cahue, 1999; Rebnegger, 2010). Small-scale agrarian societies characterized by unique ceramic technologies and burial practices developed into complex socio-political structures by 400 CE (Beekman, 2009). What followed were two major cultural transformation periods attested by stylistic variation in artifacts, architecture, mortuary practices, and local economic adaptations. The first major transformation took place between 500–900 CE (Epiclassic) and is characterized by the emergence of the city-state model. The other major transformation occurred between 1350–1450 CE (Late Postclassic) with the development of capital and tributary city models during the formation of the Purépecha Empire (Michelet, 2008) (see Figure 3.2).

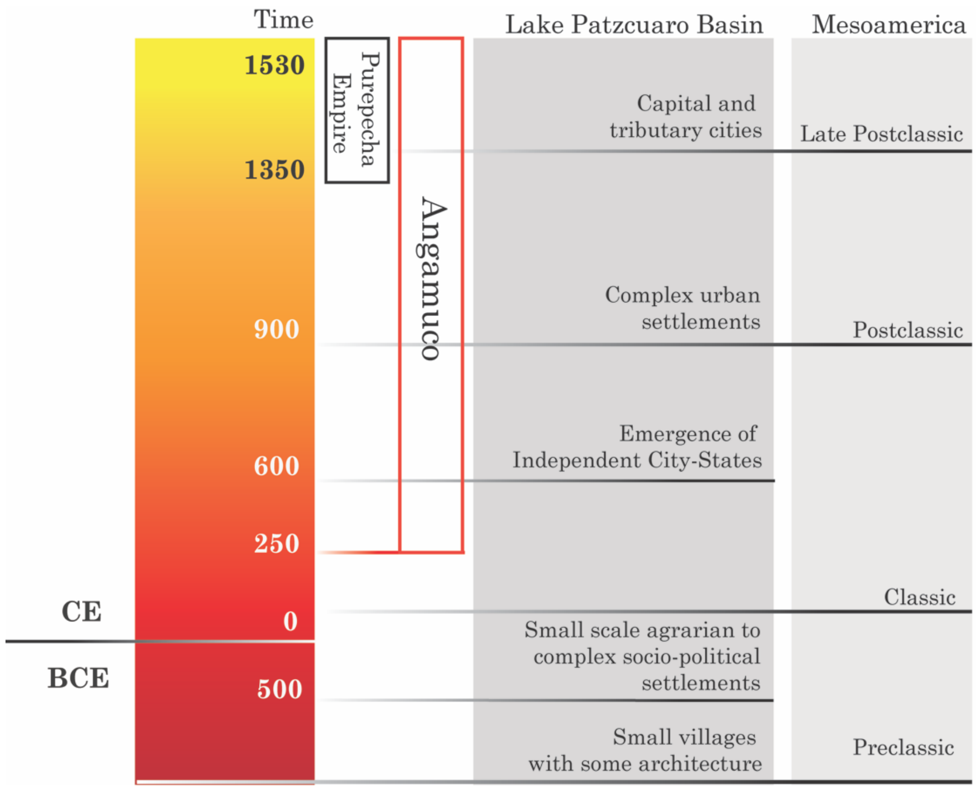

Figure 3.2. Chronology of the Lake Pátzcuaro Basin and Angamuco. Modified from Cohen 2016, Fisher et al., 2019, Pollard 2008, Haskell & Stawski, 2017.

Most of our understanding of the interaction between the Purépecha capitals and their tributary cities during the late Postclassic period (1350–1530 CE) comes from descriptions of limited ethnohistoric sources[1]. Some Purépecha cities were established by the Empire as religious, political, or commercial centers, such as Ihuatzio and Tzintzuntzan, and others were subjugated through military domination, such as Pátzcuaro and Urichu (De Alcala, 2012 [1541]). It is assumed that conquered polities maintained some form of local self-governance that

[1] Among the most important ethnohistoric sources is the *Relación de Michoacán* (Alcalá, J. de, 1541). Several other documents including maps, legal, and ecclesiastic documents from the 16th century, and additional chronicles have also been useful for understanding the cultural development of the Empire.

incorporated elements of the sociopolitical and economic Purépecha models (De Alcala, 2012 [1540]; Espejel Carbajal, 2008; Warren, 1985). Eventually, once incorporated into the Purépecha Empire, cities were organized following a pattern of districts and neighborhoods. These social units may have been defined by kinship or ethnic groups, task specialization, tributary collection systems, or a combination of these factors (Espejel Carbajal, 1992; Martinez Baracs, 2005).

Archaeologically, the urban layout of Purépecha cities has been explored primarily by Pollard through the analysis of the distribution of ceramics and lithic tools, as well as the function associated to material assemblages in Tzintzuntzan and Ihuatzio. Pollard, in line with the ethno-historic sources, proposed the Purépecha city model (Pollard, 1977; 1993; 2003). It is very likely that the urban layout of these cities was never fully standardized, which explains the different urban configurations in Purépecha cities.

In the case of pre-existing pre-imperial cities, the Purépecha incorporation may or may not have resulted in significant changes in the extant urban layout. Social units, such as districts and households, may have responded differently to interior and exterior forces, as has been suggested for other areas of Mesoamerica (e.g., Carballo, 2010; Hirth, 2003; Monnet, 2003). Other archaeological work in areas distant from the core-center (beyond LPB) and along the borderlines of the Empire suggests a slower acceptance of the adoption of Purépecha socio-political governance models, a process that was interrupted by the European conquest (Lefebvre, 2011; LeFebvre, forthcoming; Liot & Urrea, 2011; Michelet, 2008). Nevertheless, a handful of scholars have characterized the urban layout of polities in the Zacapu, Cuitzeo, and Sayula Basins, as well as the eastern borderline of the Empire as slight variations of essentially the same Purépecha urban model. For example, these cities were all developed around a central ceremonial center and were organized in residential zones (elite and commoner), public zones, and manufacturing zones, but had different construction systems, architectural configuration, and ethnic composition from one other.

These urban variations seem to be the result of external/internal forces, regional ethnicity, and differences in the existing landscape (Darras, 2008; Foster, 2014; Pereira et al., 2011; Valdez & Liot, 1994). It is unclear whether or not these differences represent variations of the mapping of Purépecha characteristics onto already existing local models, variations within the Purépecha model, or are the result of competing urban expressions.

These variations are important in the study of Angamuco, particularly in light of the long periods of habitation that preceded the formation of the Purépecha Empire at the site. Sociopolitical models have been suggested in other sites/regions where connectivity between areas of activity and residence has held a more important role. For example, the *Altepetl* model (Hirth, 1992), and collective action urbanism models (Blanton & Fargher, 2011). However, in all of these models, roads are seen mainly as a byproduct of human settlement, commercial activity, and regional communication systems. More importantly, the social interactive relationship between roads and people is not considered as a factor when explaining the spatial layout and transformation of a city.

The site of Angamuco is a unique location to study how the urban layout might have been transformed because of the Purépecha Empire, and how urban roads might reflect some of these transformations both physically and socially. Angamuco's long history —before and during the Empire—, landscape, state of conservation, and distinct road network make it an ideal case study for such research.

3.2. Angamuco

The site of Angamuco (250–1530 CE) is located on the eastern edge of the LPB and is situated about 13 km northeast of Pátzcuaro and 7 km southeast of Tzintzuntzan, respectively the first and last capitals of the Purépecha Empire (Pollard, 1993) (Figure 3.3). Angamuco was first studied in 2009 during a regional survey as part of the NSF-funded *Legacies of Resilience: The Lake Pátzcuaro Basin Archaeological Project* (LORE-LPB) (BCS 0818662), directed by Christopher T. Fisher (Colorado State University), and excavation under a separate NSF grant (BCS 1220016) from 2013 to 2014. This research, together with the data summaries and analysis published the following years of work, has provided information on the socio-temporal model of the site (e.g. Fisher et al., 2017, 2019b, Fisher & Leisz 2013). The following section summarizes some of the main findings and interpretations reported in these publications and reports.

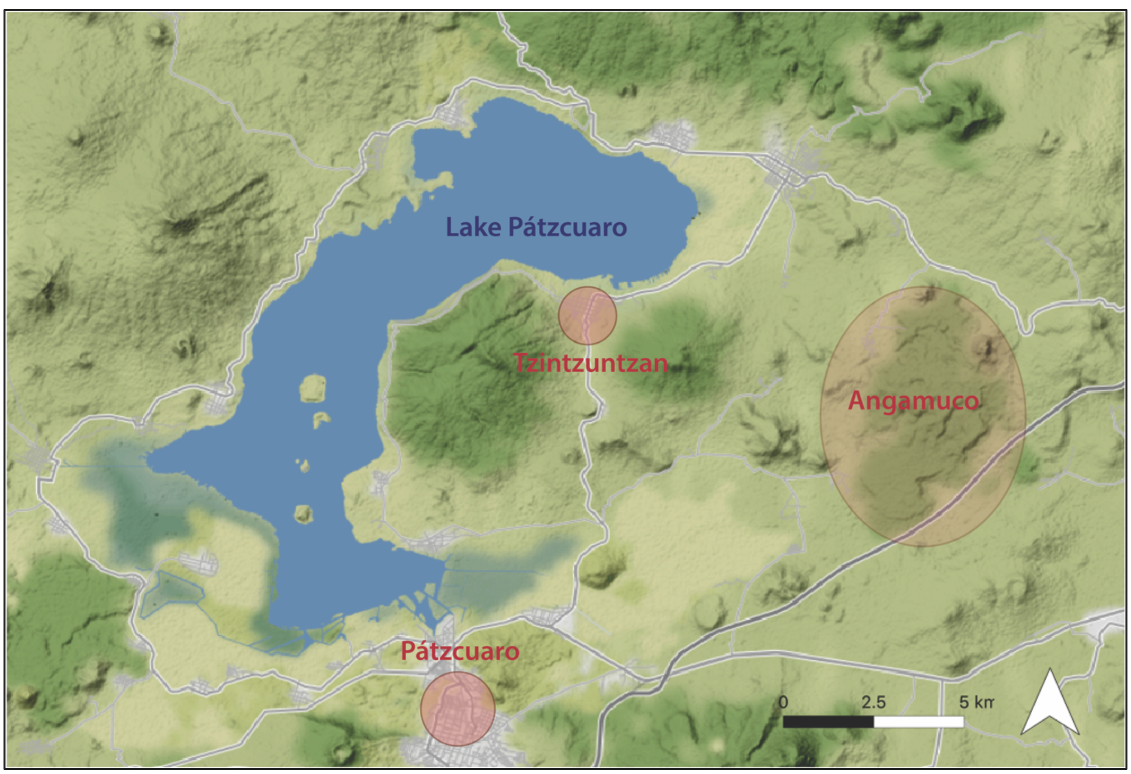

Figure 3.3. Map of the Purépecha Core-region around the LPB showing the first (Pátzcuaro) and last (Tzintzuntzan) capitals of the Empire in red circles. The circles only represent the location of these sites.

The size, complexity, and organization of Angamuco suggest that it was undoubtedly an important urban center in the lake basin that predated as early as 250 CE the Purépecha Empire and continued during the formation of the Empire through 1300–1400 CE.

Five years of full coverage survey, excavation, and analysis of this site (LORE-LPB 2009–2014)[2] indicate that for much of the Postclassic period, the city may well have hosted a population of over 30,000 inhabitants with an extensive built environment comprising over 40,000 architectural features situated on a malpaís (mid-Holocene lava flow), with an overall size that exceeded 6 square km.[3]

The rugged terrain characterized by large amounts of volcanic boulders on the surface, a diverse topography, and shallow soil deposits have proved unsuitable for post-conquest settlement and modern agriculture and thus, has remained virtually unaltered since its abandonment in early 1500s. This makes the overall prehispanic urban layout (architecture) and road network easily identifiable on the surface.

Angamuco is primarily located over two main lava flow episodes from the nearby El Aguila Volcano that form Upper (>2100 masl) and Lower malpaís zones (<2100 masl).[4] These two different areas are separated by an escarpment of ~40 m high that surrounds the southern half of the site —a type of natural barrier. Furthermore, these two lava flow episodes together with other subsequent smaller episodes are responsible for the hills, valleys, ridges, gullies, and

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[2] In addition to three dissertations that have stemmed out of the project (Cohen, 2016, Urquhart, ongoing, and this dissertation) that have focused on unique topics and collaborate to the general cultural understanding of the site.

[3] In spring of 2016, during the planning for this dissertation fieldwork, a supplemental lidar scanning of an additional ~20 km^2 to the north of the site was acquired by LORE-LPB. This data was not fully processed and analyzed until fall of 2017 once the fieldwork and image analysis for this research were finished. There are proposals that suggest the site had a total extended area of 26 km^2 and thousands more built structures. This, however, has yet to be confirmed archaeologically, and until then, this research is limited to the known extension of the site informed by the first lidar scanning of 2011 plus three full-coverage surveys and two excavation sessions between 2009 and 2014.

[4] Upper and lower zones will be referred as Upper Angamuco and Lower Angamuco throughout this dissertation. See chapter seven for a more detailed description.

other such natural geological features in this area. This irregular terrain, and the availability of material for construction (in this case, medium-size basalt boulders) was readily exploited through countless episodes of human modification. For example, much of the soil development on the malpaís are anthrosols, the result of human activity (Cohen, 2016).

Upper Angamuco is an environmental zone densely covered by forests dominated by oak, *madroño*, pine, maguey, and nopal. Lower Angamuco which originally extended to the lake shore to the east has largely lost its native forests to allow the development of milpa-style non-mechanized agriculture by the local ejido community, a practice limited to the flood zones or water reservoirs in ancient times (Figure 3.4). The area is also characterized by the presence of several other water sources from springs and underground water reservoirs for wells, and lush vegetation that attracted numerous birds and small to large mammals. All these factors have contributed to Angamuco attracting settlers continuously for over 1,300 years (~250–1530 CE).

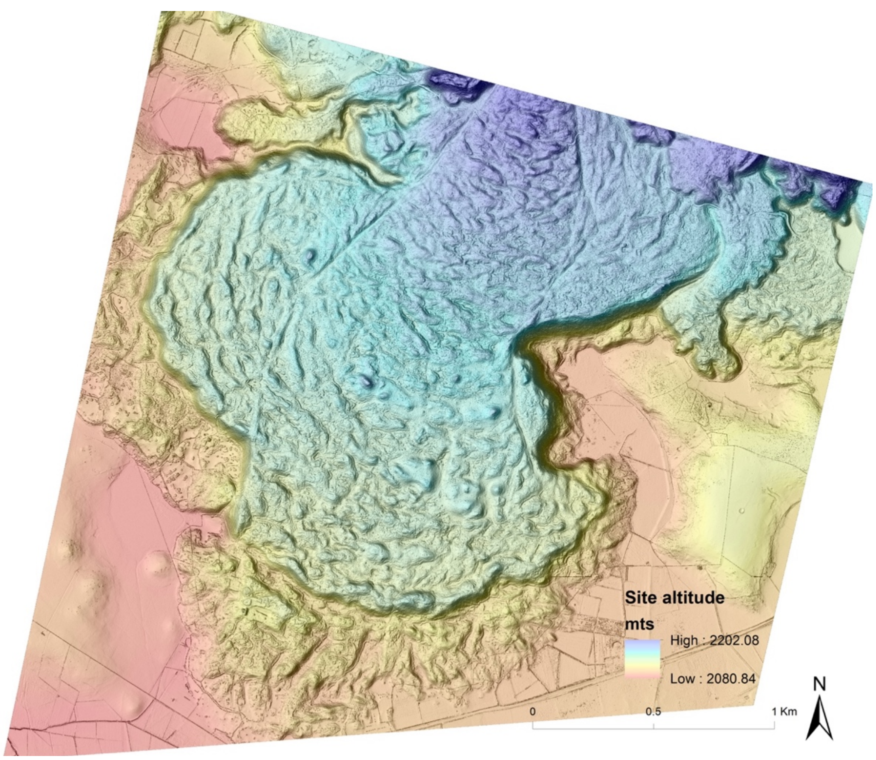

Figure 3.4. General map of Angamuco showing elevation of topography. Blue marks the second lava-flow event that formed the Upper Angamuco area. Below, yellow areas show Lower Angamuco.

3.2.1. Angamuco chronology

The Angamuco occupation model is constantly under revision as new evidence appears. However, at the time of this dissertation, the model suggests that there were various periods of settlement with both slow and rapid transformations of the landscape for an extended time span of ~1,300 years (Fisher et al., 2019b).

During the Classic period (250–600 CE), the first residents initially settled on the lower parts of the site due, most likely, to the close access to the lake shore and other water sources. This is similar to other urbanization processes in the area at this time. Eventually, and as a response to constant flooding during lake transgression and regression episodes, occupants moved to higher landforms relatively close by within the site (see Cohen, 2016 for discussion).

The following ~500 years, from the Epiclassic to Early Postclassic periods (600–1100 CE), residents slowly moved towards Upper Angamuco, above the escarpment. This period did not represent a complete abandonment of Lower Angamuco; however, it is likely that preference for higher ground was made to occupy hilltop defensible positions due to large population movement across the area from lake regressions and natural environmental transformations such as volcanic action.

Middle to Late Postclassic periods (1100–1530 CE) saw widespread resident resettling, mainly influenced by the emergence of the Purépecha Empire. Elites preferred Lower Angamuco, probably once the Empire had developed techniques to stabilize Lake Pátzcuaro fluctuations and the shore receded permanently (Fisher, 2005). For the centuries that followed, from the arrival of the Purépecha Empire until the European conquest, Angamuco seems to have continued expanding in all directions of both zones, stopping only at the natural topographic and environmental boundaries of the malpaís landforms (Table 3.1).[5]

DATES (CE)	PERIOD	OCCUPATION AT ANGAMUCO
After 1521	Colonial	Conquest and abandonment of Angamuco
1350–1525/1530	Late Postclassic	Expansion of residents towards all areas of the malpaís
1000/1100–1350	Middle Postclassic	Elite settles back in Lower Angamuco
900–1000/1100	Early Postclassic	Expansion towards Upper Angamuco
600/700–900	Epiclassic	Residents move towards Upper Angamuco zone and higher landforms
550–600/700	Middle Classic	
250–550	Early Classic	First settlers move to lower areas of the site

Table 3.1. Chronology of Angamuco's occupation model.

3.2.2. Angamuco urban layout

The architecture of the site relies on the volcanic stone (basalt) that is native to the site, generally without any type of cement or mortar, although a few buildings have shown evidence of the use of mud. Externally, built structures are modest, simple, and unsophisticated. Some buildings can be massive (>6 m tall) but the styles are unadorned —e.g., stones do not seem to have been faceted, carved, covered in stucco, or painted. The architecture includes variations of rectangular and circular rooms, platforms for building complexes, buildings composed of several rooms, open and sunken plazas, yácatas,[6] terraces with retaining walls, storage rooms, wells, and

[5] A more detailed description of the chronology of the site and the evidence that has been used to build this model is presented in chapter five.
[6] Yácatas are unique forms of religious buildings in the Purépecha Empire. They have a key-hole shape or a combination of circular and rectangular bases with front and back sides used for ritual celebrations.

other urban forms. These architectural structures can be classified into ritual, residential, economic-subsistence, and urbanistic categories (see Table 3.2 for examples) (Bush, 2012; Cohen, 2016; Fisher, 2010; Fisher et al., 2012, 2014, 2019a).

CATEGORIES OF ARCHITECTURAL STRUCTURES AT ANGAMUCO

CATEGORIES	EXAMPLES
Ritual	Cemeteries, open plazas, sunken plazas, and religious buildings
Residential	Elite and non-elite housing
Economic and subsistence	Markets, farming areas, terraces, patios, quarries, Areas for clay and wood extraction, storage rooms, workshops, wells, springs, water catchers, natural and artificial water tanks.
Urban	Middens/trash pits, drainage/runoffs, walls, roads, entrances, stairways, bridges, and ramps

Table 3.2. Broad categories of architecture during the Postclassic period in Angamuco, Michoacán, based on LORE-LPB and ethnohistoric sources (Fisher et al., 2019a).

The diversity of buildings in the city is ubiquitous and recurs throughout the city. For example, ceremonial centers, plazas, and farming terraces appear in all areas of Angamuco. Importantly, the site presents a complex road network that includes road segments of different sizes and extensions, as well as crossroads covering all areas of the site.

In order to better comprehend the dimension and extension of the city, full-coverage archaeological surveys were done in 2009, 2010, and 2011, and Airborne Light Detention and Ranging (Lidar) scanning were conducted in 2010 and 2016. As a result, we have detailed coverage of 100% of the site. This data has additionally provided a new understanding of the urban layout of the city through the identification of clusters of architectural features enclosed by possible roads using visualization of high resolution (25cm) Digital Elevation Models (DEM).[7]

[7] See chapter four for details on lidar.

This rich database provides yet another avenue to archaeologically explore the roles of the road network and the organization of the urban space.

Following the concepts of urban morphology and space syntax (Smith, 2010), Fisher and Urquhart have interpreted clusters of architectural features in order to develop a socio-spatial configuration model for Angamuco (Fisher & Leisz, 2013; Urquhart, 2015). These occur at three scales of organization and spatial dimensions:

a) *Complejos* or groups of households and other architectural features

b) *Neighborhoods* or groups of complejos

c) *Districts* or groups of neighborhoods.

Road segments are primarily responsible for defining these social clusters in combination with natural topography and built environment.

Before this dissertation research, it was unclear whether these road-like features acted as social boundaries, and if so, whether they were deliberately created and subsequently planned, constructed, and maintained, or if they were the result of natural corridors and/or emergent self-organizing processes (e.g., Helbing et al., 1997). Fisher (2011, 2013) used the presence and length of road-like features to produce a preliminary interpretation of the city layout into the three aforementioned social units. Fisher's proposal clearly aligns itself with the city model suggested by ethno-historic sources and previous researchers in the area (Pollard, 1993; 2003).

Angamuco, however, was at least partially populated and with indications of an earlier urban plan since the Early Classic period (~250 CE), several centuries before the Purépecha Empire was developed (Fisher et al., 2019b) (Table 3.1). Therefore, the applicability of the Purépecha city model would only hold if this model was actually older and later adopted by Purépecha cities, instead of having originated with the Purépecha Empire. Thus, it is critical to the understanding of the Empire's influence at the site that the earliest socio-political urban model for Angamuco is fully investigated.

Before this dissertation, certain features such as staircases, entrances, elevated segments, walls, or breaks in topography had been observed along and across roads through survey, however, they had not been identified or classified, and their relationship with the road network was not fully understood. As it was at the time of this dissertation, the urban plan of Angamuco presented three main problems: 1) roads were not entirely identified; 2) features associated with roads, such as blockages and entrances, were not completely identified, and their roles were not well understood; and 3) it was unclear to what extent the road network of the city had remained the same or was transformed throughout its 13 centuries of inhabitation (250–1530 CE). There is still uncertainty on the architecture variation and the cultural development of this massive urban center —a work that will continue for decades— especially in view of the recently acquired lidar for the site that would expand Angamuco to over 25 km^2. The following chapter outlines the structure of this research, the guiding concepts, and the field methods for mapping, recording, and excavating roads at Angamuco, as well as the identification of the road network through computational analysis.

CHAPTER FOUR: Field methods

Identifying roads (creating and collecting data)

One of the biggest challenges to studying roads is understanding precisely what data is necessary to collect. In other words, identifying explicitly what material evidence would help answer the research questions and how to collect it. Particularly, because the archaeological study of roads is not common, and there are few examples within Mesoamerican contexts that guided this research, designing the best strategies to collect data for further analysis was an essential and challenging part of this dissertation. The main two goals for this stage were: 1) To identify all possible man-made and Prehispanic roads of Angamuco, and 2) To collect data that would inform on the morphological (shape), physical (dimensions), temporal (chronological markers), and experiential (effort, visibility, direction, etc.) characteristics of the entire road network. This chapter will discuss the field and computational methods developed and adopted to meet these two goals, as well as my expectations and sampling strategies.

These methods are divided into two stages of data collection:

Stage 1: The processes used for identifying roads, which include work in the field site (survey and excavation); and,

Stage 2: The digital extraction of the roads (lidar survey).

During the first part of this chapter I discuss how I chose the analytical units for the study of the road network (*nodes* or road intersections, and *segments* of roads) and their anticipated attributes. In general, I was successful in identifying the entire road network of Angamuco. Two unique factors were fundamental to this success: the outstanding state of conservation of the site;

and the possibility of gaining access to high-resolution Digital Elevation Model (DEM) of its surface, produced from the lidar scanning of 2010.[1]

The following section of the chapter centers on Stage 1: the field survey and mapping methods I developed for the specific characteristics of Angamuco's landscape (rugged terrain, extended area, dense vegetation, and vast number of architectural features). This task provided me and my crew of field archaeologists, the opportunity to document 344 road segments, 316 nodes, and to collect over 700 artifacts from the surface during a period of 5 weeks. I have included a summary of the data and artifact cataloguing, coding, and documenting protocols.

Next, I describe the rationale for the excavation strategy, which includes a combination of vertical and horizontal techniques and a mix of test pits and trenches across the width of roads. Here I also discuss how I selected the areas for testing that ultimately allowed me to collect a sample of different types of roads. I leave the description of the stratigraphy, cultural deposits, and documenting strategy for chapter five.

Stage 2 is focused on the image and computational analyses for the digital extraction of roads from the DEM. This stage addresses the rationale behind data collected, its standardization; the procedure to derive road data from DEM and the topological rules that were implemented. This process took about 12 months and was finished thanks to the collaboration of undergraduate volunteers working with me at the DigAR Lab.

[1] See chapter three.

4.1. Goals and expectations of fieldwork and lidar survey

The goals that guided the design of fieldwork and computational methods stemmed from the following questions: How can we identify roads or their remains in the archaeological assemblage? What material objects are associated with human movement? Are roads bounded units and, can they be measured? Can we infer experience of traveling by studying physical characteristics of roads? How can we approximately date when roads were created, used, or abandoned?

The processes and techniques used by archaeologists to identify and measure roads (paths) in the field are not well defined or established. This is because while some roads (or road sections) can be very easy to recognize in the ground, like the elevated causeways in the Maya region, pathways in the arid landscapes of Mesopotamia or American Southwest, or the paved surfaces of Roman roads, the vast majority of roads are much more challenging to identify.

The following are my main expectations that would result from fieldwork and computational (lidar) survey:

1) I expected that the field survey and mapping of roads would provide a sample of the diversity of roads likely made by humans prior to 1530 CE including their morphology and some aspect of their experiential attributes. To this end, I intended to fully cover three to four areas of the site (~10% of the total surface). These areas should represent various regions of the site including both previously surveyed and unexplored regions. This sample of roads would be comparable to sampling strategies used in other sites of Mesoamerica (e.g., Garcia Cook, 2003; Hutson & Welch, 2010).

2) I also expected to excavate a sample of different types of roads in order to collect evidence that could be used for absolute and/or relative dating, and to determine whether there was any evidence of architecture that could be used to infer intentional planning.

3) My third expectation, specifically with regards to computational mapping of roads, was to recover >90% of all roads within the site (the extent of my DEM) and thus, identify the layout of the road network in its totality.

The distinction between these goals has to do with the kind and scale of data. Points 1 and 2 provided more detailed data of a few roads, and point 3, a more global dataset of the complete network, or less detailed data but for more roads.

In general, I was able to achieve these goals. Details are described in the following sections.

4.2 Analytical units to study road networks

Outside archaeology, other disciplines including urban studies, architecture, or geography have provided methodologies, techniques, and frameworks from the context of contemporary urban centers to study road networks (e.g., Hillier, 2007; Louf & Barthelemy, 2014; Marshall, 2006). In order to measure and analyze roads, they have to be represented in some form of analytical units. There are several methods to do so that stem out of geometry and mathematics, such as *graph theory*. In this theory, the graphs are data structures that represent relations and connections of geographical units (data) in two forms: nodes and edges each with their own attributes (Telega, 2016).

A whole suite of methods and approaches have developed once the data has been represented as nodes and edges (e.g., Crucitti et al., 2006; Isaksen, 2008; Kirkley et al., 2018).

Among these, and particularly for the analysis of road networks, two useful approaches (each one with their strengths and limitations) have been distinguished by Porta et al, (2006b,a) as the *primal* and *dual* approaches:

1) The *primal or direct* approach turns road intersections into *nodes* and represents them as points in the graph (although they can also be represented as polygons or areas depending on the analyses) and roads are turned into *edges or links* (that I call *segments*) between those nodes and represented as axial lines in the graph (Figure 4.1 top); and

2) The *dual or indirect* approach which switches these representations so that roads are represented as *nodes* (points) and the intersections as the *edges* (lines) in order to highlight the relationships between nodes (Figure 4.1 bottom);

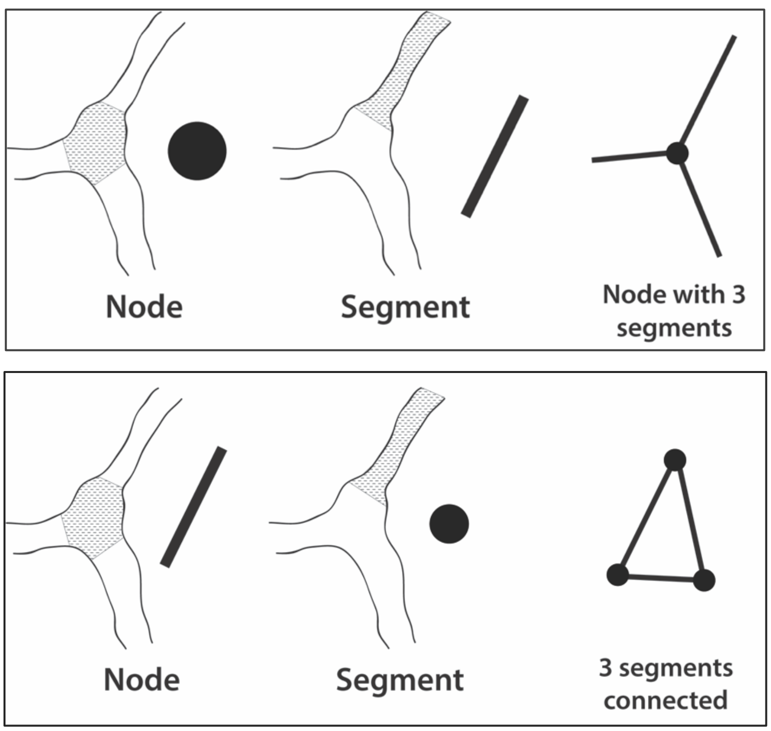

Figure 4.1. Top: Example of primal approach for roads. Left: shaded area represents a road intersection or a node. Center: shaded area represents a road or segment. Right: graphic representation of a node with three segments. Bottom: Example of dual approach with reversed representations of elements. In this case, what is highlighted is the type and direction of relationship or connection all segments have.

There are two main perspectives to study roads in archaeology that is worth clarifying.

On the one hand, there are several good examples of archaeologists who concentrate on unique roads (whether there are in regional or urban contexts) (e.g., Tikal in Hohmann-vogrin, 2005). Roads here, are seen as linear features that connect an origin to a destination. The shape, influence, experience, prevalence, or any other quality of the road can be explored from different perspectives, but these qualities are always founded on the basis that a road is one unique route between two points. In this case, roads are existing features, known and/or identifiable by the users. The *dual approach* has been used in archaeology for this kind of work. Particularly, Space Syntax —a collective of conceptual and analytical techniques that has become a dominant method to study movement and urban forms in archaeology.

On the other hand, studies of road networks that are more interested in the global composition of the entire network. Again, roads are linear features, but in this case, roads or routes are created at the moment of travel. The network is in reality a movement infrastructure that has the potential to create multiple routes with many origins and many destinations, some of them recurrent. The roads are created by users according to their needs, skill, ability, the physical expressions of the network itself, etc. For example, a person can choose to take the same route for a second trip between the same two points, but could also take a detour, or even change the route completely, and the reasons for those decisions can be based on a myriad of factors. In this sense, a network is composed of linear segments that allow movement, and the points of intersection between these. It is precisely because of this view of the road network —as a structure with the potential to create many routes— that I have decided to adopt the *primal approach*.

The dual approach is based mainly on qualitative observations of unique routes or roads. It is very useful for characterizing the relationships between roads. Nonetheless, it often requires that the destinations and origins to be known a priori, that some aspect of rank is associated to roads depending on what locations they are connecting (e.g., Figure 4.2), and assumes that the network is contemporaneous. In contrast, the *primal approach,* as it has been applied in archaeological research, is the best strategy for identifying origins and destinations and explore the network without ranked nodes, segments, and destinations.

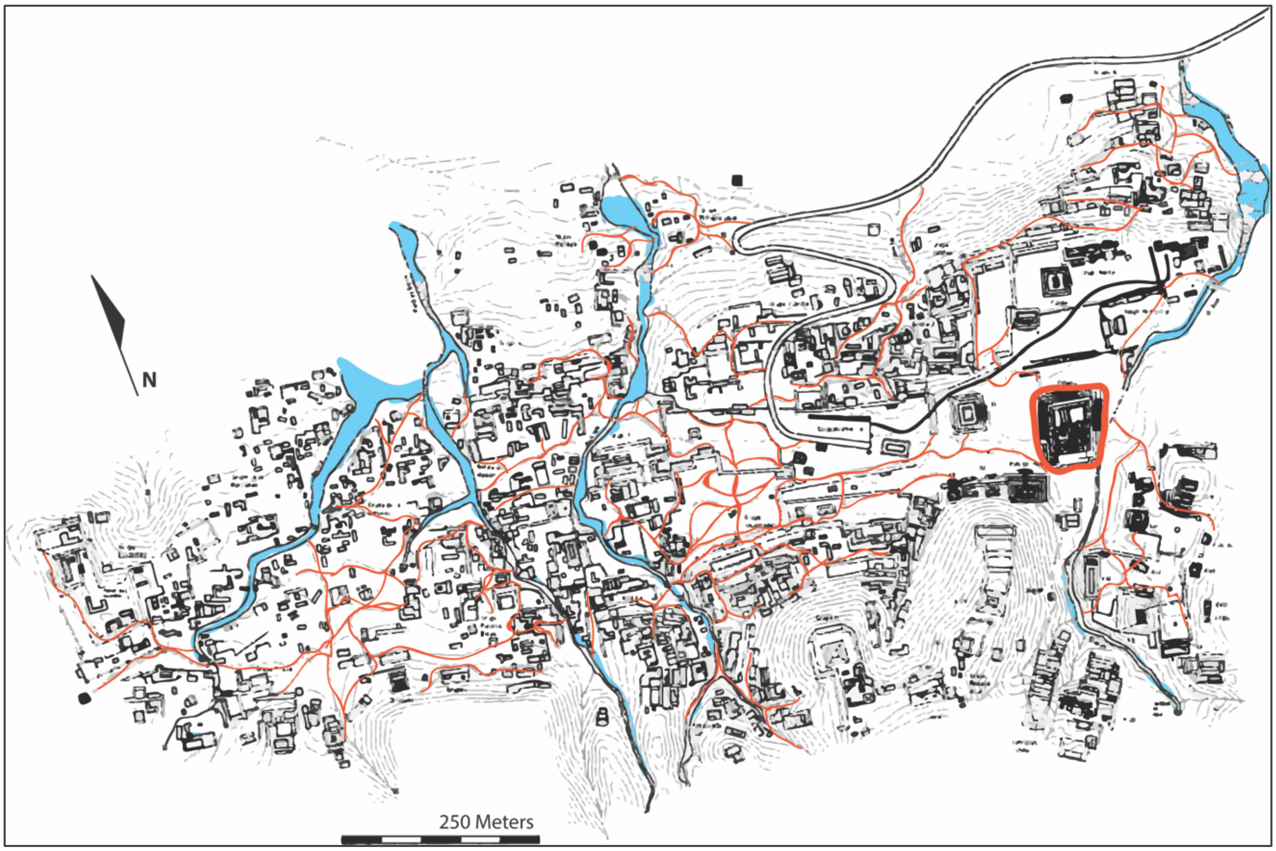

Figure 4.2. Map of Palenque, Chiapas. Adapted from Robertson, 1983. Red lines represent pathways and blue the rivers and water sources. To the right, the big palace of Palenque (circled in red) which has considerably less routes to access than any water source.[2]

[2] This is my interpretation of the pathways. No actual research on the road network of Palenque has been done to my knowledge, so this example should only be used as a visual hypothesis to justify the importance of research on road networks.

There are another three additional advantages to use the *primal approach* in Angamuco.

First, there is a direct correspondence of the shape of features in the ground to their representation in the graph. That is, road segments as lines or edges, and crossroads as nodes.

Second, the terrain characteristics of Angamuco is challenging for identifying the road network, as opposed to other archaeological road networks where the planimetry is evident and clear (for example, Roman cities) and the dual approach is more easily applicable. Having a planimetric representation of the road network, also helps identify locations.

Third, the primal approach allows for measuring distance in both topological terms (spatial relationships), and metric terms (by means of scale). For example, an important factor for my research is identifying travel time, which can only be calculated if the metric distances of the road segments are preserved in the graph, as evidenced in the *primal approach*.

My research goals and/or the physical characteristics of the site made it easier to implement this approach in GIS and other open source tools for spatial analysis.

Thus, the two basic analytical units I have adopted for the study of the road network of Angamuco are:

a) Road *segments* which are the walking surfaces between nodes; and,

b) *Nodes* which are the junctions where road segments end and start.[3]

In this sense, segments and nodes are two separated categories of data each with their own quantitative and qualitative attributes, they are related to each other in function and space, and thus can be investigated metrically (with absolute dimensions) and topologically (with relational dimensions).

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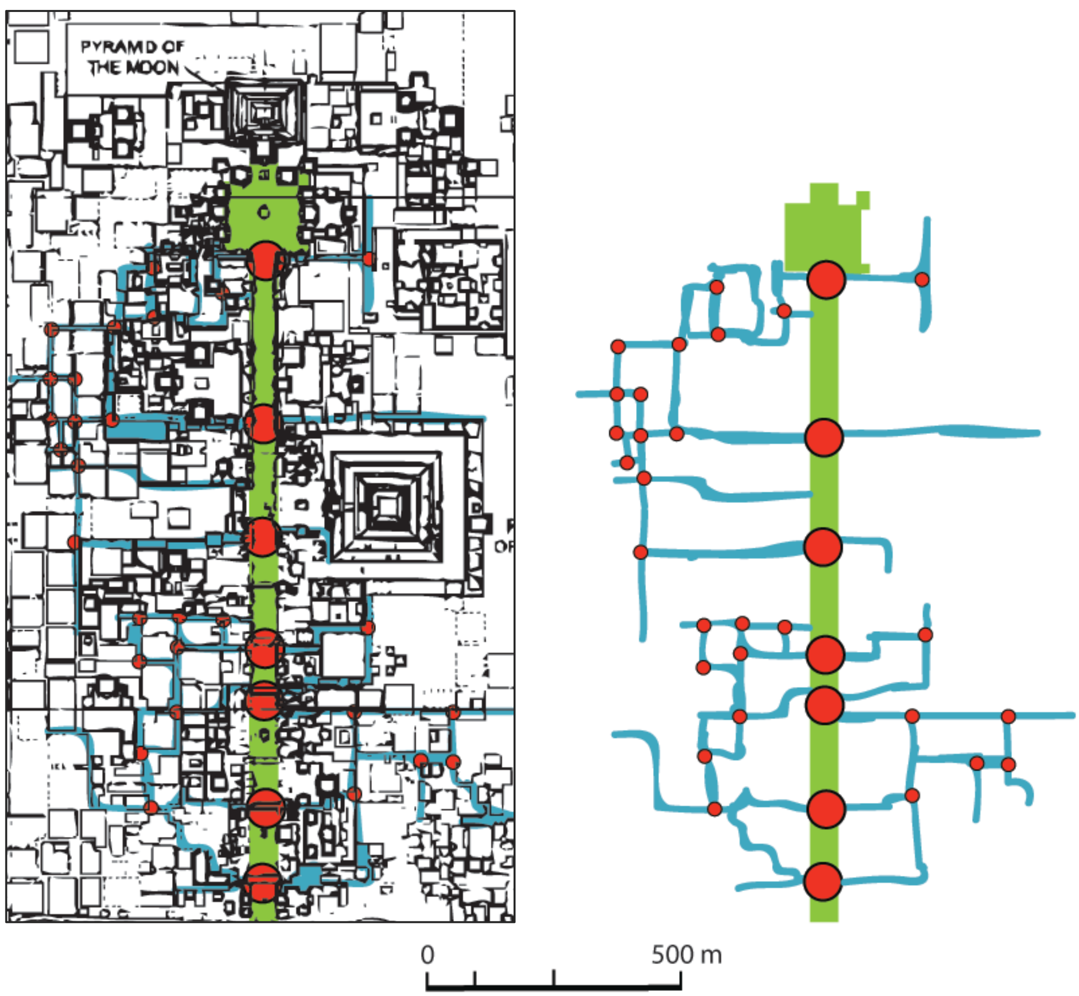
[3] Further, I identified different types of nodes and segments. See chapter seven for a discussion on all classifications.

Using nodes and segments following the *primal approach* reduces subjectivity because it is not necessary to define a road conceptually a priori. All nodes and segments are explored inductively —for their own traits. For example, for the *Calzada de los Muertos* in Teotihuacan all the segments that share certain attributes (for example, the same width, the same construction style, the same morphology, the same slope, etc.) could be aggregated into "*one road*" that might have afforded behavior differently than another cluster of segments with similar attributes, or, another "*one road*" (Figure 4.3).

A



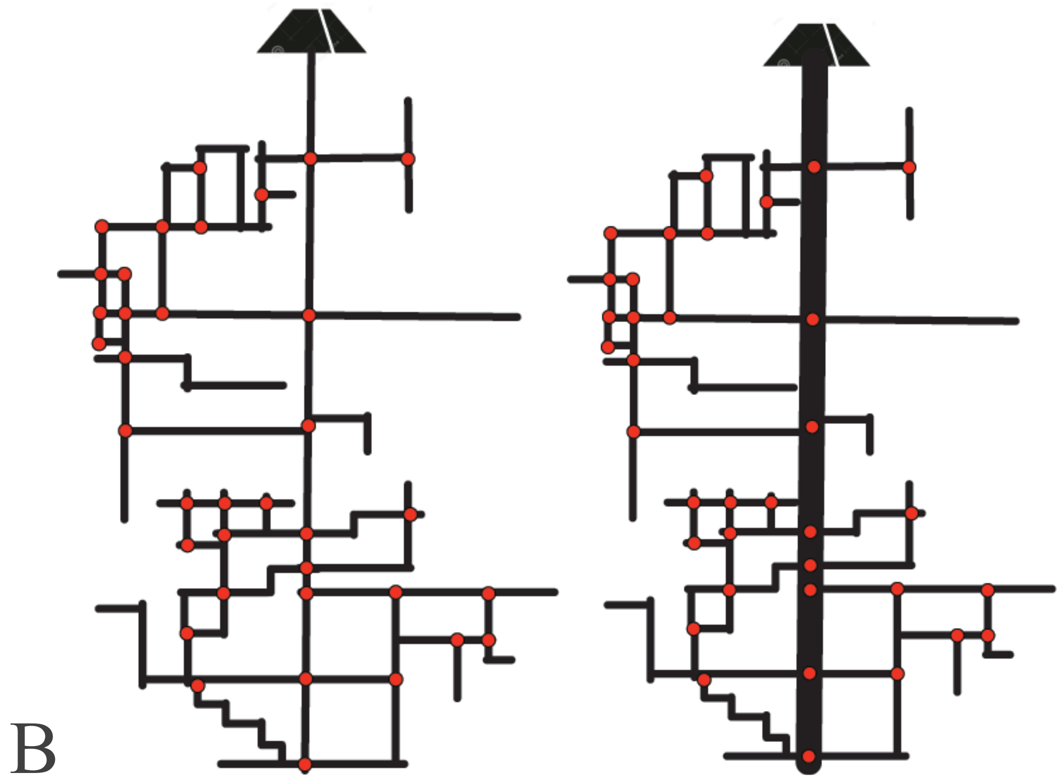


Figure 4.3 A: Detail of Calzada de los Muertos, Teotihuacan. Adapted from R. Million Map. In this example, the red dots represent road intersections (nodes), the green color represents segments of the calzada that are between 40-50 meters wide, and blue lines are road segments not wider than 5 m. B Left: a graphical representation of most nodes and segments without any distinction of their width. B Right below: graphical representation of the roads and nodes symbolizing wider roads differently.

One final important advantage of the *primal approach* is that crossroads (nodes) become a fundamental element of the network. Usually, nodes are nearly invisible in the archaeological record. Roads are observed, described and excavated, but their intersections remain ignored. Even for studies that adopt a spatial network analysis, nodes are generally just a topological necessity and very little attention is paid to them. For example, nodes as the endpoints of roads are relevant when they are identified as architectural features or sites. In such cases, nominal data is ascribed to them, for example the entrances to houses and the types of houses in the study of Pompeii (Laurence, 1995) or the population size and chronology when sites are seen as endpoints (nodes) in Peru or Cambodia (Hendrickson, 2011; Saintenoy, 2016). In sum, nodes take a more prominent role under a *primal approach*. As I demonstrate in this research, nodes provide unique data, for example, evidence of superposition of roads, and planning. They represent exceptional spaces for interaction much different than what roads provide, they create places that might have hosted social and cultural activities and thus, present different material deposits.[4]

Figure 4.4. Picture of hikers interacting as their approach a trail intersection. Original photo taken from Wikimedia

As further described in this chapter, both nodes and segments have a distinctive set of attributes observable on the field and this acknowledgement needed to be explicitly defined before starting any part of this analysis. Unfortunately, guidance on exactly how to collect these data in the field and through computers is scarce. Most of the urban network analysis has been done in archaeological sites with very good state of conservation for both roads and buildings, where

[4] See chapter seven

mapping segments and nodes has been pretty straightforward (e.g., Kaiser, 2011; Laurence, 1995; Poulter, 2011).

The next section I describe the importance of a high-resolution DEM that together with carefully planned fieldwork, aided me in the development of my own methods to identify nodes and segments for the site of Angamuco.

4.3 Lidar and DEM for Angamuco

As I mentioned in the previous chapter, Angamuco provides an ideal case study of urban road networks for three main reasons: 1) It has remained virtually untouched from modern development and destruction which allows the site to be studied to its full original extent; 2) It was a very densely populated urban center with heavy landscape modification; and 3) while covered by dense vegetation, lidar scanning provided a high-resolution cloud point of the entire ground surface of the site.

Angamuco has a very rugged topography —including valleys, ridges, draws, and slopes— with shallow soil deposits and a very dense vegetation of medium-to-high trees —pine, oak, fir, mesquite and nopal— as well as several secondary herbaceous plants and shrubs including maguey. The rugged topography and vegetation cover the entire site limiting its detection from conventional remote sensing methods like satellite and aerial images and hindering the visibility of architectural features on the ground.

Traditional techniques used to register the surface topography and architectural features are very challenging. During the first two pedestrian survey and mapping seasons of LORE-LPB in 2009 and 2010, it took a total of 7 months and over 30 people to document approximately 2,500 architectural structures —building foundations, walls, man-made mounds, terraces, plazas, etc.—

and cover an area equivalent to 2% of the site (Fisher et al., 2011; 2012). For those reasons, Fisher introduced airborne Light Detection and Ranging (lidar) scanning in 2011 that resulted in an impressive dataset for many types of analysis (Fisher & Leisz, 2013).

Lidar has become a very useful tool for archaeologists in the last decade (Crutchley, 2010; Devereux et al., 2005; Fernandez-Diaz et al., 2014; Masini et al., 2011; Opitz, 2013), and particularly for Mesoamerican sites. It is starting to gain popularity as a reliable method to study ancient settlements regardless of the high costs and need for technical expertise. In 2011 lidar was still very new for archaeological investigation in Mesoamerica. Only a few promising examples had provided a sense of its advantages through work in the Mayan area (Chase et al., 2011; Rosenswig et al., 2013) and other subtropical areas of the world (Evans et al., 2013).

Airborne lidar (also known as Airborne Laser Scanning or ALS) is a remote sensing technique that provides millions of measurements of the surface based on laser pulses emitted from an instrument mounted on an airborne device. Many laser pulses are projected directly into the ground, but the wavelength of the laser cannot pass dense surfaces. So, when a pulse finds a light obstructing surface (e.g., a tree leaf, a stone structure, or the ground) it is then reflected back — called a *return*— to the scanning device. This information is then used to compute the distance between that return point and the aircraft. Since hundreds to thousands of these pulses are emitted per second, enough of these returns make it through the vegetation and into the ground (Figure 4.5).

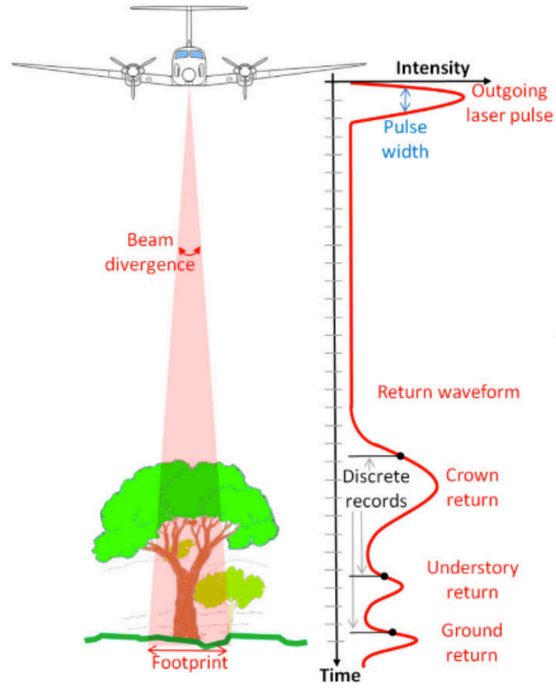


Figure 4.5. Illustration describing how airborne lidar works. Image from Fernandez et. al. 2014

The output of this scan is a point cloud wherein every point is a unique measurement with x, y, and z coordinates that then gets classified and discriminated through various algorithms (Meng et al., 2010) and finally extracted for visualization and analysis. For example, points considered vegetation are filtered out, and points considered human modified structures or bare earth are left in the point cloud (Hesse, 2010).

The lidar dataset for Angamuco was collected through a systematic series of flights over the site, with calibrated GPS positioning through 2 base stations and another 4 GPS control points around the area. We used WGS84 for the horizontal datum,[5] Gravimetric Geoid (GGMO5) for the vertical datum, UTM Zone 14 N for the coordinate system, and meters for measuring units. The protocol for the lidar sensor (Reigl VQ-780i) was set to 16 ground returns per square meter (~1

[5] The point cloud was actually re-projected to WGS 84 in 2016 by Juan Carlos Fernandez-Diaz from the University of Houston/NCALM to fix a disparity in the z-values

per 25cm^2) providing a point cloud of >1.8 billion points. Using Merrick Advanced Remote Sensing 7 (MARS) software, this dataset was first transformed to orthometric heights and interpolated to create rasters (DEMs), the best of which with a resolution of 25 cm per pixel on a side and a 10 cm contour interval. Some filtering of noise and vegetation was also performed before the interpolation through varied methods (i.e., nearest neighbor, and Multi-directional Ground Filtering (MGF) algorithms (Fisher & Leisz, 2013; Fisher et al., 2012; 2017)). Essentially, we ended up with a DEM representing the topographic surface that also shows all human modified structures above ground cleaned from all vegetation, with such good resolution for archaeological investigation that features on the ground as small as cinder block (~30 cm^2 x 25 cm height) are visible in the computer (Figure 4.6).

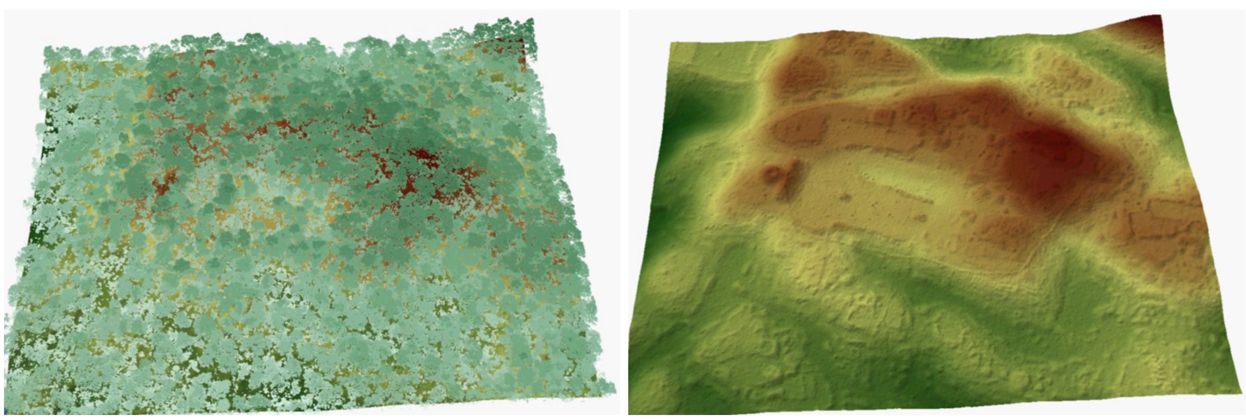


Figure 4.6. Two images showing the same area of the site (Tile 35) of approx. 250 m^2 through filtering processes. Left: the site covered in forest canopy. Right: surface after vegetation has been filtered out. Images by Christopher T. Fisher (resilientworld.com)

In general terms, the resulting DEM was good enough to identify roads. However, it is important to note that like all lidar datasets, the Angamuco dataset also had its limitations and problems including noise and glitches (see Fernandez-Diaz et al., 2014; Urquhart, 2015).

Furthermore, most of the problems working with a lidar derived DEMs are not related to the scan or post-processing, but in the interpretation of the cloud of points as topographic features.

For example, Fisher and Pezzutti (publication in progress) discuss this by exploring the classification of topographic features —large architecture— through an automated IBM Watson visual image recognition system for this site. Here, I approached the feature recognition through a less automated process of image analysis.[6]

Initial exploration of the DEM in preparation for this dissertation's proposal allowed me to identify some clearer examples of extended bas-relief linear features at the edges of ancient household complexes (*complejos*[7]) that had been interpreted as major roads by LORE-LBP (Fisher et al., 2011; 2012). This had been documented somewhat unsystematically through LORE-LPB surveys, hence, more detailed investigation and ground-prof on roads were essential.

A closer look into the DEM showed many other similar elements in the topography sharing the same linear, bas-relief characteristics but smaller in size within the *complejos*. It was also clear that those possible roads suggested diverse shapes —straight, sinuous, curved, jagged, etc. All these needed to be explored both in the field, and through more systematic approaches.

In sum, the high-resolution DEM became an essential tool for my dissertation research in three ways:

1) It helped in the development and implementation of the field survey and mapping strategy to identify and register roads on the ground;

2) It served as the basis for image analysis for road identification in the computer; and,

3) It was used to inspect the shape and topographic profiles of road examples through the site for specific case studies.

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[6] See section 4.5.3.
[7] See discussion of complejos in chapter seven.

4.4. Stage 1: Fieldwork

Identifying and mapping roads in the field is not a common practice in archaeological research. Some archaeological work in diverse parts of the world guided me for the field data collection of roads at Angamuco (Branting, 2004; Erickson, 2001; Hutson, 2004; Keller, 2006; Ladefoged et al., 2003). Although their approaches were not ideal for my research because they either treated roads as confined features, or concentrated in only one area of their sites, they did serve as starting points for my own survey/mapping strategy and field techniques. I created my own road-survey methodology considering the characteristics of the site and the explicit goal of documenting *nodes* and *segments*.

Our knowledge of the general stratigraphy, construction techniques, materials deposits, and general chronology were also considered for the road-survey methodology (Cohen 2016; Fisher et al., 2014; 2016).[8]

Fieldwork goals and design

Angamuco is a very large and complex archaeological site with a dense vegetation (especially during the summer rainy season), rugged topography and common similar architectural features that, in addition to the limited visibility, made it a challenging environment for mapping.

The fieldwork goals were:

1) To document physical and experiential attributes of nodes and segments of a total area of ~10% of the site.

[8] See chapter three and five for chronology and materials' discussion.

2) To survey 100% of the nodes and segments within four subsample areas distributed across Angamuco.

3) To identify promising nodes and segments for excavation.

4) To excavate 10 of such locations.

Survey was planned for 5 weeks and excavation for 4 weeks during the summer of 2016 and primarily funded by a Doctoral Dissertation Research Improvement Grant from the National Science Foundation (BCS 1565506). Preparations for this work began in summer of 2015 including applying for grants, assembling the fieldwork crew, designing field methodologies, exploring and preparing data, planning logistics for field season and acquiring permits both from University of Washington[9] and Mexico's Government (INAH). I registered my dissertation project: *Proyecto Arqueológico de Caminos Urbanos de Angamuco* (PACUA) with INAH. Here, I briefly describe some of these preliminary steps, most of which were performed at the DigAR Lab in UW, Seattle.

Lastly, Angamuco's landscape is rough. I established a protocol for suspending fieldwork in case of a medical emergency (injury, snake bite, etc.), weather (thunderstorms), or unsafe situations.[10]

Research permit and funding

The final but essential part of the preparation for fieldwork consisted in securing funding and permits for research. Funding was mainly provided by the NSF (BCS 1565506). Together with personal funds I was able to pay for travel, accommodations, car rental, salaries for the local

[9] Areas of Michoacán are considered unsafe for field research by the US government. The UW global travel office also requested that I get safety training and design risk mitigation protocols for me and my crew.
[10] Fortunately, this was never necessary.

workers, C14 analysis and other materials. The Department of Anthropology of the University of Washington through their Student Technology Fee (STF), and LORE-LPB provided the equipment for this research.

According to Mexican laws, all archaeological research must be approved by the *Consejo de Arqueología* of *Instituto Nacional de Antropología e Historia* (INAH). This process took about 3 months and by early May of 2016 the permit 401.B(4)19.2016/36/1023 provided legal authorization to conduct this research.

Lastly, a memorandum of agreement (Acta *ejidal*[11]) was established with the *ejidatarios*[12] who own the land. This is an agreement that establishes the collaboration with the community, by providing employment for local ejidatarios as field assistants, and to formalize our commitment to protect the site and respect their land (see Cohen & Solinis-Casparius, 2017).

Field crew

A total of five experienced archaeologists and four to six local workers formed the field crew. The crew was divided into two teams during the survey (two archaeologists + one local worker). Each archaeologist also led their own excavation unit with the assistance of two to three local workers.

Setting up a spatial provenience system

A good provenience system is fundamental for archaeological fieldwork especially for an area of +6 km^2. LORE-LPB has created a provenience system[13] based on a virtual grid of 1 x 1 km

[11] For request of a copy of the INAH Permit and Acta Ejidal contact the author.
[12] In the Mexican system of government, an ejido is an area of communal land generally used for agriculture, on which community members individually farm designated parcels and collectively maintain communal holdings.
[13] See Fisher et al. 2011 for LORE-LPB provenience protocol.

quadrants where the corresponding SW corner's UTM is used as the origin's location.[14] These quadrants are coded using a local grid nomenclature (letters for the Y axis and numbers starting at 1 for the X axis) for example: "Quad J-19", "K-20", etc.

Further, quadrants are subdivided into 4 cardinal *sub-quadrants* of 500 x 500 m, for example: "Quad J-19, sub-quad NE".

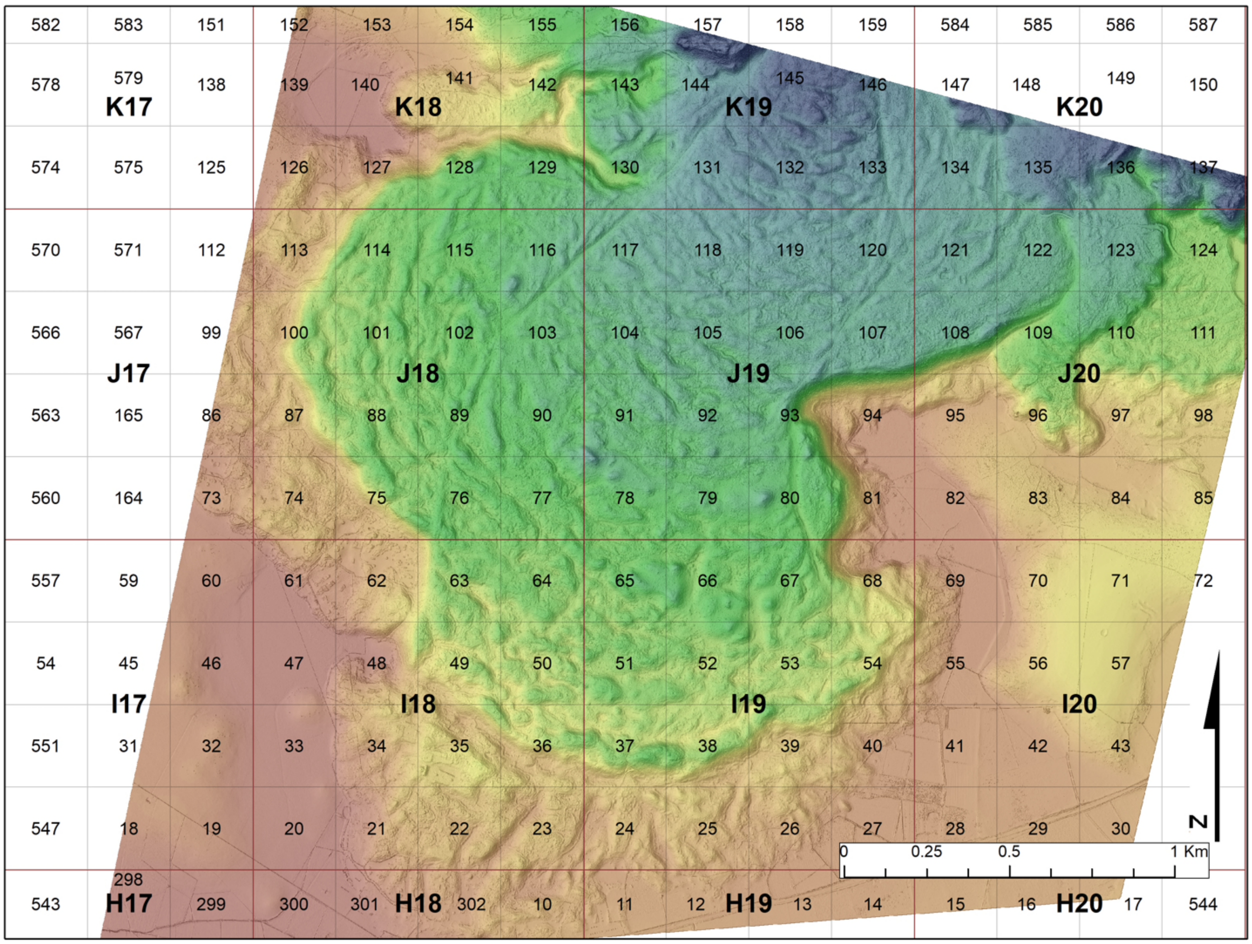

Figure 4.7. Image of the site with Quadrant and Tile grids (not to full extent). Red grid and bold letters refer to quadrants. Black grid and small numbers refer to tiles. Elevation is represented by the color ramp (from lower or red to higher elevation or dark blue) although here is shown only for general reference.

[14] NAD83 / UTM zone 14N

Another subdivision of 250 x 250m called *tile* was then created, but its coding has been inconsistent during the four previous field seasons. Problems like unnamed tiles or a discordant system (e.g., tile 201, tile 33a, etc.) had occurred in the past, and would arise again during my survey. I replicated the tile system and created a protocol for coding the tiles in a more systematic manner (Figure 4.7). Ultimately, all tiles of the site[15] are numbered now, and other gaps in the virtual grid have been fixed. Tiles are geographically the same as LORE-LPB, so features are still relatively easy to locate within the master virtual grid. However, the names of tiles have changed. Going forward, this new organized tile coding has now been proposed to LORE-LPB to further insure consistency.[16]

Similarly, a new organized structure and clean copies of the LORE-LPB geodatabase (files for GIS analysis like shapefiles, rasters, and tables) was created under PACUA name. All this work was performed through ArcGIS Desktop Advance software (versions 10.3 during 2015, and 10.5 during 2016-2019).

The final step setting up the spatial provenience was to define and name areas of research and excavation. Starting in 2013, LORE-LPB arbitrarily named areas of excavation using letters (A, B, C, D, E, F, and G), however the spatial limits of each area were not defined. I continued this work respecting and expanding the designation. I also created arbitrary spatial dimensions for all areas. These dimensions are loosely based on topographic features and are not related to any cultural significance, so these areas should only be used as guidance for provenience reference.

Following the goals of this research, I aimed at inspecting all possible roads within four areas of the site: Areas A–D, I, F–G and H (Figures 4.8 and 4.9). The sum surface extent of the proposed four areas is 733,503.87 m^2, representing a sample of ~12.5% of the total extension of

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[15] Before the 2016 scan of the northern section of the site.
[16] For example, for K. Urquhart's dissertation research.

the site. Based on my previous experience at Angamuco I calculated that it would take about 5 weeks for two teams of three people to survey this area. In fact, after our fieldwork concluded, we ended up surveying 90,967.87 m^2 more than expected for a total of ~14.3% (Table 4.1).[17]

I chose these areas for the following reasons:

1) Half of these areas had been previously surveyed (for architecture) and excavated, providing us some knowledge of the materials, chronology, and architectural features.

2) Areas H and FG were located between lower and upper zones.

3) Access to these areas was more feasible and safer.

Additionally, nine excavation units were selected after survey within these areas.[18]

Finally, nodes and segments would be individually recorded using GPS. In sum, in this spatial provenience system all nodes, segments and excavation units were easily located in the site.

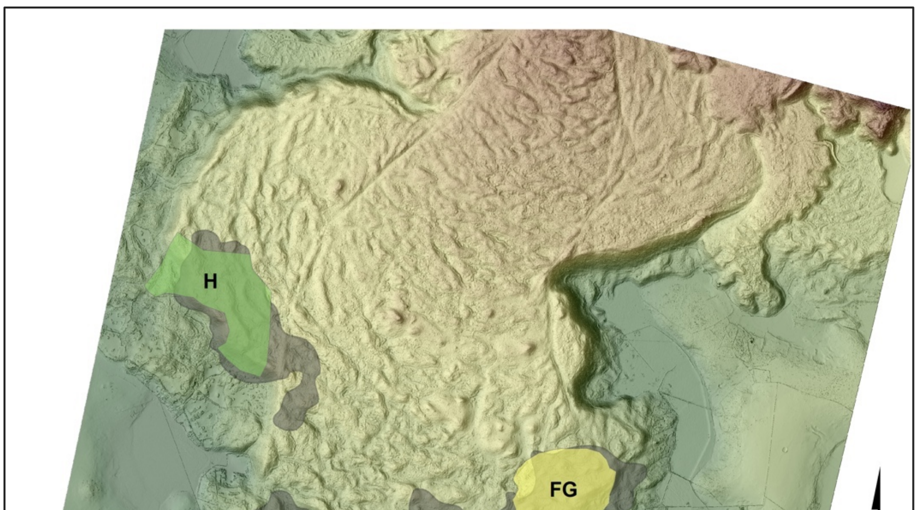


Figure 4.8. Arbitrary dimensions of areas for survey/mapping of roads. Colored areas proposed, and grey areas actual surveyed after fieldwork.

[17] See chapter seven
[18] See excavation section below

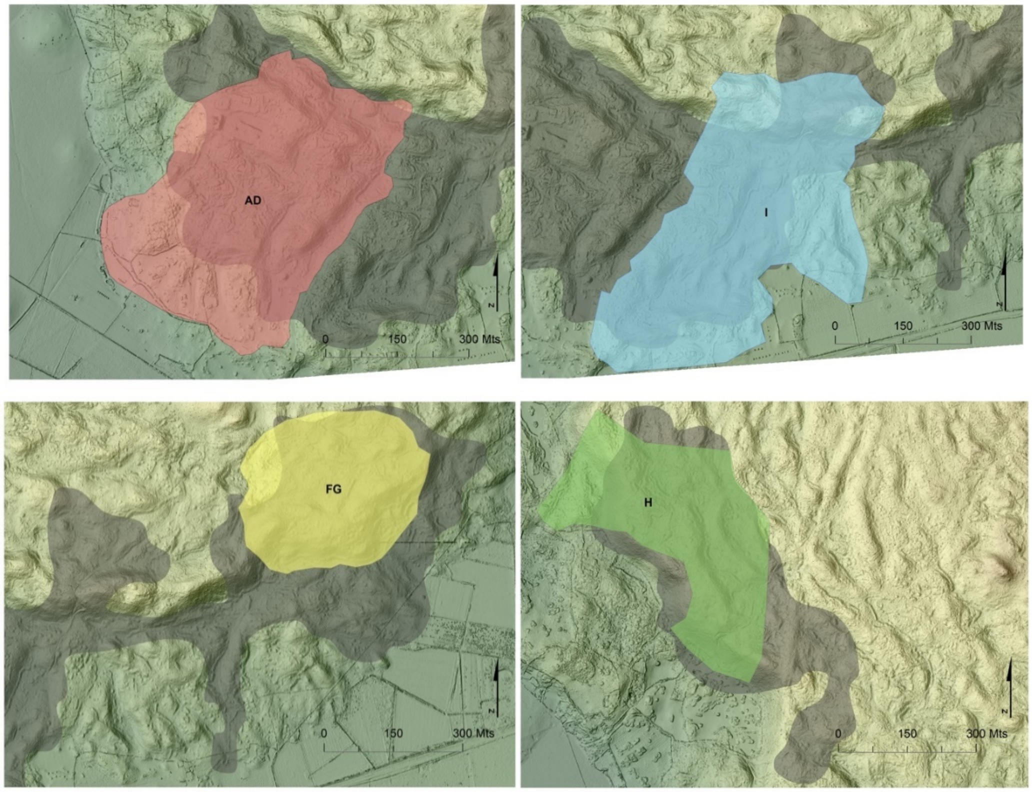


Figure 4.9. Detail of four areas of road survey. Colored areas are proposed and grey actual surveyed areas after fieldwork.

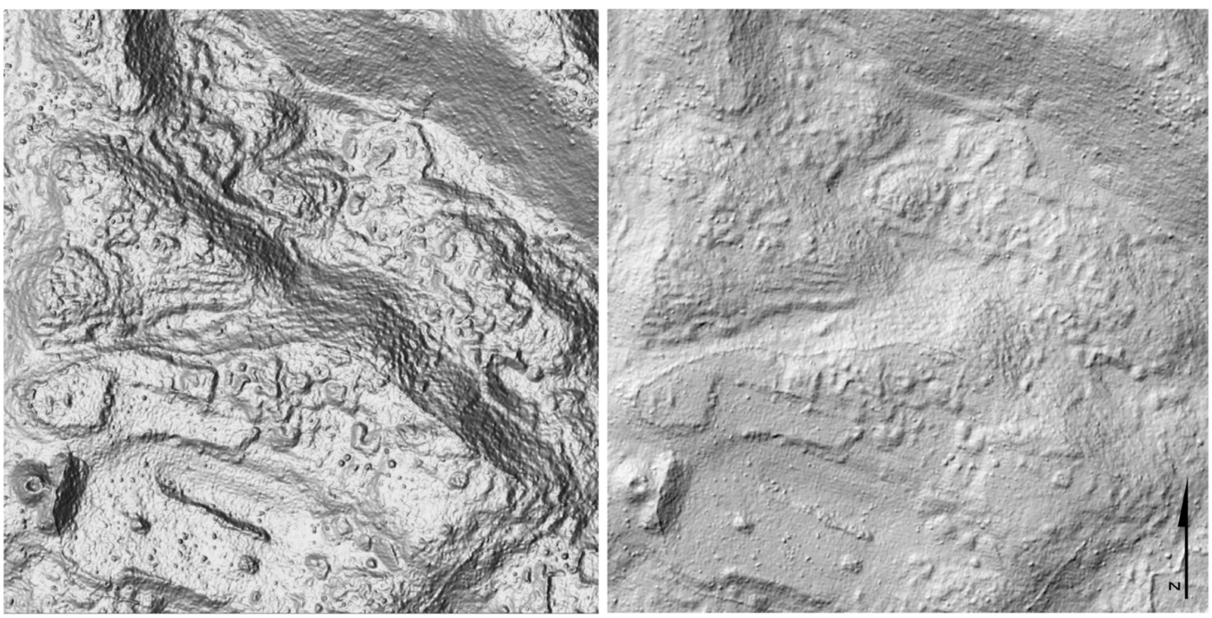
	EXPECTED SURVEY AREA IN M^2	ACTUAL SURVEY AREA IN M^2
Area I	247,341.64	253,411.48
Area AD	235,647.21	203,542.12
Area H	136,983.37	202,172.25
Area FG	113,531.65	165,345.87
Total	733,503.87	824,471.72
	~0.73 km^2	~0.82 Km^2

Table 4.1. Table of expected and actual survey areas

In addition, a new organized structure and clean copies of the LORE-LPB geodatabase (files for GIS analysis like shapefiles, rasters, and tables) was created under PACUA name. All this work was performed through ArcGIS Desktop Advance software (versions 10.3 during 2015, and 10.5 during 2016-2019).

Multi-directional hillshading

For the purposes of surveying and navigating Angamuco *multi-directional* hillshades were created for the entire site. These images were generated by processing the DEM through a method found in most GIS called hillshade[19]. This raster function generates a visualization of the terrain that resembles shading from light coming from one direction giving a 3D effect that often helps reveal topographic and architectural features which otherwise would be hard to spot (Figure 4.10). Multi-directional hillshades were uploaded into the GPS data loggers to aid archaeologists detect, identify and interpret features on the ground.



[19] I actually used a function called multi-directional (16 direction point) hillshade. Here, 16 different hillshades are created (light is simulated from 16 different directions), then each hillshade is multiplied, summed, and normalized to produce an easy to interpret image with three-dimensional features (similar to Devereux et al., 2008; Fernandez-Diaz et al., 2014).

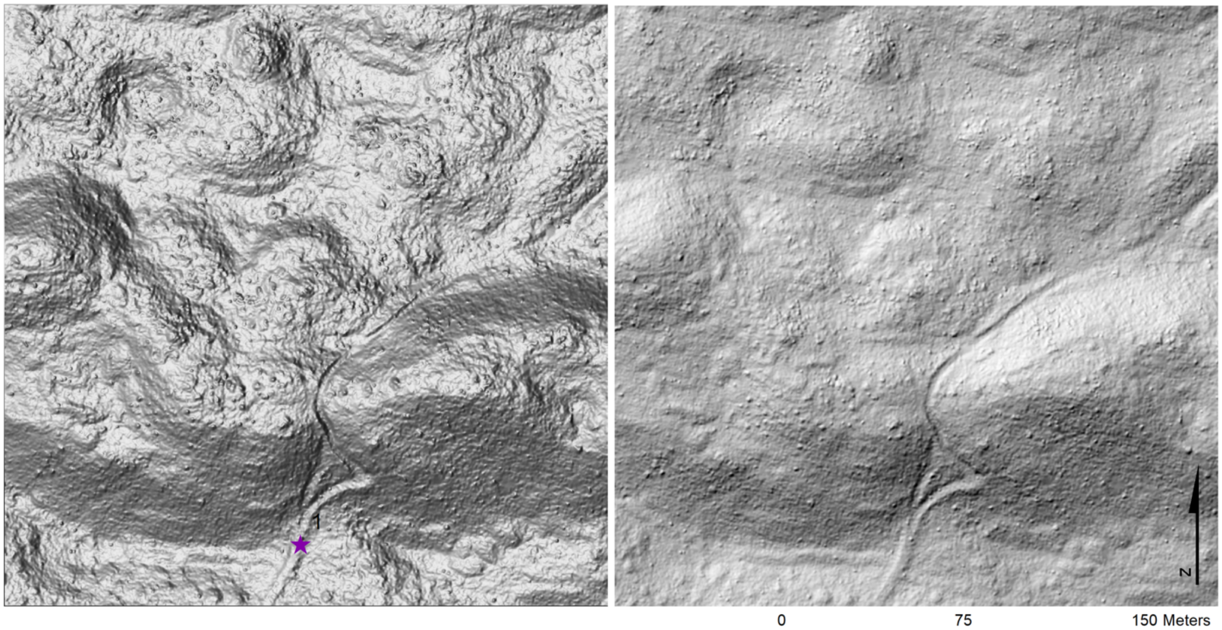


Figure 4.10. Two sets of shaded relief images of same area (Tile 35 on top and 37 on bottom). Left images have been processed through the multidirectional hillshade factor. Right images use a simple one-direction hillshade effect.

Field recording

The road-survey/mapping method was designed to:

1) Traverse easily through the landscape,
2) Identify nodes and segments on the ground,
3) Document their location directly into georeferenced polylines or points,
4) Register their physical and experiential attributes both electronically and on paper, and
5) Give each node and segment their unique identifier codes.

The expectation was to collect 100% of the nodes and segments within the selected areas A–D, F–G, H, and I. Five types of data collections were expected from fieldwork. Protocols for collection included:

A) Geodatabase of shapefiles for georeferenced features. The main two features that were recorded were: road segments using polylines and nodes using points. However, additional features like entrances to complejos, potential areas of excavation, datums, wells, and excavation units were also recorded using points; and internal pathways within architecture were recorded using polylines. Each feature had its own unique identifier and was associated to a series of attributes that were entered directly into the geodatabase by surveyors. For this, I used ArcPad Studio Ver. 10 (ESRI) to generate a project that contained editable layers for point and polyline features mentioned above plus a series of un-editable layers with ancillary information (hillshade basemap, tiles, and quadrant grids, and so on). Each of the feature types would automatically have their unique symbology for easy identification. Attribute information for each feature was entered via purposefully designed forms that enforced strict norms in order to guarantee data integrity, (e.g., in order to record a feature, a surveyor had to enter certain information like feature code, initials, area, etc.) thus preventing features from being registered with incomplete information. Other attributes were filled in automatically, such as the date of data entry. This ArcPad project was loaded into two FZ-G1 Panasonic Toughpads that served as GPS data loggers in the field (Figure 4.11).

Figure 4.11. Data logger loaded with ArcPad project being used in the field.

B) Field forms (node and segment attributes): one paper form for nodes, and one for segments. These forms registered dimensions, spatial and topological relationships, experiential attributes as well as provenience, identifiers, and additional information not collected digitally through the ArcPad project, like collection materials, photographs, a sketch, and additional notes. The forms were designed to facilitate recording process in the field through a combination of check-boxes, and clearly specified categories. Such types, classes, and categories of segments and nodes were distinctly defined in a data dictionary before fieldwork began (Figure 4.12 & Table 4.2).

Segment form

The segment form is divided into several sections:

1. A unique identifier (ID code) was generated for each segment. This identifier corresponded to the following pattern:

S (segment) + (computer number) + (area letter) + (next available number using 3 digits)

For example, S1F003. Since each computer (two in total) had their own count, team leaders noted the last used code of the day in the project's field journal.

2. Class: three choices based on the width of the segment. *Pasillo* (hall) = < 1 m; *Sendero* (trail) = 1 to 3 m wide; *Camino* (road) = > 3 m. A small section to register three measurements along each segment was also included.

3. Type of end/start of segment. This information is important because some features such as entrances to buildings were not recorded through a node form. The complete list included *node, plaza, patio, wall, dead-end,* and *other*.

4. Shape described the morphology of the segment. Options were *straight, curved,* and *sinuous*.

5. Slope: *flat, irregular* (meaning topographic changes along the segment), and *slope* (regardless direction).

6. Architecture/construction described clear evidence of construction for that segment. The options included: *building, ramp, paved, raised, stairs, sunken, retention wall, blockages*, and *banqueta.*[20]

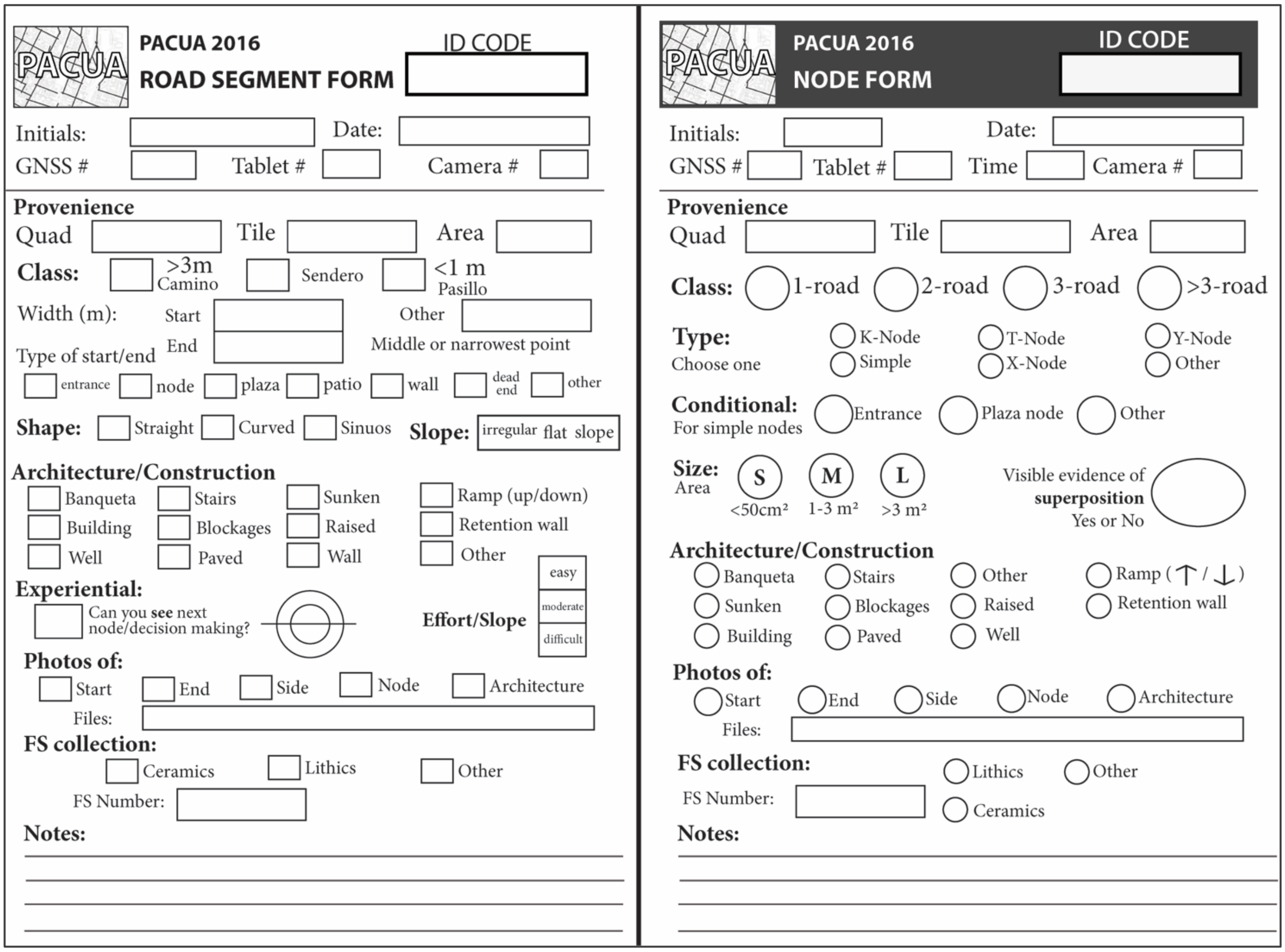
7. Experiential was subjective. The surveyor registered: a) if the next node/decision-making point was visible; b) the distance/visibility in an infographic of two concentric circles (closer to center = close, and further from center = far) and the facing direction. This information cannot be inferred from GIS analysis because other factors besides topography affect visibility, such as vegetation and light; c) effort needed to traverse the segment, (*easy, moderate* and *difficult*).

8. Finally, details of photos or field specimen (FS) collections (bags of materials) and notes complete the form.

	SEGMENTS		NODES	
CATEGORIES	CODES	MEANING	CODES	MEANING
Class	C, S or P	Camino, Sendero or Pasillo	1, 2, 3 or 4	One, two, three or more than three connecting segments
Shape	S, C or SI	Straight, Curved or Sinuous		
Slope	I, F or S	Irregular, Flat or Slope (unidirectional slope)		
Type			K, T, Y, X, S or O	K, T, Y, X shapes, Simple or Other
Size			S, M or L	Small, Medium or Large
Superposition			Y or N	Yes or No

Table 4.2. Data dictionary for survey/mapping

[20] See section 5.1.1 Stratigraphy and road construction techniques.



PACUA 2016
ROAD SEGMENT FORM
ID CODE
Initials: Date:
GNSS # Tablet # Camera #
Provenience
Quad Tile Area
Class: >3m Camino Sendero <1 m Pasillo
Width (m): Start End Other Middle or narrowest point
Type of start/end
entrance node plaza patio wall dead end other
Shape: Straight Curved Sinuos Slope: irregular flat slope
Architecture/Construction
Banqueta Stairs Sunken Ramp (up/down)
Building Blockages Raised Retention wall
Well Paved Wall Other
Experiential:
Can you **see** next node/decision making?
Effort/Slope easy moderate difficult
Photos of:
Start End Side Node Architecture
Files:
FS collection:
Ceramics Lithics Other
FS Number:
Notes:

PACUA 2016
NODE FORM
ID CODE
Initials: Date:
GNSS # Tablet # Time Camera #
Provenience
Quad Tile Area
Class: 1-road 2-road 3-road >3-road
Type: Choose one
K-Node T-Node Y-Node
Simple X-Node Other
Conditional: For simple nodes
Entrance Plaza node Other
Size: Area
S <50cm² M 1-3 m² L >3 m²
Visible evidence of **superposition** Yes or No
Architecture/Construction
Banqueta Stairs Other Ramp (↑ / ↓)
Sunken Blockages Raised Retention wall
Building Paved Well
Photos of:
Start End Side Node Architecture
Files:
FS collection:
Lithics Other Ceramics
FS Number:
Notes:

Figure 4.12. Field forms used to document segments (left) and nodes (right). Additionally, nodes would be sketched on the reverse of the page.

Node form

The node form is very similar to the segment form, with a different style used to avoid confusion in the field. Its sections are:

1. Identifiers are similar to the segments' form although it adds information on the time of registry. The unique ID code uses the following pattern:

N (node) + (computer number) + (area letter) + (next available number using 3 digits).

For example, N2H017

2. Class refers to the total number of segments that join this node. The options are: *1-road, 2-road, 3-road* or *more than 3*. It is important to clarify that this is the total number of segments, for example a dead-end node has one segment. Class 2-road was only used for very clearly sharp turns or large nodes, (i.e., plazas or patios).

3. The type of node section was aimed to help define the typology,[21] and it is based on the shape created by the segments that join it. The options included: *K, T, X, Y, Other*, and *Simple*. Simple nodes refer to end-nodes, they are always class 1-road and have a conditional attribute that can be *Entrance, Plaza-node,* or *other*.

4. Size of the node was calculated with pacing the larger side/diameter since nodes have various shapes. Some were large enough that would take too much time measuring with a tape. Options are *small* (<50 cm^2), *medium* (1-3 m^2), and *large* (>3m^2).

5. A *yes/no* question for visible evidence of superposition was subjective but helpful to select potential excavation areas. The idea was that if a segment clearly passes over another segment, then perhaps it is not a real node but evidence of a later segment being constructed over an earlier segment.

6. The architecture/construction descriptions were copied from the segment form for this section.

7. Photos, FS collection, and notes completed this form.

8. Finally, surveyors were asked to draw a small sketch of the node in the back of the form clearly titled with the ID code of that node (Figure 4.13).

[21] See section 7.1.2. Typology of nodes

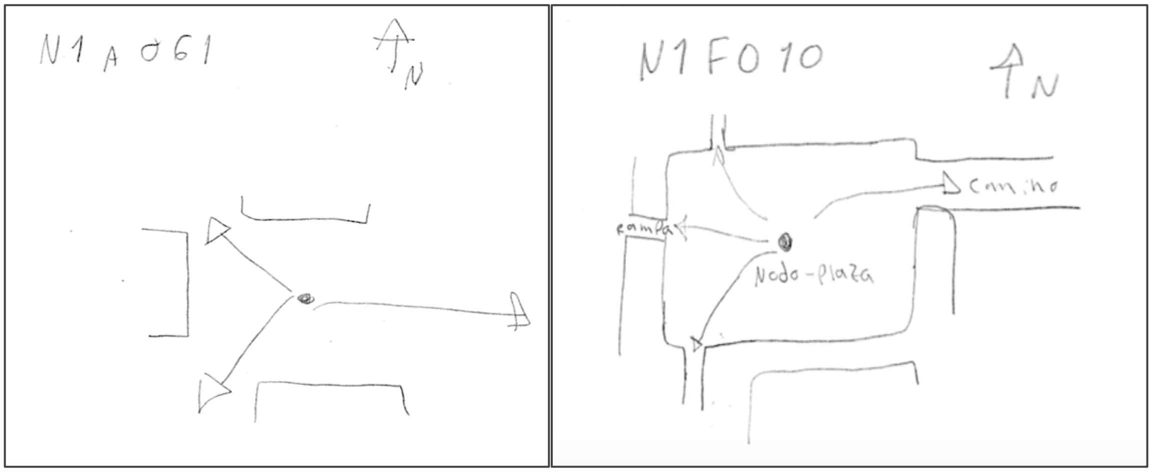


Figure 4.13. Examples of sketches by Urrutia at reverse of Node form.

C) <u>Photographs' database</u>: We used two 12-Megapixel Olympus Tough TG-5 digital cameras to document photographs and videos of segments, nodes and excavation. Additionally, a 12-Megapixel and 4K video GoPro HERO4 was used to document the landscape, and videos traversing the roads. Three folders by camera name were created with additional subfolders by date.

D) <u>3D models of units</u>: At the end of the excavation of every level, we created a 3D model of the interior of each unit using Agisoft Photogrammetry Software. Other models were created of examples of superposition at particular nodes in the site. These models were created to further explore stratigraphy during excavation for features that might not have been clear through photographs and are stored in PDF format.

E) <u>Artifact collection</u>: The FS strategy for PACUA was very straightforward. During survey and excavation, we used two FS logs (one per team).

For survey, artifacts were placed in bags separated by material type (i.e., ceramic, lithic, organics for C14 dating, or sediment sample). All these bags were put inside a larger bag and all were identified with provenience, date, initials, and its FS number (Figure 4.14). If materials were too many to fit in one bag, then the FS number would include a sequence such as 1/2, 2/2 in the label. All the information from the bag was recorded in the field forms and GPS forms in addition to a master FS log.

For excavation the strategy was very similar, however a level could have more than one FS number, depending on the excavation process if, for example, a feature was encountered. In sum, FS numbers were unique to segment, node, unit/level, or feature.

PACUA 2016
P.I.: Rodrigo Solinis-Casparius

FS #: FS0001
Material: Cerámica
Area/Tile: A-D/22
ID Code/Unit: N1A006
Level: Surface
Collector's Initials: KB
Collection Date: 6 June 2016
Notes: 4 Ceramic Frags

Figure 4.14. Example of bag tag. Designed by Kate Boston.

4.4.1 Survey and mapping

The survey was performed through the month of June 2016. I rented a house in the neighboring city of Patzcuaro for the team's accommodation that also served as the field lab and storage for materials, equipment, and tools.

The crew arrived by the end of May. Several of the team members had never been to the site, so we took few days to walk around the site and getting acquainted with the landscape and architecture. We also used the first few days to test the equipment, forms, and strategy before we began work formally.

The site is located about 20 km from the field house, a 30 min drive. One access road leads to the entrance of the site on the Southeast region of the site (a private parcel known as "Los

Alamos"), another leads to the entrance on the East side (through a private property that runs parallel to the "21st century" highway to Morelia), and a last access road to the other entrance on the West side of the site (another private property in the community of "Los Corrales"). All these roads are partially paved, with the last 7 km unpaved and in very bad shape. We used a 4x4 SUV to safely drive through the dips and puddles. Once parked at any entrance to the site we still had to hike carrying the equipment and tools for about 30 minutes through the site to the work areas. Fieldwork was performed Monday through Friday, from 7am to around 2:30 pm, the time that afternoon showers fall in the region during the rainy season —June to October.

The survey was done in two teams. Each team carried a GNSS receiver (Trimble Pro 6H with decimeter accuracy), a 2m carbon pole, a data logger (Panasonic Toughpad FZ-G1) with ArcPad 10.2, a digital camera, compass, 20m long tape, their own FS and Photo logs, node and segment paper forms, plastic bags, safety materials (radios, whistle, cell phone, first aid kit), water and personal items. Teams were defined by the data logger number (either #1 or #2) used (regardless the GNSS receiver and team membership) and were associated to their unique FS log. Photo logs were associated to each specific camera (either #1 or #2).

The following road-criteria guided the identification of segments:

1. Segments are linear and planar features that afford pedestrian walking.
2. Segments begin and end at a node (or entrance to complejo).
3. Segments do not cross through architecture.
4. Segments must be longer than 3 meters.

The survey method consisted of the following 7 steps.

1) <u>Reconnaissance</u>: The process started with a simple walk around a subsection of the survey area to have a sense of the architectural features and roughly identify nodes and segments following the road-criteria. Usually, the team would take about an hour to walk around, observe, and point out relevant features in the vicinity, either together or separated. Instead of documenting their observations, the team would reconvene to discuss their observations. For example, what to some surveyors might look like a segment could also have been seen as a terrace or narrow platform to others. It was very important that the archaeologists discussed and came to consensus about their decision adhering as closely as possible to the road-criteria and following the architecture typology from LORE-LPB (Fisher et al. 2019).

2) <u>Marking segments and nodes</u>: Using a pin-flag, the team marked nodes by staking a flag somewhere near the center of each node and choosing a direction to move towards. This step was modified by each team and adapted according to the landscape. Some would only mark the next 3-5 nodes and others would mark as many as possible in several directions. By marking nodes, the team was able to strategize what nodes and segments to map next, and in what order (Figure 4.15).

Figure 4.15. Left: Kate B. marking a node with a pin-flag after reconnaissance on the right (yellow arrow). Right: Kyle U. clearing the path for GNSS.

3) Clear path from obstructing vegetation: Some segments were not easy to traverse due to large branches, trees or shrubs. Enough vegetation was cleared using machetes to allow walking with the GNSS receiver (step 6a). This was done right before documenting a segment (Figure 4.15).

4) Setting up GPS: The GNSS receiver was mounted on top of a 2 m carbon pole. We used the following settings: *Positions ArcPad extension* for connection protocol; GPS Height of 2.2 m; Point capture average of 100, and 5 for vertices; integrated SBAS or WAAS real-time correction; and a maximum of 50 for PDOP. It is important to note that the very first time of the day we turned on a GNSS receiver we moved to an area relatively cleared from vegetation, such as an opening in the tree canopy, to facilitate better initial connection to the satellites (Figure 4.16).

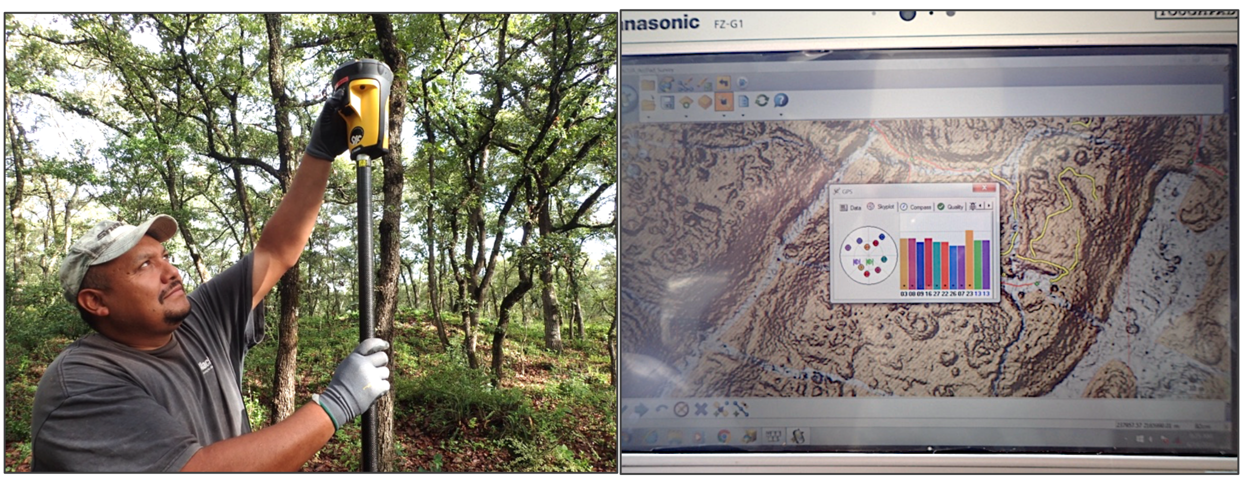


Figure 4.16. (Left) Javier Juárez turning on GNSS receiver. (Right) ArcPad screen showing connection to 11 satellites.

5) Identifying provenience and starting mapping: Using the ArcPad project, surveyors identified the provenience (Quad, tile and area) of their area of work. This information was used to help establish a new ID code for nodes and segments, as well as FS and Photo Logs. Once all this information and the GNSS was ready to run, a mapper holding the GNSS stood at the

beginning of the segment or center of the node and waited for instructions from data logger operator to begin mapping.

6) Mapping segments (6a) and nodes (6b).

6a) Mapping segments:

A) On the ArcPad project, we selected the appropriate capture feature from *capture menu* (Figure 4.17). In this case, the *segment feature capture* icon for segments is the red line, but this process is the same for all linear features.

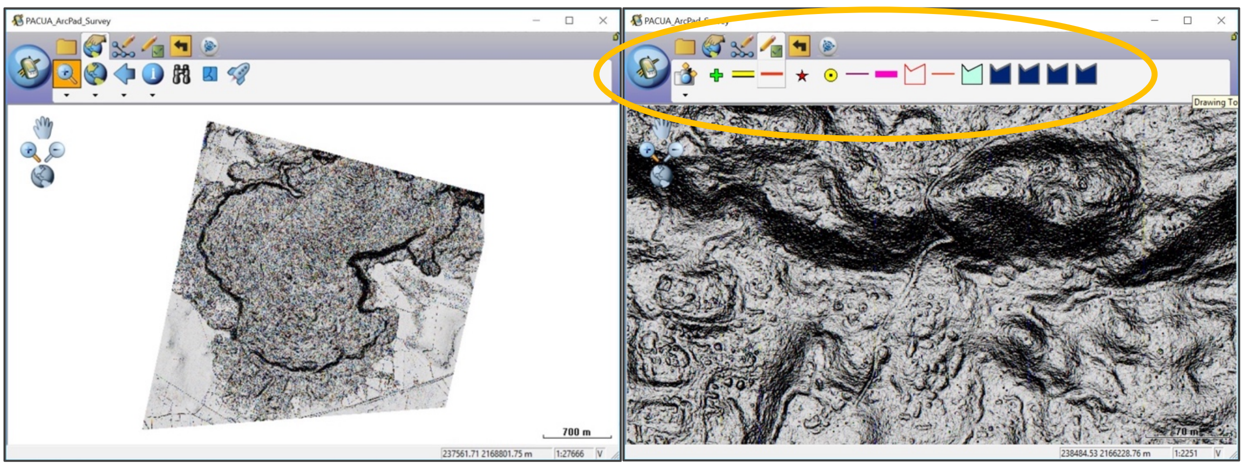


Figure 4.17. On the left side, an image of the ArcPad project with the site at full extent. On the right side, an image of ArcPad project screen zoomed in, showing the capture features menu on the top (yellow). Each icon creates a new feature on its unique shapefile. In this example, segment icon is selected.

B) Once ready to start registering the segment, the mapper holding the GNSS walked at a normal pace, keeping the base of the carbon pole close to the ground and straight until they reached the next node. The data logger operator walked along, and a third person walked ahead and made sure no branches were in the way of the GNSS (Figure 4.18).

Figure 4.18. Javier J. and Andee D. registering a segment with the GNSS receiver.

C) At the end of the segment we registered the segment in the ArcPad project through the pre-loaded segment form (Figures 4.19, 4.20, 4.21).

Figure 4.19. (Left) Kate B. registering segment on paper form. (Right) Andee D. registering segment on ArcPad project.

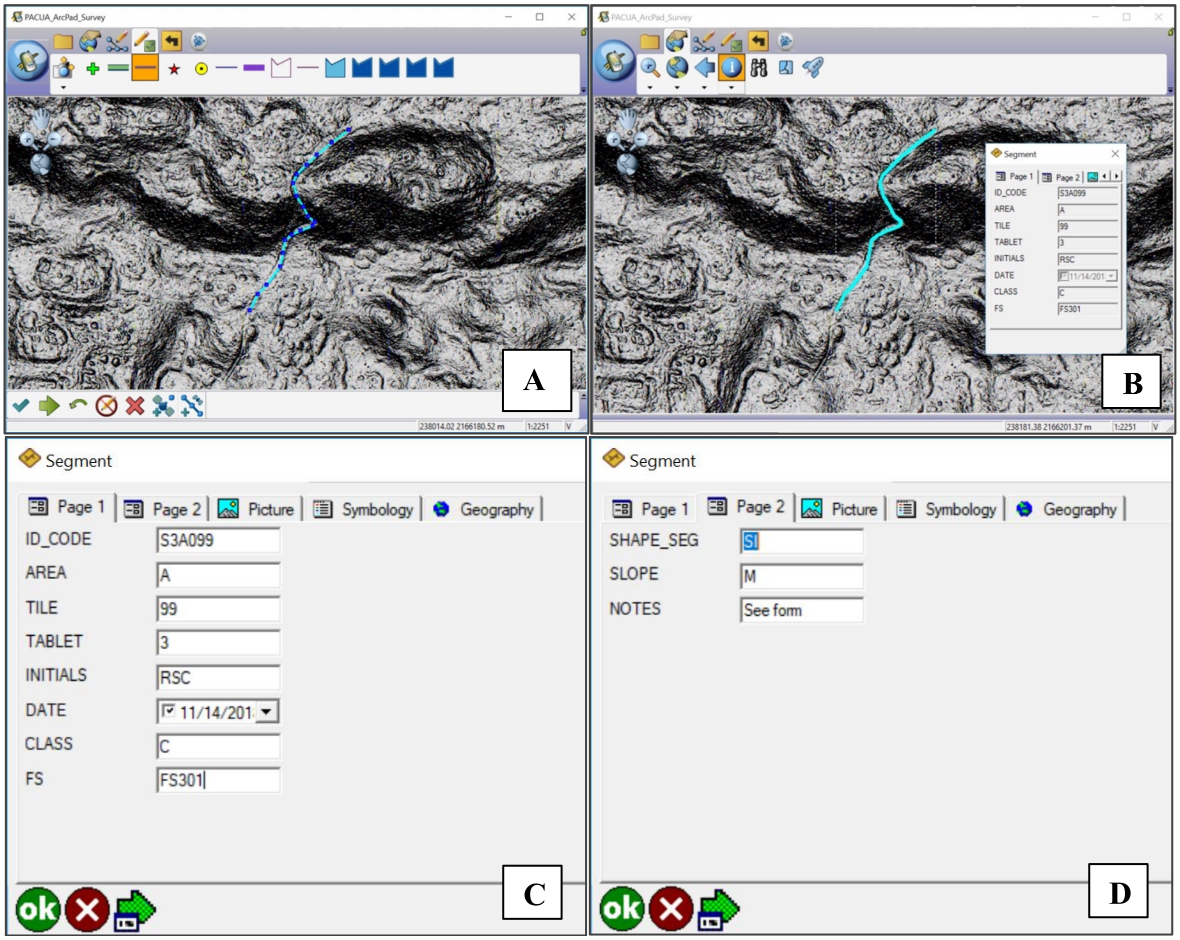


Figure 4.20. (A) ArcPad screen showing example of segment after being walked and ready for register. (B) Same example after being captured. Using the identification tool, every feature can be explored. (C and D) Capture data screen for segments.

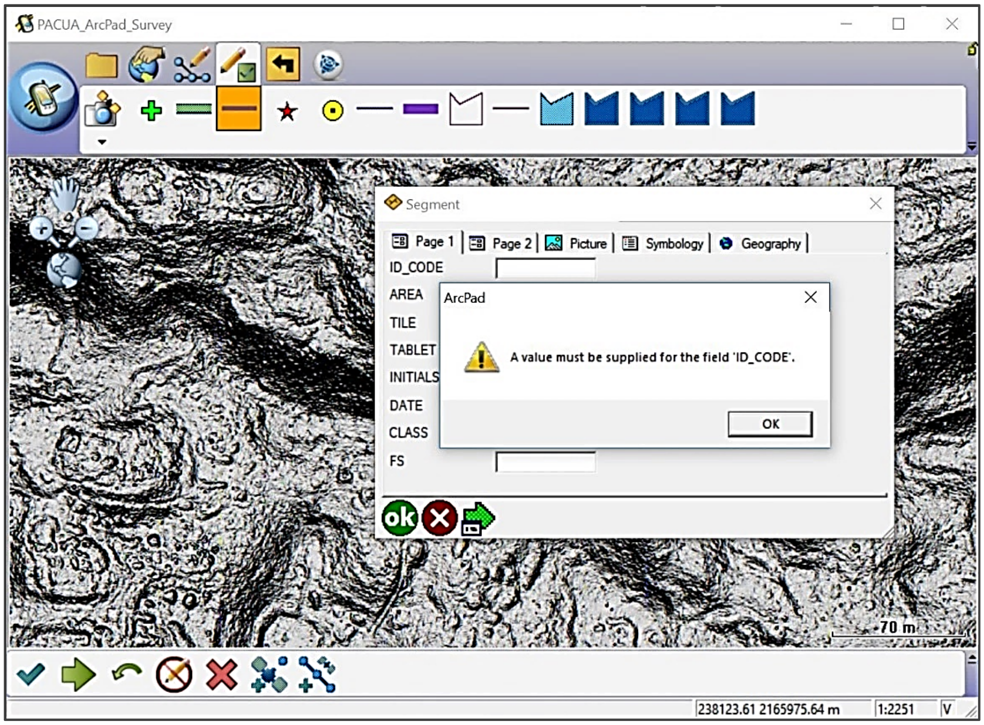


Figure 4.21. Example of warning message if accidentally clicked for register feature with missing fields.

D) Once GPS registration was finished; an archaeologist entered information in the paper form making sure ID code was correct (Figures 4.12 & 4.21).

E) The rest of the mappers then walked back to the starting node, and again back to the end node surveying the ground for cultural materials. All ceramic fragments with an area >1 cm^3, or any lithic fragment (generally obsidian or clearly worked basalt tool) found resting on the surface along the walking surface of the segment was collected. If materials were identified, sometimes with the help of a rake if visibility was bad, an FS # was assigned for the bag.

F) Another mapper took width measurements at start, middle, and end of segment.

G) Finally, photos and notes were taken if important features were observed, such as evidence of superposition, pavement, or exceptional ground visibility (Figure 4.22).

Figure 4.22. From top left to bottom right: Kate B. raking the ground looking for surface materials. Kyle U. measuring width of segment. Kate B. creating an FS bag for material. Kate B. photographing a step.

6b) Mapping nodes: Steps for mapping nodes were very similar to the recording of segments.

A) After initial reconnaissance of the area, the GNSS holder stood at roughly the center of the node remaining still and gently resting the pole on the ground while the data logger operator started the GPS registration of the node.

B) The pre-loaded node form came up after selecting *node feature capture* icon (green plus sign in Figure 4.17). We entered the associated attributes including provenience and identifiers while 100 points were averaged by the GPS (Figure 4.23).

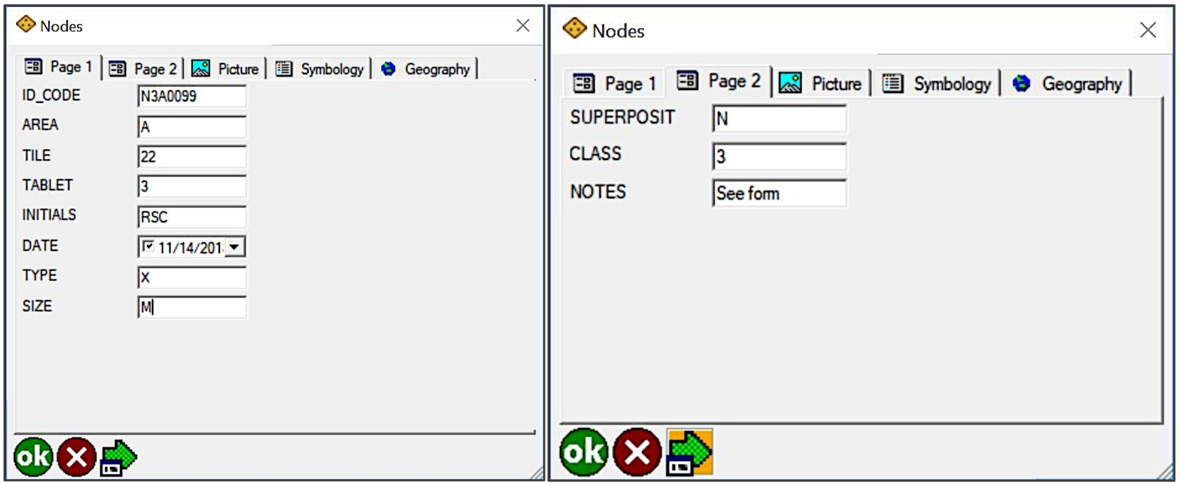


Figure 4.23. Capture data screens for node form on ArcPad project

C) During GPS registration, another archaeologist entered information on the node paper form (Figure 4.12) making sure that the ID code was correct. Additionally, a simple sketch of the node was drawn on the back of the page. There were no standards for these sketches other than aiming for a planview representation of the node, including a legend for any additional features, clearly noting which node the sketch was referring to, as well as including the North direction using a compass (Figure 4.13).

D) Either during GPS registration or after, the mappers took about five minutes to walk around the node looking for cultural materials on the surface and pace the size of the node by its longest axis or diameter.

E) Finally, any additional photos or notes were collected.

6c) <u>Mapping other features</u>: On occasions, other point features were registered only directly on the ArcPad project —no paper forms— following a similar process as node registration. These features included: *entrances* to complejos (usually facing a segment but also seen facing large nodes like patios and plazas), *excavation candidates* (potential excavation locations like nodes with interesting characteristics), and *other* features (wells, relevant architecture, looting evidence, etc.).

7) Marking last registered node: At the end of each day, we marked the last node recorded with a pin-flag and took notes of the location, so we knew where to start the following day or in case teams changed.

Some of the results of the 5-week survey are summarized in Tables 4. 3, 4.7 & 4.8 below. A more detailed discussion of the survey/mapping results is presented in chapter seven as part of the suggested typology for the nodes and segments of the site.

	TOTAL FEATURES MAPPED	WITH SURFACE MATERIALS	LOCATION (AREA) OF BIGGEST ABUNDANCE
Nodes	316	41	AD (127)
Segments	344	48	AD (137)

Table 4.3. Brief summary of survey results

4.4.2. Excavation

Excavation was carried out through the month of July 2016. Preliminary results of the survey helped decide the best locations for excavation within all four surveyed areas. The goals of the excavations were:

1) To have a better sense of the construction techniques,
2) To document the types of cultural deposits (materials), and
3) To collect carbon samples to date the use or construction periods of roads.

Roads are linear features and one of the characteristics I observed during the survey is that most segments were flanked by some sort of curb (*banqueta* in Spanish) or walls.[22] The most suitable excavation technique was a trench cutting across the entire width of the segment in order to obtain a vertical profile. Although, 1 x 1 m units, fast and easy to excavate were opened at the center of some roads in order to save time. Units were excavated following a priority order (see below). Less promising segments were excavated using 1 x 1 m test units at the center of the segment, more promising segments were excavated using trenches, and the top priority segment (U1I03) was excavated through a large trench (Figure 4.24).

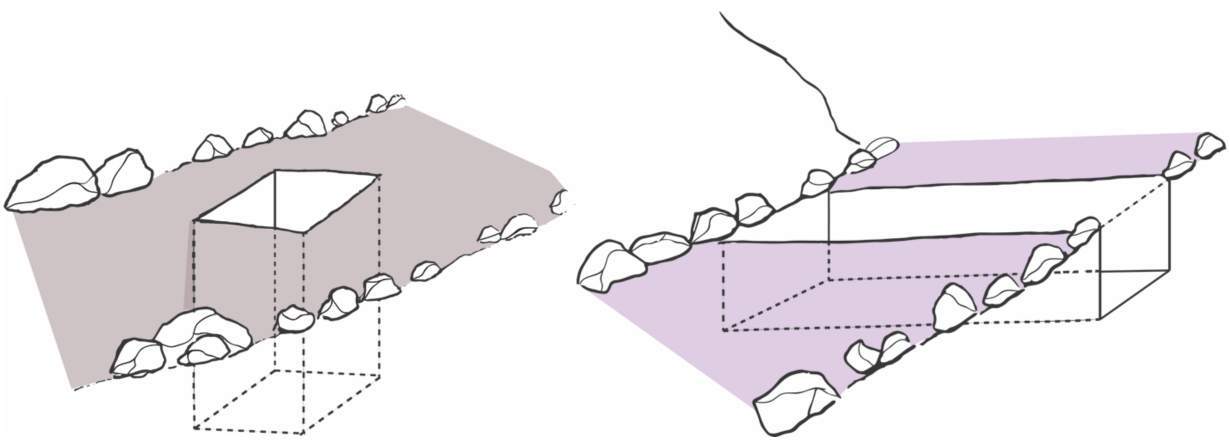


Figure 4.24. Mixed sample of excavation units. Left 1 x 1 m test unit, Right: excavation trench

A total of 23 locations were selected as candidates for excavation and then ordered by priority. Only nine were ultimately excavated (Table 4.3 & Figure 4.25). The choices of the excavated locations included: evidence of paved segments, segments at base of ramps or access to other areas of the site, flat-wide segments, clear evidence of superposition, raised segments,

[22] There are several different types of banquetas and construction styles, see chapter seven for details.

evidence of blockage or possibly major roads connecting important areas of the site. These nine locations represented a good sample of the type of segments found throughout the four areas of research.

#	RATIONALE FOR EXCAVATION	AREA	TYPE OF UNIT	ASSOCIATED SEGMENT/NODE	RANK
1	At base of massive ramp connecting upper and lower site	I	Large trench	S2I005	1
2	Segment with retention wall connecting to a plaza	I	Small trench	S1I021	2
3	Segment connecting plaza and paved ramp into complejos	A	Small trench	S1A059	3
4	Segment between buildings	I	Small trench	S1I020	4
5	Clear evidence of superposition	A	Small trench	S1A013	5
6	On North massive ramp-road by West entrance	H	Test unit	S1H009	6
7	On main road, ramp towards complejos on East	FG	Test unit	S2F043	7
8	On South massive ramp-road by West entrance	H	Test unit	S1H007	8
9	On main-flat road, in direction to entrance to site	FG	Test unit	S2F063	9
10	"Aduana", area of narrowing segment guiding traffic	AD	Small trench	S1A059	10
11	Possibly paved, long road leading to residences	AD	Test unit	S2A017	10
12	Superposition. Road descending into plaza	AD	Large trench	S2A038	10
13	Clear evidence of ramp of superposition	I	Small trench	S2I020	10
14	Good conservation of retention walls on both sides	FG	Small trench	S2F032	10
15	Sunken semicircle enclosure with double stacked walls	AD	Large trench	N2A038	10
16	Raised and flanked by terraces	AD	Small trench	N1A010	10
17	Clear superposition	I	Large trench	N2I006	10
18	Segment with ramp and high concentration of artifacts	I	Small trench	S2I010	10
19	Segment with good retention wall	I	Small trench	S2I015	10
20	Clear superposition	FG	Large trench	N2F014	11
21	Clear superposition	H	Large trench	N1H006	11
22	Blockage	H	Large trench	S1H006	11

Table 4.4. Complete list of excavation candidates. First 9 locations were excavated.

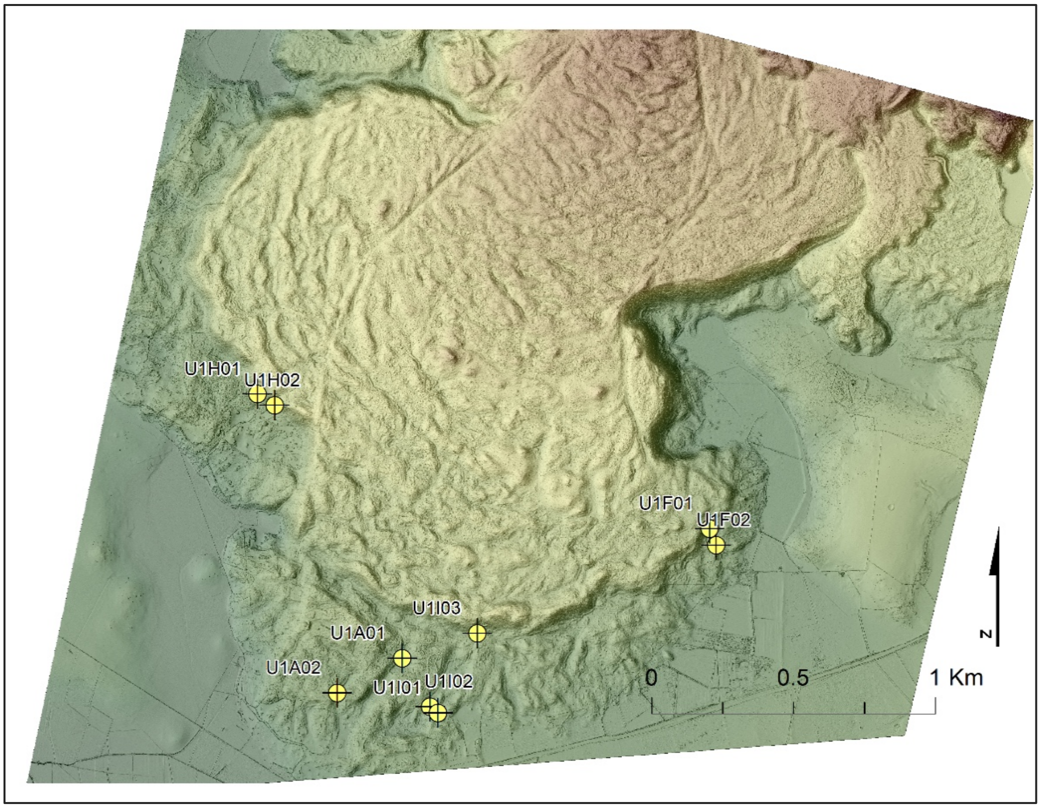


Figure 4.25. Map showing location of excavated units.

Excavation protocol

I divided the six archaeologists and four to six local workers into four teams to work simultaneously on four units relatively close to each other to share some of the tools and resources.

Unit IDs were created using the following pattern:

U (unit) + (computer number) + (area letter) + (next available number using 2 digits)

For example: U1A01.

Once located on the ground, I personally laid out each unit/trench using compass, measuring tape, big iron nails for the corners or stakes when necessarily, and cotton string. Each unit corner was recorded with the GNSS receiver using similar settings as other GPS points but with an average of 250 points. All corners were clearly marked with orange flagging tape labeled with the unit ID and cardinal direction. The SW corner of each unit was always used as the reference point for all measurements.

A sub-datum was created for each unit by securing a 20 cm long iron nail into the closest large tree at about knee height. The location and absolute altitude of the head of the nail was then recorded with the GNSS receiver, this time averaging 500 points. A long piece of string was tied to the end of the nail and with a line-level, used for measurements. We used centimeters for all the measurements in the excavation, and *centimeters below datum* (cmbd) for all depths.

The excavation method was generally the same for all units. The top layer of each unit was usually excavated following natural stratigraphy (humus layers were typically less than 10cm thick). Subsequent levels were excavated in arbitrary 10cm levels unless there was a very clear change on the stratigraphy. Each level had its own FS bag separated into internal bags by materials, for example: FS0045 contains ceramic and lithic materials. All the materials were placed into a plastic bag (2 mm thick) and tied with a knot once finished for easy access at field lab. The outside of the bags was marked with provenience information —unit, level, date, initials, contents, FS #, and additional notes if necessary. Excavation was performed using hand trowels at all times, and carefully scraping the level in small increments of 2-3 cm at a time. All the dirt was screened using one quarter of an inch wire-mesh. The lead archaeologist of the unit would take notes during the excavation using the level forms specially created for the project.[23] We kept a strict control of the information, for example, making sure that every photo was recorded on the photo log as well as in the level form (Figure 4.26).

[23] See forms in appendix E

Excavating features

If relevant features were encountered —e.g., internal wall, earlier road, blockage, etc.— then the feature was given a code and registered in the feature log using: *the letter of the area + next available two-digit number,* for example: *A-01, F-01, F-02*. Features were treated differently by case and under the discretion of the archaeologist, for example, some features were excavated in their own levels, keeping an FS # per level, and other features were all excavated within one unique level/FS number.

Organic samples

I collected sediment and charcoal samples during excavation.

Sediment samples were very straightforward. I collected two liter, non-screened, samples for each unique stratigraphic context. This sample was collected using bare hands from the unit wall at the very end of excavation (after mapping), or during excavation if the stratigraphic layer was clearly identified and not near an important feature.

The charcoal sampling protocol was more rigid. When charcoal was found excavation was stopped. Next, the lead archaeologist cleaned their trowel using a bandana and rubbing the trowel on the dirt while using gloves. The charcoal was then collected wearing a bandana on the face to prevent dropping saliva or sweat over the sample. If the fragment was >1 cm^3 it was collected and placed on an aluminum envelope previously prepared. Using a sharpie, the aluminum envelope was marked with the FS number followed by a dot and the next available number (in case there were multiple charcoal samples within the same level), for example: *FS2008.1, FS2008.2*. All the aluminum envelopes from the same level were then placed inside a plastic bag with the usual information labeled outside.

Once the charcoal sample was safely put away, we documented its location on X, Y, and Z using the datum and the SW corner of the unit. Finally, we ranked samples using a 3-category system: 1) Relatively good context (best); 2) Questionable context; and 3) Likely modern or disturbed (bad). Taking notes of each sample helped me build a rank list of all the samples per unit and choose samples for testing.[24]

Maps and documentation

At the end of the excavation (once we reached a sterile layer, or four consecutive layers without materials/architecture, or bedrock), I created stratigraphic profile drawings for each wall in each unit, together with a 3D model using photogrammetry. These two techniques helped recreate the stratigraphy and contextualize the finds in the excavation (Figure 4.26).[25]

When units were completely excavated and documented, we covered them using the rocks and screened dirt from excavation. We laid out 30 x 30 cm plastic bag cut-offs at the bottom before filling to mark the end of the excavation without creating an impasse for roots, animals and water.

[24] See chapter five
[25] See chapter five

Figure 4.26. General images of excavation process. From top left to bottom right: 1) Rodrigo S. and Kiyo G. drawing profiles of unit. 2) Ruben A. screening dirt. 3) Jose Luis U. and Alberto J. excavating unit. 4) Jose Luis U. and Kiyo G. excavating Feature. 5) Andee D. documenting unit findings. 6) Kyle U. excavating unit.

Ultimately, we created five logs during excavation:

1) Unit log (their location, dimensions, associated sub-datum, etc.);
2) Sub-datum log (location in UTMs);
3) Feature log (location, unit, and description);
4) Photo log (one for each camera);
5) FS log (one for each subarea that included C14, sediment samples, and cultural materials).

I also created a documentation package for each unit kept in its own folder containing a level form for each level, associated feature forms, a unit summary form, and all associated notes and maps.

Summary of excavation

Through the excavation, I encouraged all excavators (archaeologists and workers) to continuously discuss their observations and make their own decisions, however, I also made sure I was regularly updated and constantly checked that excavation was properly performed and documented. Similarly, I urged all teams to take photographs and notes beyond those required by the level forms.

A more detailed discussion of the excavation results is presented in chapter six. However, it is important to summarize some of the observations after the second part of the fieldwork.

After 4 weeks of excavation, a total of 9 units were excavated ranging from ~50 cm to ~1.80cm deep (Table 4.5). All but two (U1F02, and U1H01) of these units showed some evidence of architecture either retention walls, *banquetas*, fill, or earlier paved roads. These construction techniques are similar to those observed by LORE-LPB (Fisher et al., 2014; 2016) and are characterized by larger non-faceted basalt rocks on the base of walls, mud-based mortar, and mostly rough or unsophisticated architecture styles.

In general terms, the stratigraphy also followed our observations from previous excavations from LORE-LPB (Ibid). This stratigraphy can be generalized as shallow deposits (except units U1A01 and U1I03) with three to five strata (levels approximately 20-30 cm deep). First levels were generally a very thin layer of humus (0-5 cm) or a semi-compact silt (road surface) followed by variations of semi-compact loam-to-silt layers, with medium to large concentrations of rocks, and a final sterile stratum of compact sand or clay.[26]

[26] See stratigraphy description in chapter five and appendix D

UNIT	AREA/TILE	DIMENSIONS	ABSOLUTE EXCAVATED DEPTH
U1A01	A/23	4 x 1.5 m	1.82 cm
U1A02	A/22	5 x 1 m	63 cm
U1F01	FG/54	1 x 1 m	55 cm
U1F02	FG/54	1 x 1 m	70 cm
U1H01	H/75	0.5 x 1.5 m	70 cm
U1H02	H/75	1 x 1 m	81 cm
U1I01	I/10	4 x 1.5 m	72 cm
U1I02	I/23	4.5 x 1.5 m	63 cm
U1I03	I/37	8 x 1 m	1.05 cm

Table 4.5. List of excavation units.

A total of 87 FS bags containing 1,385 fragments between ceramic and lithic and with a total weight over 5 kg were created through the excavation. Nevertheless, this is a low number of cultural deposits for excavation units in general for Angamuco (Cohen, 2016), which suggests how limited cultural materials can be found on urban roads.[27]

Overall, 70 carbon samples were collected, however, only 17 were considered as *relatively good context* and worth testing. Ultimately, nine samples were sent for analysis.[28] A total of 13 features —usually describing some architectural element like a wall, a ramp, etc.— were found and excavated (Table 4.5).

FEATURE ID	UNIT	AREA/TILE	DESCRIPTION/TYPE
A-01	U1A01	AD/23	Small stone platform between banquetas under pavement
A-02	U1A02	AD/22	Fill for blockage
I-01	U1I02	I/23	Fill area
I-02	U1I02	I/23	Segment wall (North half)
I-03	U1I01	I/10	Segment wall (South half)
I-04	U1I01	I/10	Segment wall
A-03	U1A02	AD/22	Segment middle wall
A-04	U1A02	AD/22	Segment wall (East)
I-05	U1I03	I/37	East interior ramp
I-06	U1I03	I/37	Segment wall (West)
I-07	U1I03	I/37	East retaining wall
I-08	U1I03	I/37	East banqueta
H-01	U1H01	H/75	Segment wall

Table 4.6. List of excavated features.

[27] See discussion in chapter seven
[28] See results and dates in chapter five

It is important to note that several challenges influenced the excavation session. For example, by the time excavation had started, rainy season was at its peak. Showers usually happened around the end of our fieldwork day, so we spent a considerable amount of time (last 30 minutes of work) covering units with tarps and sealing them with large rocks to prevent water from getting into the units.

4.4.3. Field Laboratory

There were two stages of material analysis during this research. The first one can be considered a *field lab analysis* or *pre-sorting* of materials and was performed for a few hours every weekday and Saturday mornings during fieldwork at our field-house in Patzcuaro (June and July of 2016). The second stage of analysis, described in detail in chapter five, was performed at the *Laboratorio de Estudios Mexicanos y Mesoamericanos* of Universidad de Guadalajara (September and December of 2016).

The goals of the first stage, field-lab analysis were:

a) To clean and mark all materials for further analysis;

b) To double check provenience information in all FS bags;

c) To create an inventory of pre-sorted materials;

d) To create new/clean FS bag tags and re-house materials into clean zip-lock bags.

Other activities related to data, equipment, and project directions were also conducted during this stage.

The bottom floor of the field house was arranged to work as our field-lab. Fortunately, we had enough space and some equipment borrowed from LORE-LPB, like tables, desk lamps, and reference bibliography. The rest of the equipment (computers, scales, calipers, magnifying glasses, printer, etc.) was either borrowed from University of Washington or purchased by PACUA project.

Lab space was subdivided into five areas or stations (Figure 4.27):

1) A data backup area that consisted of one semi-permanent laptop computer, external hard drive and all necessary cables for daily backup of GPS and cameras;

2) Equipment charging area (GNSS receivers, data collectors, cameras, and radios)

3) Material storage area, that included a section for finished pre-sorted materials and on-going analysis;

4) Pre-sorting or analysis area, an area facing windows with the most natural light that had desk lamps, loupes, scales and space for analysis;

5) The washing and drying area was located in the terrace of the house.

Figure 4.27. General images of field-lab work. From top left to bottom right: 1) Kyle U. backing up data. 2) Field-lab. 3) Kate B. entering data into database. 4) Kate B. and Kiyo G. pre-sorting ceramic. 5) Ceramic materials. 6) Jose Luis U. inspecting a lithic fragment.

To oversee field-lab duties, I recruited Kate Boston to act as the lab manager. Her experience at the Burke museum and diligence to detail enormously helped me devote more time to the preparation of everyday field work, logistics, and oversee every other aspect of this project. Tasks at the field-lab were slightly different during survey and excavation sessions. However, pre-sorting was the same for all materials collected regardless of whether they were coming from excavation or the surface. In general terms, our protocol can be described as follows:

1) Confirming provenience: as soon as we came back from the field, the first thing we did was to double check the number and provenience of the bags each team had collected. The simplest method was to count the bags and double check with the FS log. We looked at the segment/node or level forms for that day to solve discrepancies. We also made sure that the label outside the bag was legible, if not a new fresh bag was used. Once provenience was checked, if FS bags contained ceramics or lithics, they were placed in a large plastic tub for washing (labeled: "to wash"). If FS bags contained charcoal or sediment samples, they were placed in a box labeled: "to fix samples".

2) Washing and drying: We washed all ceramics and lithics using soft toothbrushes and cold water. Before washing we marked the FS log with a star and initials next to the bag each person was going to wash. We only cleaned one bag at a time per person to avoid mixing materials. Once cleaned, we laid all fragments directly onto a *petate*[29] or an unused screen frame and left it in our garage drying under shade or indirect sun. We tried to keep all bags on their own *petate*/screen, but often we divided the surface with masking tape, always leaving a buffer between collections. We also cleaned and taped the bags and if they had lost their information, we would replace them. After materials were dry (usually not until the next day) were collected and placed

[29] Mexican mat made of dried palm leaves

them into their corresponding bags and then placed into a plastic bin for pre-sorting (labeled: "for pre-sorting").

3) Pre-sorting and labeling: all the materials from each FS bag (separated by material in the field) were further classified.

For ceramic materials, they were classified into basic morphological groups, and decoration each one with their own code (Table 4.7).

For lithic materials, they were classified into basic tool types associated to their reduction technique and material each with their own code (Table 4.7).

For C14 samples: Aluminum envelopes were placed in a new bag with their new paper bag tags. In this case the unique identifier only added the sample number from the field.

For miscellaneous materials: I included sediment and a metal fragment. The classification here was very straightforward, a special code for each type of material.

This pre-sorting or pre-classification was kept in an Excel database where each entry (row) essentially described every new category (morphology and decoration) per FS bag (Table 4.7). We ended up with a unique identifier code per category, for example, in ceramic:

(Project name or PA) + (Material: C for ceramic, L for lithic and M for miscellaneous) + (FS #) + (Morphology type code) + (Decoration code) = PA.C.FS0005.1.2.

4) Re-housing and storing: Finally, materials grouped by category were placed into new 4 mm zip-lock bags with a paper tag inside. All category bags were then placed into a larger bag by

FS number and stored in boxes by excavation unit for transport and further analysis. Therefore, we ended up with an inventory and collection by FS bag and by unit.

MATERIAL	TYPE	TYPE OPTIONS	COUNT	CLASS	CLASS OPTIONS	COUNT
Ceramic **2,091 fragments**	Body	-	1,903	Decorated	Paint, slip, negative, incision, appliqué	1,063
	Element	Rim, support, handle, base	182	Undecorated		1,004
	Special	Pipe, spoon, figurine;	2	Other		21
	Indeterminate	Not clear	4			
Lithic **95 fragments**	Tallada	Blade	31	Material	Obsidian	67
		Scraper	5		Basalt	25
		Point	1		Other	2
		Flake	37		Unknown	1
	Groundstone	Metate	1			
		Mano	0			
		Figurine	0			
	Other	Core, debitage, grinder, preform	20			
C14 **70 samples**	By rank	Good	17			
		Questionable	30			
		Bad	23			
Miscellaneous **38 samples**	Sediment	-	36			
	Metal	-	1			
	Other	-	1			

Table 4.7. Pre-sorting categories and counts.

Other tasks at the field-lab included digitally transferring all the information from node and segment forms into Excel spreadsheets, a job that helped double-check that our information was correct or that there were no missing entries. I also kept a project journal in which I urged members to write their day summaries and observations (per team). This journal became a very good synthesis of our fieldwork, often including small sketches. I believe that forcing archaeologists to abstract their observations and begin considering interpretations helps them more thoughtfully design their excavation and survey decisions. Ultimately, this journal became a fundamental tool to double check discrepancies in data, and a good guide for unit summaries. Daily backup of GPS and cameras, and production of photogrammetry 3D models of excavated units and other features, complemented our work on weekday evenings.

Finally, I called for weekly meetings every Wednesday night in which all members informed on their progress, observations, and status. I tried to make sure that all archaeologists' opinions were incorporated as long as they enhanced our work and supported the goals of the project. I used this space as well to share my ongoing observations, interpretations, and update on logistics and data.

Summary of Field laboratory

In sum, field-lab work procedures helped us stay in focus with my research goals. During this stage the following goals were achieved:

1) The recovery, re-housing, and pre-classification of a total of 95 lithic and 2,091 ceramic fragments, plus 70 charcoal, and 36 sediment samples (Table 4.6);
2) Correcting all corrupted provenience information;
3) Four pre-sort Excel inventories —ceramics, lithics, C14, sediments— including counts, weight, location, and notes;
4) Two Excel inventories of segments and nodes;
5) Twelve 3D models of units and road examples;
6) Over 40 profile and plan-view maps;
7) And over 1,800 photographs indexed by camera and date.

		TOTAL	EXCAVATION	SURFACE
Ceramic Total		**2,091**	**1,376**	**715**
Morphology types	Body	1,903	1,258	645
	Element	182	113	69
	Special	2	2	0
	Indeterminate	4	3	1
Decoration class	Decorated	1,063	950	113
	Undecorated	1,004	420	587
	Other class	21	6	15
Lithic Total		**95**	**61**	**34**
Types	Blade	31	24	7
	Scraper	5	4	1
	Point	1	1	0
	Flake	37	19	18
	Other	20	13	7
	Metate	1	0	1
	Mano	0	0	0
	Figurine	0	0	0
C14		**70**	**70**	**0**
Sediments		**36**	**36**	**0**
Metal		**1**	**1**	**0**

Table 4.8. Summary of all relevant finds by count.

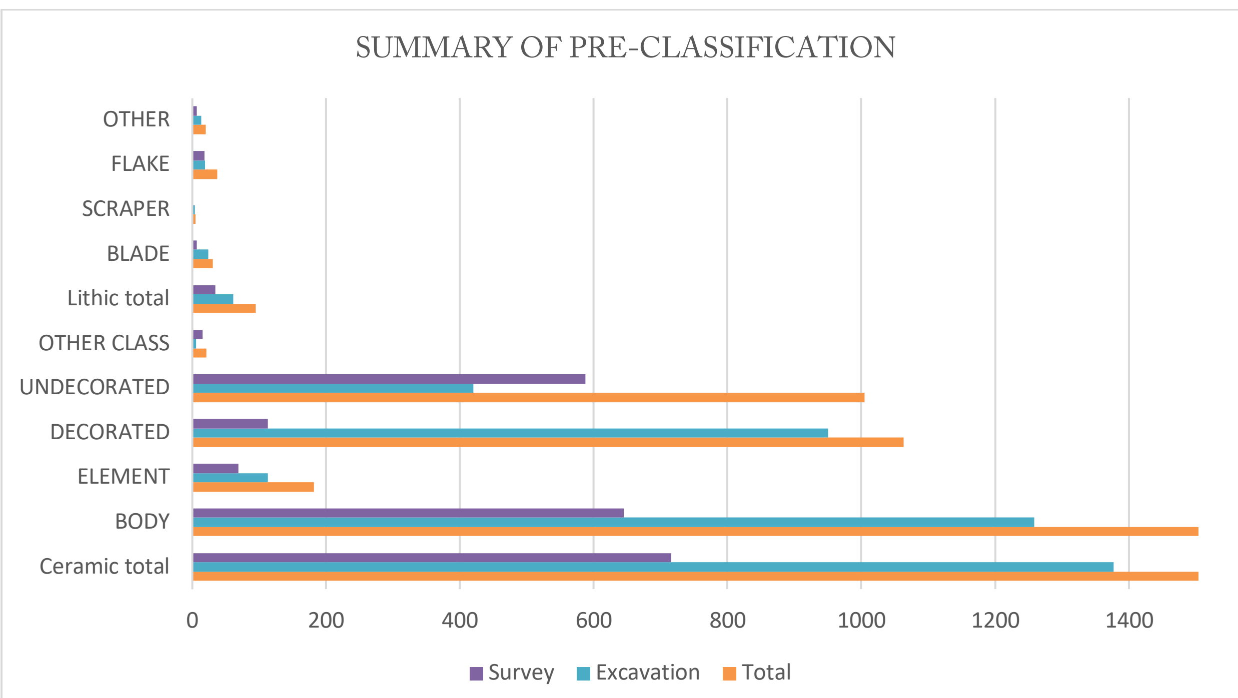


Figure 4.28. Summary of most relevant finds by count. See table 4.7 for details.

An abbreviated summary of the materials found through fieldwork is presented by pre-sorting types as well as units and segments/nodes in Table 4.7 and Figure 4.28 above. In general terms, before starting formal ceramic analysis, I saw a great diversity[30] of materials (form and decoration) within or associated to roads. These materials ranged from pre-Purépecha to colonial periods. Similar diversity of materials has also been observed at other excavated contexts in Angamuco (Fisher et al., 2014; 2016), which has been interpreted by Anna Cohen as evidence of intense interaction and exchange between areas of the site due to cultural, economic, and political practices (2016) which might have been possible with a well-integrated road network.

[30] See detailed analysis in chapter five

4.5. Stage 2: Digital road extraction

As mentioned earlier, a second goal set out in this investigation was to identify and extract >90% of all the roads in Angamuco (Stage 2 of road identification). The high resolution of the lidar derived Digital Elevation Model (DEM) provided the basis for this work, which included detecting and extracting roads into vectors for further computational analyses.

Background on feature extraction methodology

Particularly in the past 40 years, remote sensing methods have helped archaeologists collect information of archaeological landscapes such as DEMs using aerial and satellite photography, 3D scanning, and lidar (Chase et al., 2012; Crutchley, 2010; Fernández-Lozano & Gutiérrez-Alonso, 2016; Fussell, 1982; Opitz, 2013; Ur, 2003; Uysal et al., 2015). Furthermore, in the last few decades archaeologists have also adopted computerized techniques aimed at characterizing and identifying architectural features from these data sources (Brunn & Weidner, 1997; De Laet et al., 2007; Punzo et al., 2017).

One way to approach the manipulation and interpretation of terrain models for this purpose is known as *feature extraction* (O'Neil-Dunne et al., 2013). There are two main methodologies:

1) Pixel-based classification approaches. A DEM is essentially a grid of pixels each containing a value. Each pixel is classified independently of their surrounding pixels using some kind of statistical function (for example, k-means) and the results provide new representations of those pixel values. An assembly of pixels with similar values form a spatial arrangement that can be interpreted as a feature (Sevara et al., 2016)
2) Object-based classification approaches in contrast, aggregate individual pixels into meaningful clusters. For example, groups of blue color pixels as lakes, or groups of

similar elevated heights as houses. Those clusters have a geometric shape that can be defined as a one entity or object (Hussain et al., 2013).

Through these different methods —either through pixel or object-based approaches— DEMs are processed in order to identify possible candidate *features* (Baatz et al., 2008) that, when paired with ground observations help archaeologists characterize them as either natural topography or archaeological features (Lasaponara & Masini, 2012a). However, both of these methods require manual interpretation, labeling, and extraction which are very time consuming and labor intensive.

Thus, semi-automated feature extraction methods were developed and have greatly served other scientific fields —e.g., medicine, geology, forestry, ecology, etc.— (Abdullatif Alharthy et al., 2002). Automated methods have the potential of becoming an extraordinary tool for archaeology, especially with higher resolution DEMs that have more spatial resolution (Lasaponara & Masini, 2012b). However, the topography and the shape of archaeological features varies considerably from one site to another and that creates analytical and technical challenges for the implementation of semi-automated feature extraction methods in archaeology (De Laet et al., 2007; Freeland et al., 2016; Radermarcher, 2016). Some of the biggest challenges are:

- They rely on shape-to-function interpretation. For example: a 10 x 5 m rectangular feature is interpreted as a "house". The problem is that not all "houses" have the same shape or dimensions, so if we are interested in human settlements, we have to reduce the scope from looking for "houses" to looking for "very straight walls" or "90-degree corners".
- It is hard to standardize qualitative concepts descriptors. For example, identifying what metrics are relevant to classify features that have complex forms (Belgiu et al., 2014).
- Selecting relevant features or eliminating redundant features. For example, in order to differentiate well-defined natural form from human-made features, archaeologists still

have to train and supervise the process, at least until results can be comparable to those obtained by direct observation in the field-confirmed sample (Fisher & Pezzutti, in progress).

For all these reasons, adopting and developing a semi-automated approach for feature extraction in archaeological settings requires a very high level of technical knowledge, large samples, and several years of work.

Digital processing of Angamuco's road network

The highly variable topography of Angamuco —including bedrock boulders on the surface— and its wide diversity of architectural types present in the site (Fisher et al, 2019a), makes automated feature extraction to be tremendously challenging (Urquhart, 2015). Roads in particular are complex features. For example, their shape is similar to natural water drainage, and while the field-surveyed sample helped create a typology of roads,[33] it is not enough to estimate the total amount of segments and nodes of each type. Developing and training a semi-automated process for road extraction for Angamuco was desirable but would have required a considerably different research focus and technical expertise.

Instead, for my research I adopted a mixed methodology in which I used GIS-based spatial analysis (FETE[34]), and pixel-based image techniques (multidirectional hillshade, sky-view factor, and openness negative visualization) to enhance the visual detection and interpretation of all possible road features within the full extent of Angamuco. The result of these techniques was used to aid with the identification and digital capture of road nodes and segments.

[33] See chapter seven
[34] See below

This process required three steps: 1) cleaning and standardizing survey data; 2) digital extraction; and 3) fixing topological errors. The process was performed at the DigAR Lab at UW during the months of June to December of 2017, with the assistance of five digital mappers following a strict workflow based on the spatial conventions and rules derived from survey.

The biggest challenge of this stage was developing a protocol that could be used to identify roads from the DEM that could later be transformed into vector (polyline) features. To develop such, I was inspired by previous works of semi-automated road identification in archaeological contexts in Italy and Crete (Passalacqua et al., 2010; Pavlidis, forthcoming).

4.5.1. Road visual and spatial criteria

Based on two basic principles; all human movement is linear, and interaction occurs at open spaces (Hillier & Vaughan, 2007), and for the sake of clarity, I defined the following topological rules regarding nodes and segments:

1. A road segment is a linear feature of any shape (curved, straight, sinuous).
2. A segment starts and ends at a node.
3. Segments can have any length or width (the smallest resolution for a polyline in the raster is as narrow as the smallest class of segment: <1 m).
4. Nodes are the points where two or more segments meet OR where a segment starts/ends (also called a simple node).
5. Nodes can have any area size (but are represented with a point).

I also created a set of visual and spatial rules based on field observations for the digital extraction of roads (Table. 4.9):

CRITERIA	ATTRIBUTES	DESCRIPTION OF CONVENTION	
SEGMENTS	TOPOLOGICAL	A road segment is a linear feature of any shape (curved, straight, sinuous)	
SEGMENTS	TOPOLOGICAL	A segment starts and ends in a node	
SEGMENTS	TOPOLOGICAL	Segments can have any length or width (the smallest resolution for a polyline in the raster is as narrow as the smallest class of segment: <1 m)	
NODES	TOPOLOGICAL	Nodes are the points where two or more segments meet OR where a segment starts/ends (called: simple node)	
NODES	TOPOLOGICAL	Nodes can have any area size (and are represented with a point).	
SEGMENTS	VISUAL	Texture	Segments are linear features with a smooth (not granulated) surface
SEGMENTS	VISUAL	Shape	Curved, Straight or Sinuous
SEGMENTS	VISUAL	Shadows	A segment might look like a "crack" in the topography (carved between walls, terrain or architecture that looks in contrast with two parallel lines) or like a wall (one dark line) surrounding topography or architecture
SEGMENTS	VISUAL	Size	Any
SEGMENTS	SPATIAL	Orientation	Any
SEGMENTS	SPATIAL	Spatial relationships	Segments do not cut architectural features (segment-like features that cut through architecture are actually modern cattle/human trails)

Table 4.9. Topological, visual, and spatial criteria for road interpretation of Angamuco.

4.5.2. Cleaning and Standardization of digital data

Ultimately, all the data produced through this research —from the field survey, and the digital extraction of roads explained below— including data from LORE-LPB on architecture of the site were used for analysis and interpretation. Whether used as reference, for comparison, analysis, or to help draw conclusions about spatial distribution of features, all these data were to interact through GIS and other methods. For this, all data was standardized which required adjustment and cleaning.

A total of three datasets were created at different stages of this research (Table 4.10).

1. *DIGAR geodatabase*: based on the image analysis of the lidar DEM for the entire site
2. *PACUA geodatabase*: created in the field during road mapping.
3. *LORE-LPB geodatabase*: field-corroborated and digitized by several years of pedestrian survey by the LORE-LPB project.

RESEARCH PROJECT	DATASET ALIAS	YEAR	ORIGIN OF DATA	TYPE OF SHAPEFILE	CONTENTS
LORE-LPB	LORE-LPB	2009-2011	Field-collected	Polygon	Complejo divisions
				Polygon	Neighborhood divisions
				Polygon	District divisions
				Polygon	Architectural features
PACUA	PACUA	2016	Field-collected	Point	Nodes
				Polyline	Segments
	DIGAR	2017	Computer-collected	Point	B-Nodes
				Point	Nodes
				Polyline	Segments

Table 4.10. Datasets used in this research. Alias was created to differentiate between datasets

The first two, DIGAR and PACUA datasets, were created following the same general structure, classification, and coding scheme original for the fieldwork (PACUA data dictionary). Both datasets stored information about segments as polylines with 20 attribute fields, and nodes as points with 19 attribute fields (Table 4.11). Many of these attributes, could not be captured or derived while conducting image analysis (DIGAR dataset) such as the area associated with nodes. However, for the sake of clarity, all attributes were maintained and filled with null values (Table 4.11).

The two most significant attributes that were derived from the analysis of lidar imagery were the number of segments converging on a node, and unique ID codes for segments and nodes that distinguish them from field collected.

GLOSSARY OF ATTRIBUTES, RULES AND FEATURES			
Attributes from the field collection and used as Fields in ArcGIS			
Field	**Description**	**Example**	**Paper**
GENERAL			
ID	Assigned by ArcGIS		No
ID_Code	The assigned code to each node and Segment. For Nodes used format (N or S) + (tablet #) + (Area) + (next available consecutive number)	S1A001/N1A001	Yes
Initials	Field collector's initially	RSC	Yes
GNSS	The GPS unit used for this data point	4	Yes
Camera	Camera number used for this data point	2	Yes
Tablet	Tablet number used for this data point	1	Yes
Date	The date in which the data point was collected by the GPS unit	7-Jun-16	Yes
Time	Time in which the data point was collected	8:43	Yes
Quad	Quad provenience of data point	I18-SE	Yes
Tile	Tile location of the data point	22	Yes
Area	Area of research in which data point is located	A-D	Yes
Photos of	If photos were taken in this segment and of what elements of it	Side/100_0053	Yes
FS Collection	FS number and description of the material types collected	none	Yes
Notes			Yes
SEGMENTS			
Class	Based in the number of segments or roads that intersects: '2-road', '3-road' and '>3-road'	2-road	Yes
Type	Style of the intersection = 'X node', 'K node', 'T node', 'Y node', 'Simple' and 'Other'	Y-node	Yes
Conditional	If the node is simple then where does the node start/end, what type of segment takes off from it = 'Entrance', 'Plaza node' and 'Other'	Entrance	Yes
Size	The area size of the node calculated by pacing by surveyor= '<50 cm2 or S', '1-3 m2 or M' and '>3 m2 or L'	L	Yes
Visible evidence of superposition?	Simple description in the judgement of the surveyor whether or not there is evidence of superposition between two segments= 'Y' or 'N'	N	Yes
Architecture/Construction	Architectural features of evident construction techniques associated to this segment	Building	Yes
NODES			
Class	Based in the overall width, there are only 3 classes: '>2m or camino', 'sendero' and ',1m or pasillo'	Sendero	Yes
Width	Measured in the field or the start, end and other point in the segment	2.5m/0.7m	Yes
Type of start/end	architecture features associated to the beginning or/and end of segment if possible. Where does this segments starts/ends.	node/pasillo	Yes
Architecture/Construction	Architectural features of evident construction techniques associated to this segment	banqueta/building	Yes
Experiential	Based on surveyor whether or not the next node/directional decision making (from one node) is visible = 'N (no)' and 'Y (yes)' and an overall diagnostic of the slope/effort = 'Easy', 'Moderate', 'Difficult'	N/Easy	Yes

Table 4.11. PACUA data dictionary (field survey of roads). Each row represents an attribute field.

GLOSSARY OF ATTRIBUTES, RULES AND FEATURES					
Simplified attributes for DIGAR dataset					
Field	**Description**	**Example**	**ArcGIS**	**Paper**	**Notes**
GENERAL					
OBJECTID	Default	1	Yes		Ignore. Filled by the computer
ID_Code	The assigned code to each node and Segment. For Nodes used format (N or S) + (Mapper #) + (Area will always be X) + (next available consecutive number) following the Field collection	S7X001/N7X001	Yes	Yes	
Initials	Field collector's initials	RSC	Yes	Yes	You can set to fill by default
Computer	The assigned code for each mapper	7	Yes	Yes	You can set to fill by default
Date	Date of editing (default)	7-Jun-16	Yes	Yes	
Quad	Quad provenience of data point (default)	I18-SE	Yes	Yes	You can set to fill by default
Tile	Tile location of the data point (default)	22	Yes	Yes	You can set to fill by default
Notes		"Delete", "Duplicate", "Interesting"	Yes	Yes	Only something very relevant
NODES					
Class	Based in the number of segments or roads that intersects: 1 means is at the end of a segment or a simple node; 2 means that is a 2-road cross; 3 a three-road cross, and 4 anything with more than three roads	2	Yes	Yes	
Cost		NULL	Yes	No	Ignore, leave empty
Size	Area size calculated	NULL	Yes	No	Ignore, leave empty
SEGMENTS					
Class	Based in the overall width, there are only 3 classes: '>2m or camino', 'sendero' and ',1m or pasillo'	NULL	No	Yes	Ignore, leave empty
Cost	Length (calculated by default)	NULL	Yes	No	Ignore, leave empty
B_NODES					
ID_Code	Does not need an special code, just take the next available consecutive number after your Mapper code, pad it with two zeros	7001	Yes	Yes	
Class	Only one class: 0 for boundary	0	Yes	Yes	
Cost		NULL	Yes	No	Ignore, leave empty
Size	Area size calculated	NULL	Yes	No	Ignore, leave empty

Table 4.12. DIGAR data dictionary (for image analysis). Each row represents an attribute field.

The PACUA dataset needed some cleaning and editing work. Two problems were identified with this dataset:

1) Minor inconsistencies on the coding of fields, such as the wrong use of capitalization and spelling on the attributes, and inconsistent entering of metric measurements. These were all fixed through editing tools in ArcMap.

2) Inconsistencies in the classification of nodes. For example, some simple nodes (dead-ends or one-segment nodes) were marked as 0-segments instead of 1-segment nodes. Additionally, the original design of the field form did not distinguish between nodes with 4-segments, 5-segments or more, as they were all marked as >3-segments (Figure 4.29). As I discuss in chapter seven, the distinction between some of these node types might be significant as it might suggest evidence of planning. For this reason, it was important to make a distinction between nodes with 4-segments and nodes with more than 4-segments nodes. Both of these issues were resolved using basic editing tools in ArcMap.

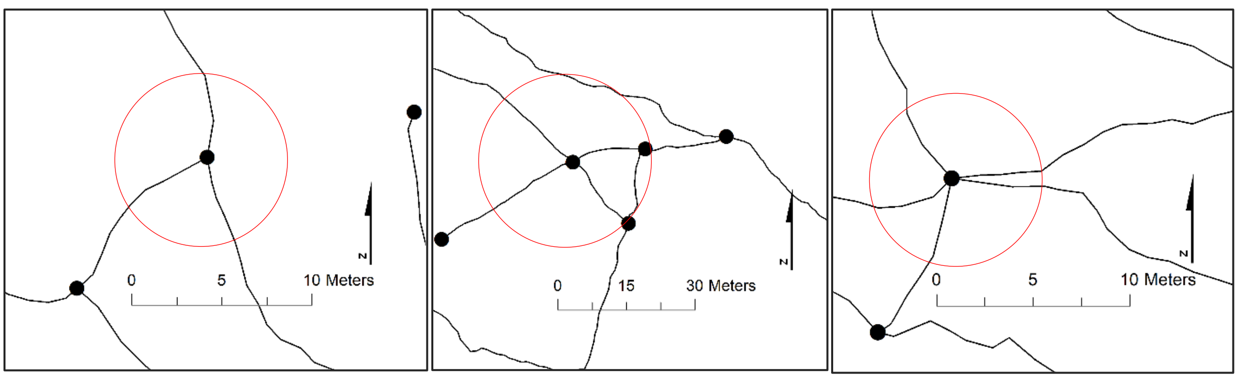


Figure 4.29. Examples distinguishing between 3 (left), 4 (center) and multi-segment (right) nodes. All at different scales.

The LORE-LPB dataset, contrastingly, required much editing work before it could be used side by side with the remaining datasets. It contained three main problems:

1) Duplicated or incomplete polygons representing architecture (Figure 4.30).

2) Inconsistency in the use of classes and subclasses for labelling architectural features.

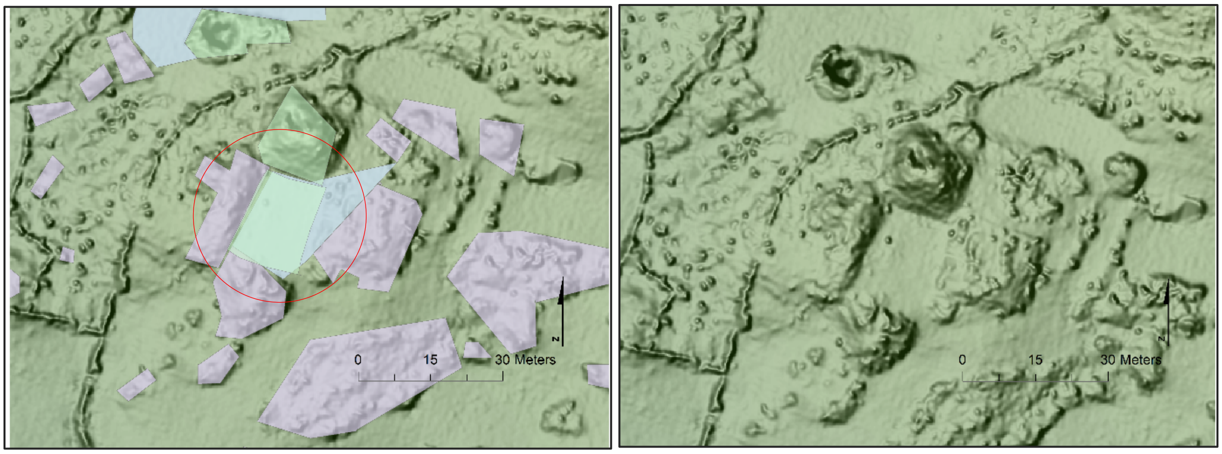


Figure 4.30. Left: Example of duplicated architectural features in LORE-LPB dataset (blue and green polygons on top of each other). These features were also incorrectly labeled.

3) Irrelevant architecture classification. The architecture typology used for LORE-LPB project was based on shape and construction technique (Fisher et al., 2011, 2012, 2019 and Cohen, 2016), which was not very useful for this research (Table 4.14). Instead of maintaining the original architecture typology, I simplified the types into two groups: private and public, based on how accessible these features are (derived by their function[35]). Further, private buildings were divided into habitational and non-habitational. I ignored all other classes or features (Table 4.13).

CLASS	SUBCLASS	TYPE
Public		Well
		Plaza
		Sunken_plaza
		Pyramid
		Terrace
Private	Habitational	Rooms
		Mounds
	Non-habitational	Patios

Table 4.13. Modified LORE-LPB architecture typology (used in this research) based on access and function used in this research.

[35] The function of each architecture type (shape) have been established by LORE-LPB (see Fisher et al, 2019a).

FORMAL CLASS Of shared scale, shape and placement to create 'behavioral expectations and actions'	PROTOTYPE CLASS Features that generate specific sets of meanings regardless their location by replicating morphology	USE TYPE May vary morphologically but share similar purpose	MODIFIER CLASS Elements that are built into or associated with defined types
Area_general	Ball_court	Square	Fogon
Artifact	Wall	Circular	Side_room
Environmental	Plazuela	L-shaped	Storage_room
Other	Sunken_plaza	I_shaped	Curb
Pyramid	Open_plaza	C_shaped	Central_building
Settlement_zone	Patio	Simple	Paved
Undefined	Habitational_terrace	Double	Plaza_associated
Building	Agriculture_terrace	1_course	
Mound	Patio	2_course	
	Well	3_course	
	Road	>3_course	
	Room	Type_A_room	
		Type_B_room	
		Type_C_room	
		Pasaje	
		Calzada	
		Granero	
		Stone_berm	
		Earthen_berm	
		Parallel	
		Talud	

Table 4.14. LORE-LPB architecture typology based on data dictionary (Fisher et al, 2011, 2019). Type = class of buildings that follow similar rules on morphology, function, placement, and relationship to other buildings

4) Incomplete site division polygons. Fisher (2011) and Urquhart (2015) suggest that Angamuco was divided spatially in urban units.[36] Although slightly different, both proposals use topography, the distribution of certain "public" architectural features —e.g., each neighborhood has at least one sunken plaza, pyramid, etc.— and a vague definition of major roads to create these divisions. I modified Fisher's original version of these site-divisions, fixing inconsistent and incomplete polygons. To some extent, I re-traced and re-created many complejos, neighborhoods,

[36] See discussion in chapter seven.

and districts. I also labeled them using letters for districts (largest site-division), and numbers for neighborhoods and complejos (Figure 4.31).

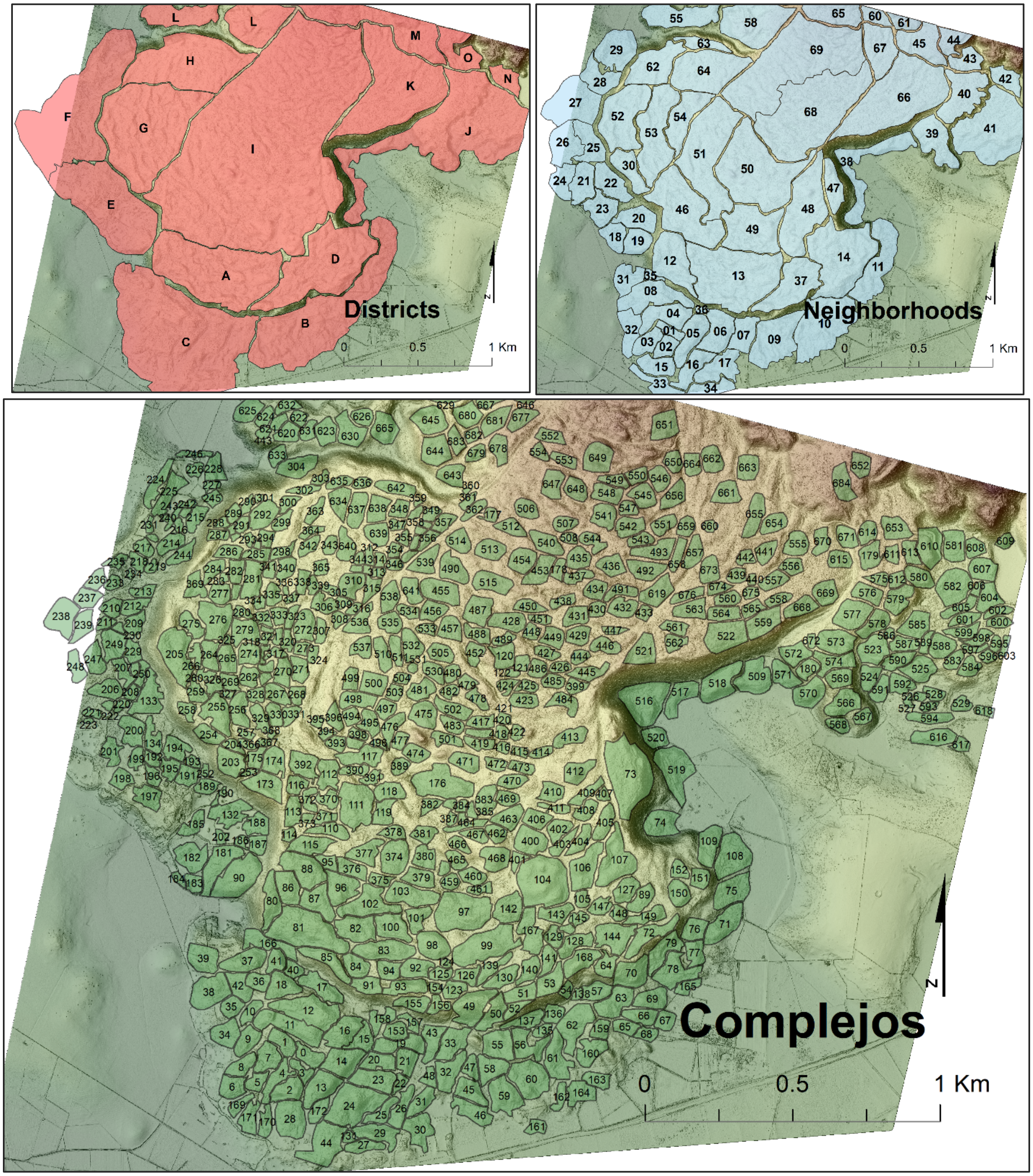


Figure 4.31. Map of Angamuco showing site-divisions.

5) Finally, I produced geometric centroids[37] for all architecture and site-division polygons. With this last step, I created a point for each type of building (following my own re-classification) and the center of each site-division which eventually was used for the network analysis.

4.5.3. Image analysis for identifying roads on the DEM

The image analysis and feature extraction processes were performed using ArcGIS 10.5 and several tools from the Relief Visualization Toolbox.[38] For this purpose, I developed a workflow. The procedure was completed with the assistance of five undergraduate students of UW.[39]

As mentioned before, the goal of this stage was to digitally identify all possible human-made and ancient road segments and their respective nodes for the >90% of surface of the site,[40] and to represent them as point and polyline feature layers for further network analysis. Since no semi-automated or automated process were utilized, it was vital to keep a strict systematic protocol to minimize errors. It was expected however, that some degree of inaccuracy and imprecision be present, especially between the work of six digital mappers (including myself). I knew that each mapper would make slightly different interpretative decisions. A set of clear guidelines for the different image analysis methods was provided to all digital mappers, that allowed for small adjustments within the scope of this procedure.

The spatial unit of analysis for this research was the *tile.*[41] The entire DEM of the site was divided using a grid of 170 equal-size tiles of 62,500 m^2 or 250m x 250m, each with its unique

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[37] Geometric centroids are the central coordinates (XY) of features. Subsequently, elevations for these geometric centroids were derived from the DEM surface.
[38] An open source toolbox developed by Klemen Zakšek from the Institute of Geophysics, University of Hamburg.
[39] See acknowledgements.
[40] The lower ~6 km^2 of Angamuco. For discussion on the actual extent of the site, see chapter three.
[41] See provenience for this site earlier in this chapter.

identifier. These tiles were generated vis a small tool I created in ArcMap (Figure 4.32). The results of this tool were 170 raster files with the same cell resolution as the original DEM.

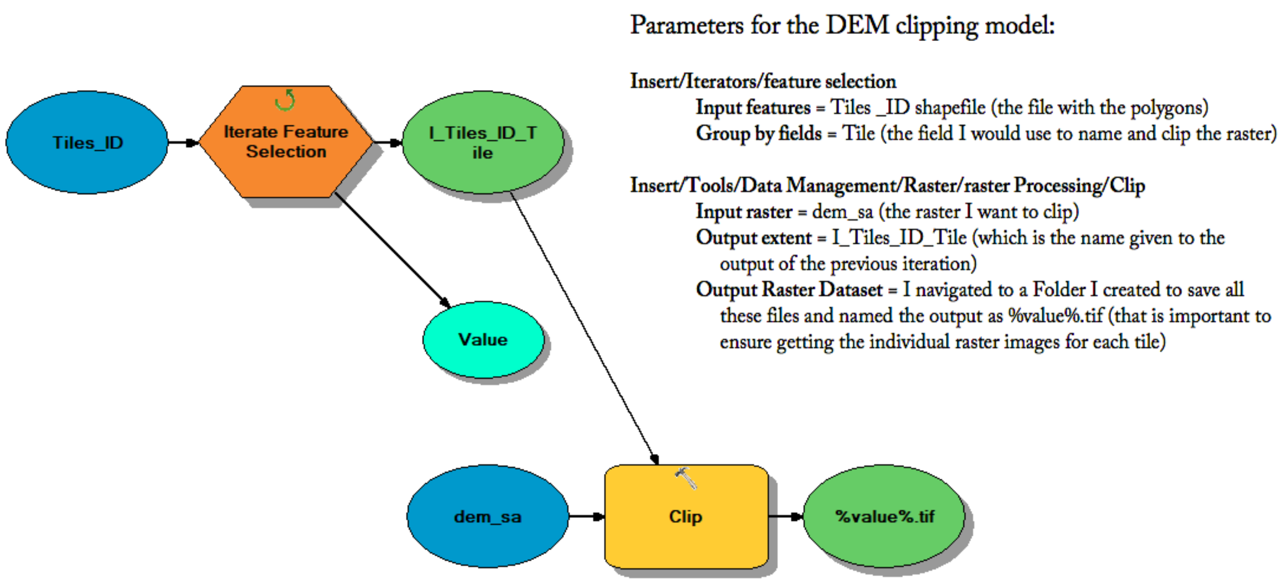


Figure 4.32. ArcMap model and parameters for dividing DEM into tiles.

Each mapper had access to four datasets to help process each tile: 1) From-Everywhere-To-Everywhere model (FETE); 2) Multidirectional hillshade; 3) Sky-view factor; and 4) Openness negative visualization. Each one of them provided different visualizations and are described below.

1) FETE: Devin A. White and Sarah B. Barber (2012) developed a spatial model to better understand regional pedestrian transportation networks in other areas of Mesoamerica. In their approach, they generated networks of possible roads based on the topography of the Oaxaca region where multiple origin and destination points are considered. Instead of providing the model with a single known origin to many known destinations, they inserted a grid with multiple regularly-spaced points in the raster. These sample points were then used to run a modified version of the shortest path algorithm resulting in a travel cost surface used to calculate the least cost paths between these points and recorded in a shared accumulative surface. The end result of the FETE

process is a travel probability surface similar to a road network. This same model was used in Angamuco with two parameters for these origin/destinations (every 10 and every 20 pixels) (Figure 4.33). The result cannot be interpreted as the road network of the site, but it became very helpful for having a first approximation of general movement patterns of Angamuco.

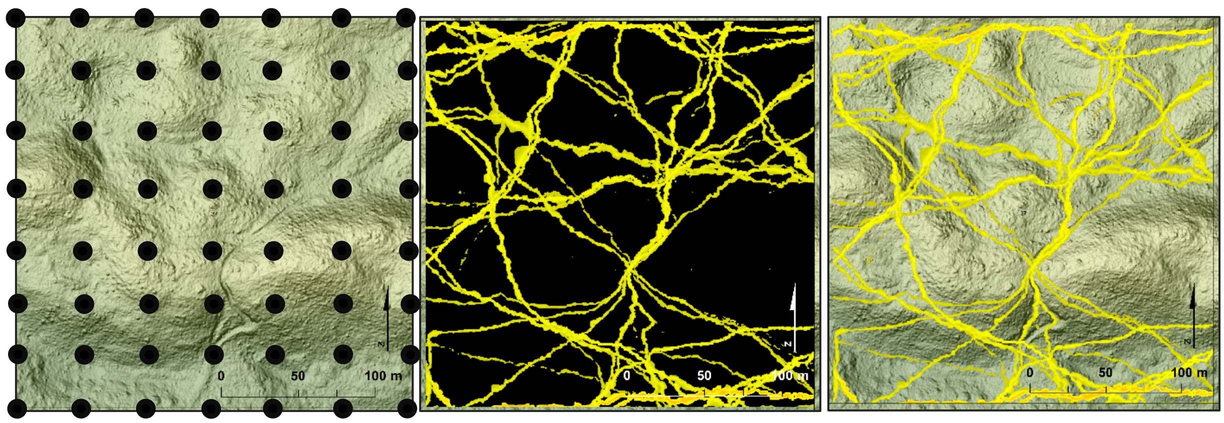


Figure 4.33. The left image shows an exaggeration of the FETE grid for Angamuco for tile 37. The center image shows the same tile with the resulting FETE network. The right image shows same tile after parameters are adjusted for PACUA. Based on White & Barber, 2012.

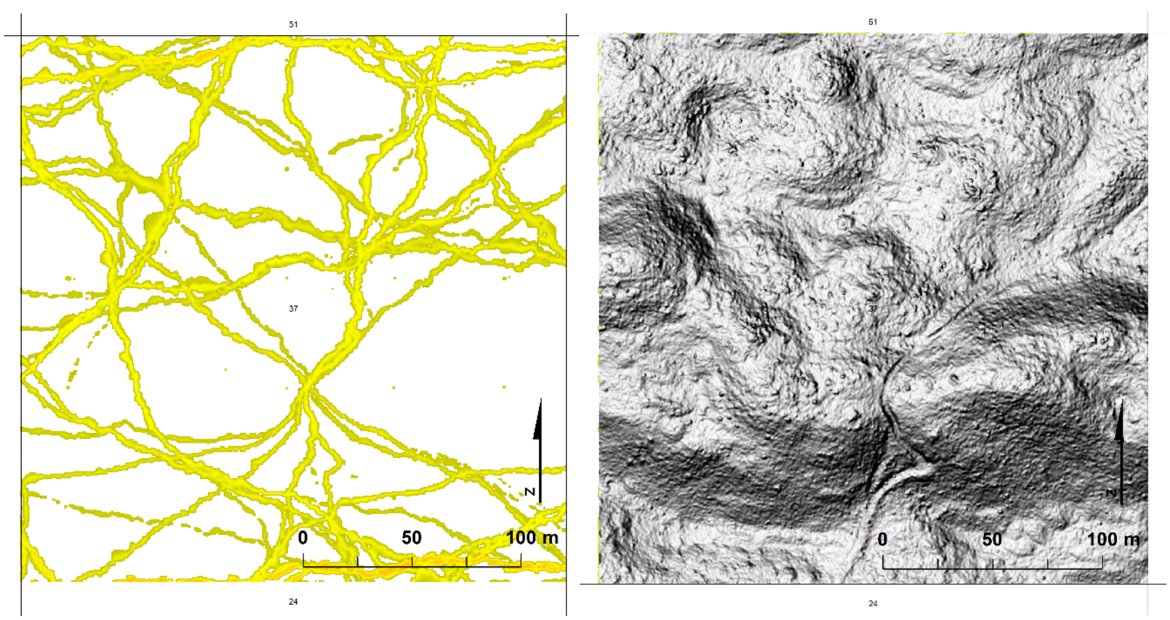
2) Multidirectional hillshade function: This is the same technique used as a background layer during fieldwork.[42] I created new shaded relief rasters for each tile using the clipped DEM tiles (Figure 4.34).

The next two image processing methods are provided by the *Relief Visualization Toolbox,* a standalone and open source software developed by the Institute of Anthropological and Spatial Studies from the University of Hamburg.[43]

3) Sky-view factor (SVF): Generally speaking, hillshades and other relief images are based on illumination (whether from one or many directions). However, this technique makes it difficult

[42] See section 4.2
[43] Available online at: https://iaps.zrc-sazu.si/node/67731#v

to see linear features running parallel to the (artificial) light beam. SVF instead creates a shaded relief based on diffuse of light by using a geophysical parameter corresponding to the portion of the sky visible from a certain point (Kokalj et al., 2011). In other words, it creates a light source from the celestial hemisphere centered on the point to be illuminated and creates a proxy relief of the visible share of sky. This method does not calculate for difference in brightness of the hemisphere or curvature, so it works best in smaller areas (<0.5 km^2) which is ideal for the *tiles*. The main parameters that influence an SVF are the number of horizon search directions and the maximum search radius. It also depends on the spatial resolution of the DEM, vertical exaggeration, and histogram stretch (Zakšek et al., 2011). These parameters have to be adjusted to the specific topographic characteristics of the area, so one tile in Angamuco might need slightly different adjustments than a neighboring tile. Overall, this method was very useful to identify well-defined roads with one or two *banquetas*,[44] or flat roads, but did not work as well to identify smaller roads (Figure 4.34).



[44] See chapter seven for road architecture

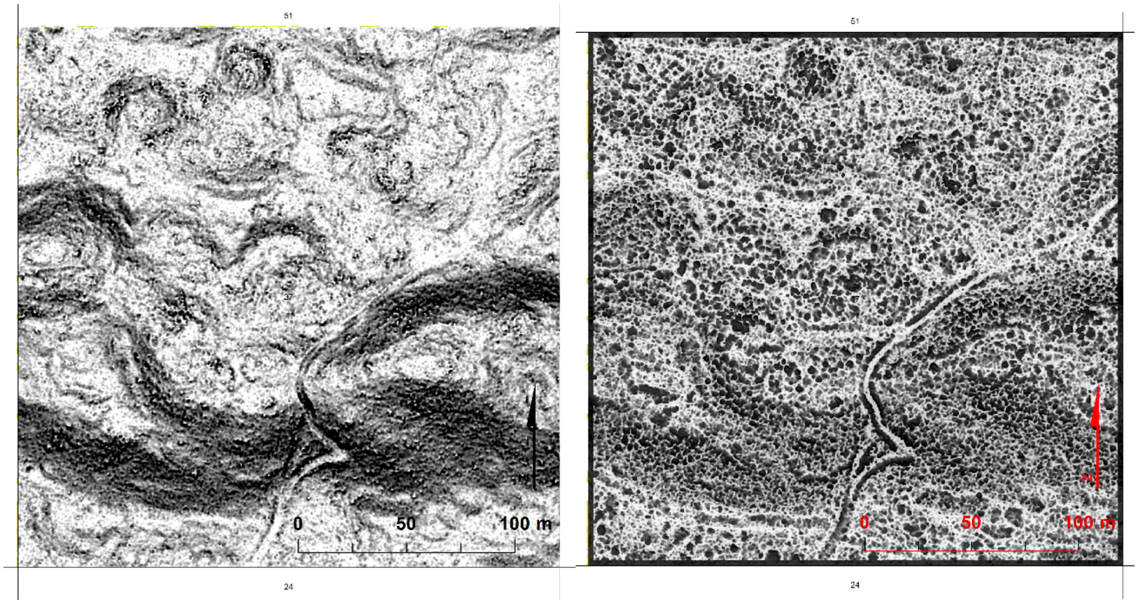


Figure 4.34. Four images of tile 37 showing different image analysis processes. Top left: FETE, Top right: Multidirectional hillshade function. Bottom left: SVF. Bottom right: Openness negative.

4) Openness negative: Openness has been used to express the degree of dominance or enclosure of a location on an irregular surface (Yokoyama et al., 2002). That is, profiles along at least eight cardinal directions are derived from a given DEM within a defined radial distance. Then, at each cell in the raster, the largest possible zenith or nadir angle along each profile is calculated. The mean of all zenith angles is called *positive openness*, and the mean nadir value is called *negative openness* (Doneus, 2013) (Figure 4.35). This method is particularly useful because it does not create a distortion (as normally hill-shading would do in order to create a three-dimensional sense). Moreover, openness negative provides a clear distinction between flat and roughed topographies and is very useful for identifying roads. Once openness was derived for the DEM, a histogram-stretch (Hist-eq) was applied to increase contrast. Additional brightness adjustments in the range of 0 to -20 were sometimes necessary (Figure 4.36).

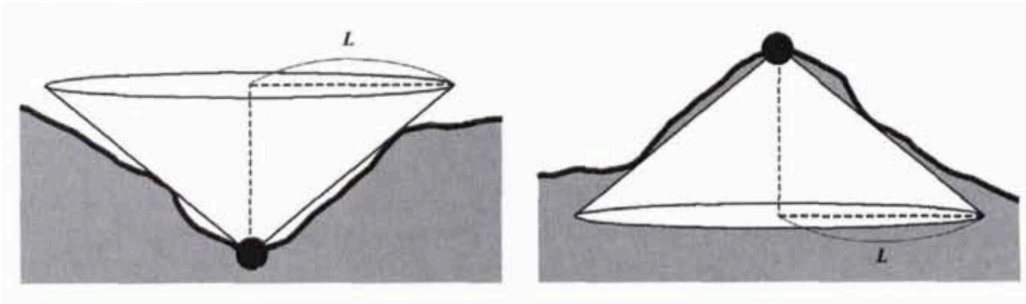


Figure 4.35. Positive (left) and negative (right) openness shown schematically for values < 90". Heavy irregular line is terrain surface; L is radial limit of calculation for chosen point (large dot) on a DEM. Image and description from Yokoyama et al., 2002.

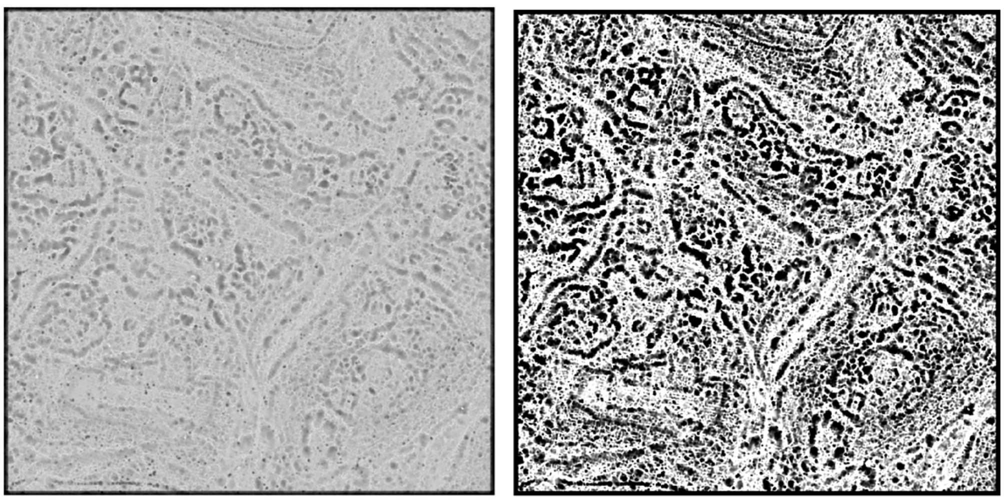


Figure 4.36. Two images of tile 22 showing Openness negative. Left: No stretch post-processing. Right: Hist-eq stretch post-processing.

While no single method was able to visualize all road-related features, the combination of these methods was instrumental in the process of identification as pointed out by others for other kinds of features (Bennett et al., 2012; Challis et al., 2011; Kokalj et al., 2013). Thus, I developed the following workflow combining all methods for the digital identification and extraction of segments and nodes in Angamuco.

First, I created a matrix and distribution of tiles by digital mapper. I tried to keep at least four adjacent tiles per mapper but also distributed mappers to reduce mapper-patterning (Figure

4.37). With this, I also created a new list of code names for each mapper. These code names were used to generate the ID codes for every new feature (Table 4.15).

MAPPER	CODE	EXAMPLE	NOTES
Computer 1	1	N1X001	Used in field
Computer 2	2	N2X001	Used in field
Rodrigo	3	N3X001	
Aegron	4	N4X001	
Jeremy	5	N5X001	
Ella	7	N7X001	
Angelica	8	N8X001	
Nick	9	N9X001	

Table 4.15. List of code-numbers for mappers. Every mapper had a unique code that was used as part of the ID_Code of every newly created feature. See Table 4.12

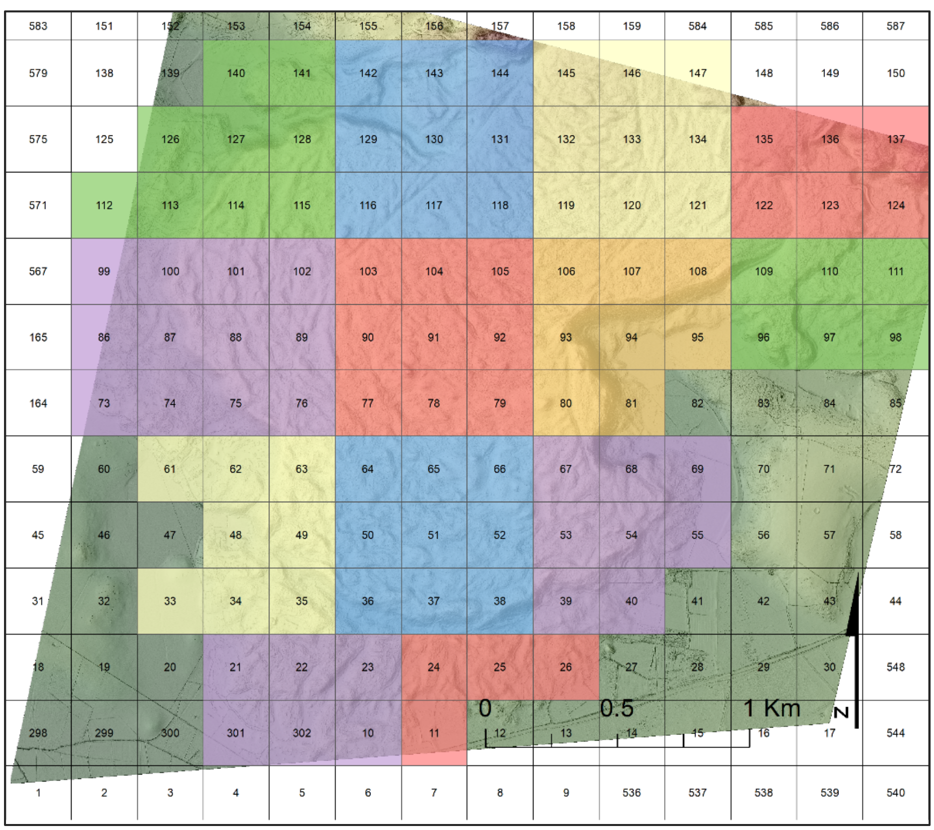


Figure 4.37. Matrix of tile distribution for Image Analysis. Each color represent a different mapper.

In order to maintain a certain level of consistency across mappers, I wrote a handbook with detailed instructions on every step to help mappers with the digital identification and extraction of roads. In addition, every mapper was given an identical geodatabase containing shapefiles for the new features, as well as other reference features such as Tiles_ID, Quad_ID for provenience information; and edited (corrected) architecture features for reference when available. The database also included all clipped DEM tiles and four folders containing results from FETE, SVF, Multidirectional Hillshades, and Openness negative for each tile.

The work flow was very simple (see Figure 4.38):

1) Using ArcMap 10.5, each mapper had to add the tiles necessary for their work;

2) Adjust brightness and sharpness as needed (respecting the allowed range);

3) Toggle between layers, primarily using FETE as a guide to identify roads;

4) Edit directly into ArcMap with editing tools, using ID_codes, rules, and classification, as well as the 2-node/1-segment method (map a node first and then the connecting segments) and finally,

5) Once the end of a batch of tiles was reached, add B-nodes. B-nodes were recorded in a different shapefile and were added at the end of a segment that intercepts the perimeter of the last tile of the mapper (Figure 4.39). B-nodes were created with two purposes in mind: to help other mappers using the adjacent tile know where they should begin their segment to follow a segment and, to help merge segments.

Instructions about how to record information regarding feature provenience, date, and other general information was also provided.

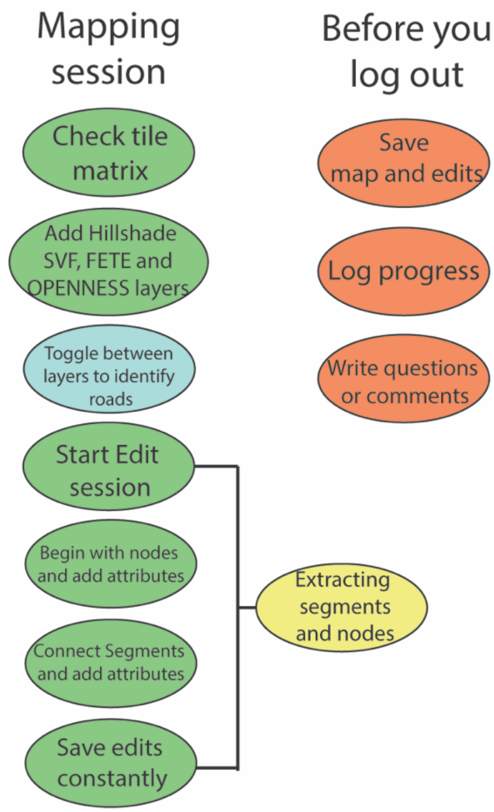


Figure 4.38. Concept map showing the image analysis workflow used by all mappers.

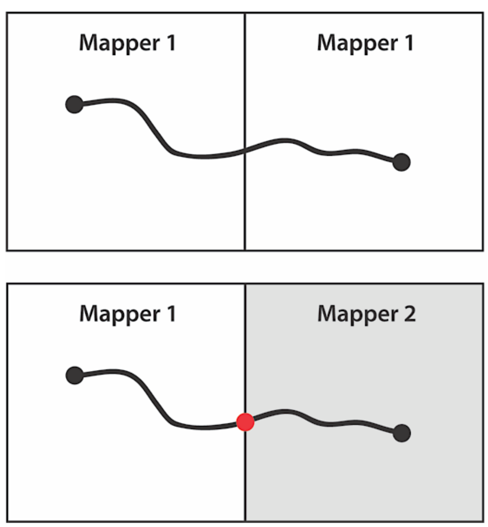


Figure 4.39. Schematic of Boundary node (in red). B-nodes are not real nodes and are used to identify the edge of a tile. Upper example shows no need for B-node since both adjacent tiles are part of the work of same mapper. Lower example creates a B-node between different mappers' tiles.

All mappers were encouraged to log their work and share their observations. We met several times a month to discuss progress, difficulties, and ways of streamlining the work. For example, through these conversations we found shortcuts in the workflow, more efficient ways to edit the attributes, and how to fix glitches in ArcMap. I periodically backed up all the work. Since we were working on independent databases, I collected all the shapefiles and placed then into a new dataset merging all the segment shapefiles of all mappers into one shapefile, and similarly for nodes and B-nodes. This process generated a total of 1,967 nodes of all classes, and 2,768 segments

4.5.4. Topological correction of roads and post-processing

The results of the image analysis yield a dense network of roads that needed to be cleaned and corrected to make it ready for network analysis. These processes needed to be performed with caution. For example, if a small group of segments and nodes were found isolated from the main network, this could be the result of an error during the image analysis or the effect of natural taphonomic processes such as erosion, earthquakes, modern agriculture and so on. Some of this was in fact observed during fieldwork. Another possibility was that some segments were in fact isolated from the rest of the road network.[45] However, the biggest two problems encountered after image analysis were: the lack of connection between some adjacent features, and duplication. In order to correct these topological issues, I generated a topology geoprocessing test using the ArcMap 10.5 topology toolbox. In it, I specified a set of topological rules (see Table 4.16) which I then ran on the entire network. This tool generated a set of points wherever topological rules were broken (Figure 4.40). I also set the following parameters of the tool: tolerance of 0.01 m for Z values and of 0.001 m for X and Y values.

[45] See section 7.2.2.

TYPE OF FEATURE	RULE
Segments (lines)	Must not self-overlap
	Must not self-intersect
	Must not overlap
	Must not intersect
	Must be a single part
	Endpoint most be covered by
Nodes (points)	Point most be covered by line
	Must be covered by endpoint of

Table 4.16. List of topological rules used in ArcMap for Angamuco.

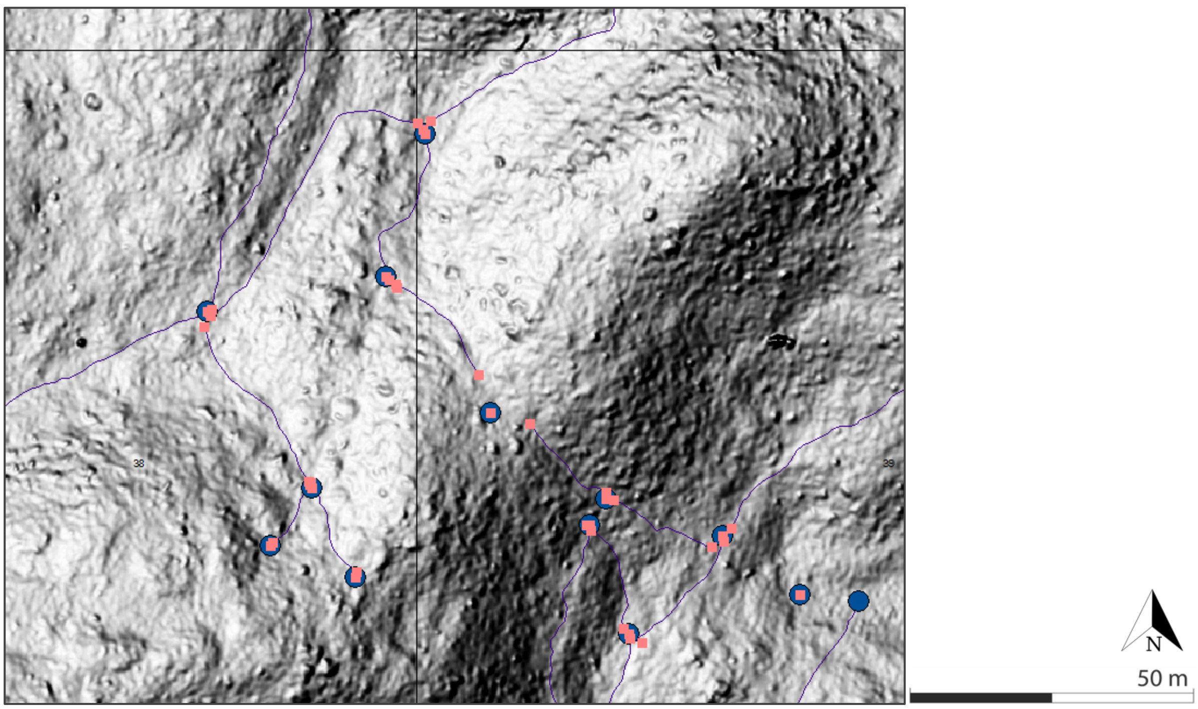


Figure 4.40. In this example of the PACUA network in tile 62, nodes and segments are not perfectly aligned. Errors are marked in red.

Editing features

Editing of features included zooming into an area, setting up snapping tools, starting an editing session, and investigating the recorded information for that particular feature. See, for example, node N2F030 in tile 38 below. Inspecting the node attributes, I found out that it was registered as a class three or 3-segment node (Figure 4.41). However, there are four segments nearby, not three. The distance between the node and the farthest segment looked significant, so it was not clear if the node was actually only connecting three segments or there is a missing end-node in the network. To confirm if the node is actually a 4-segment, I checked the field notes on N2F030 and found that the sketch describes four segments and their location (Figure 4.42)

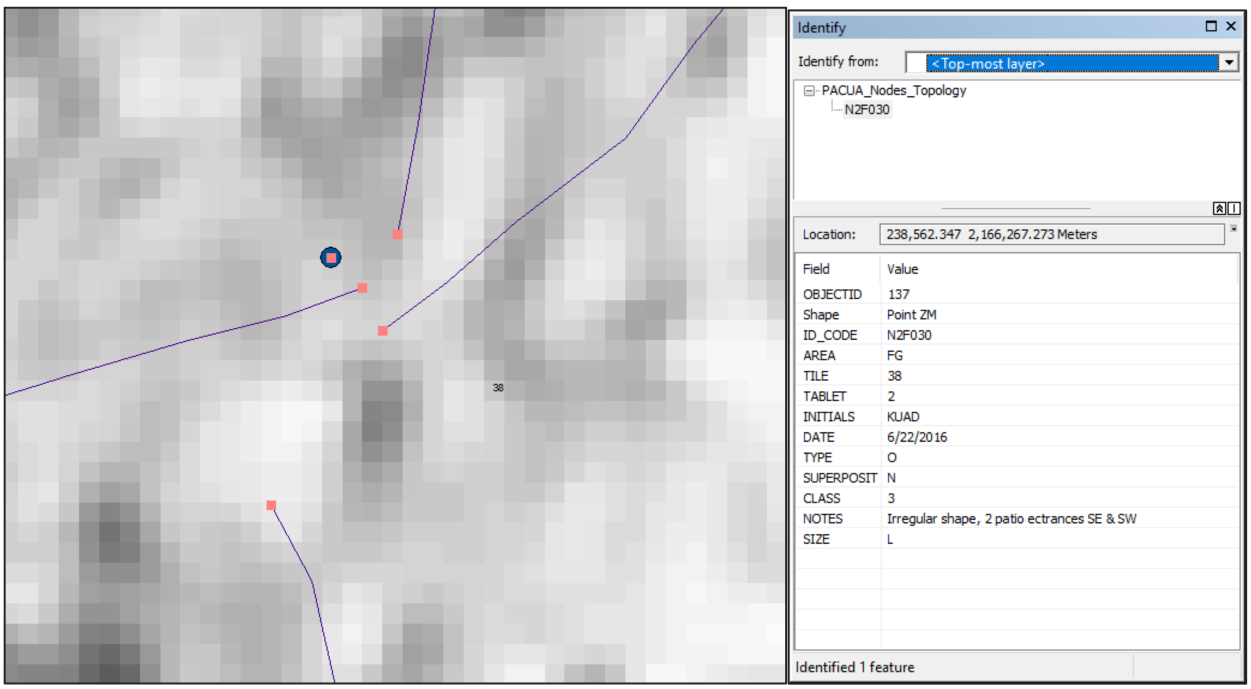
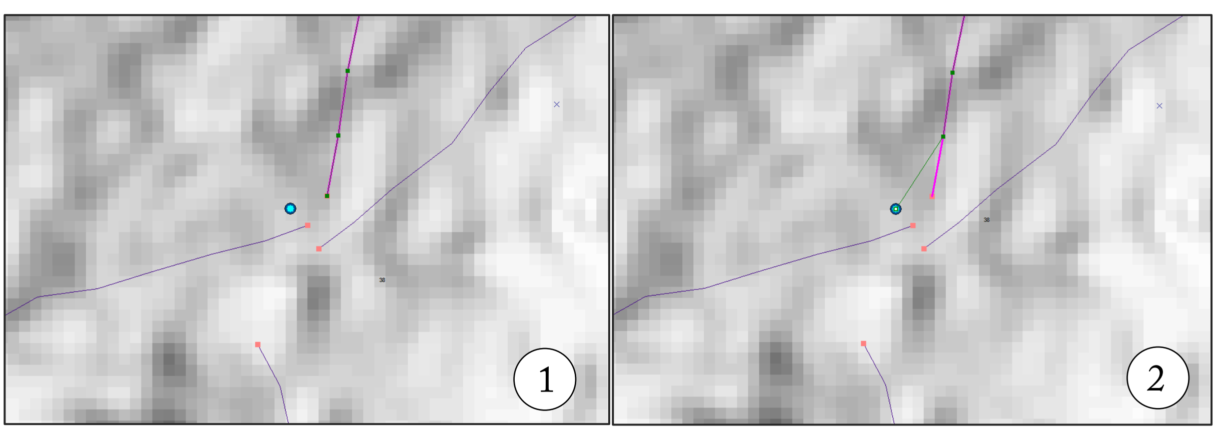


Figure 4.41. Left: Node N2F030 is not connected to the neighboring segments. Right: Attribute details of N2F030 that describes the number of segments it is supposed to connect (class).



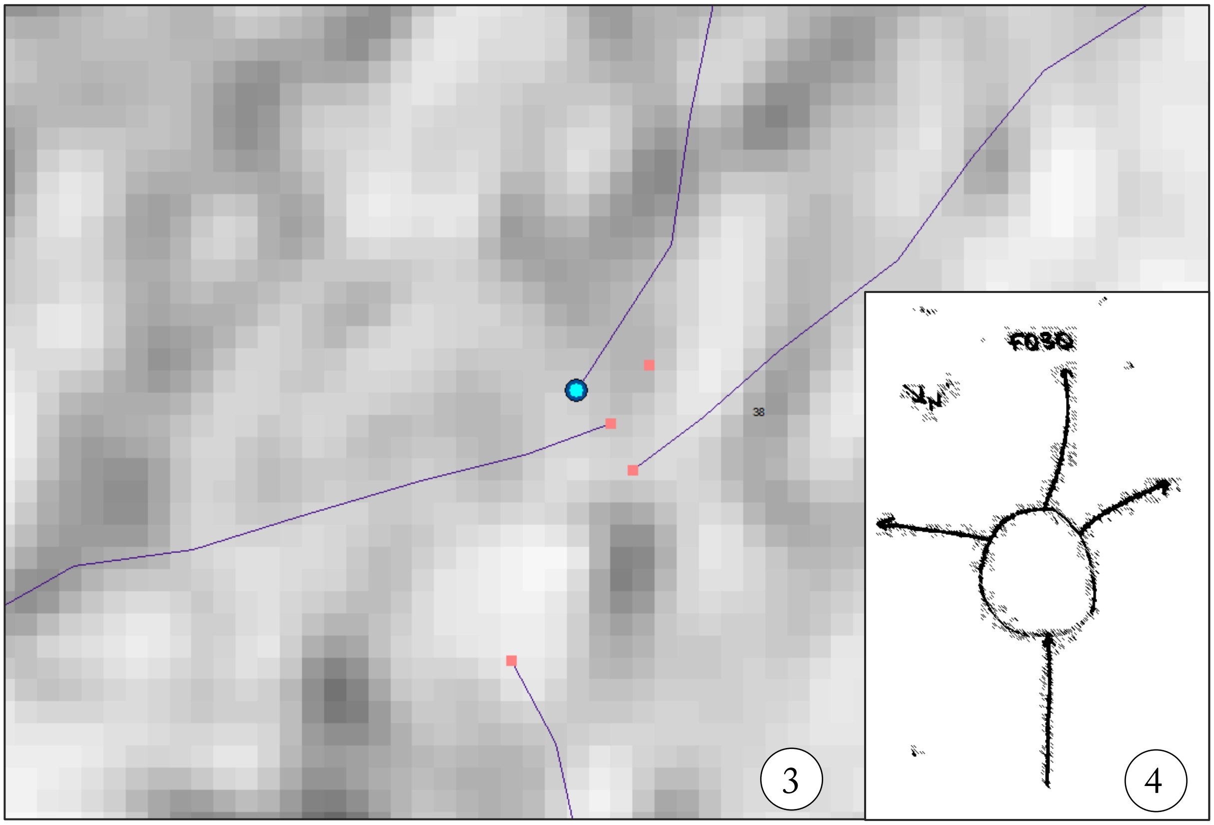


Figure 4.42. 1: Segment is selected to be edited; 2: Only last vertex of that segment is moved towards the node. 3: New location of the segment after correction. 4: Field sketch of node N2F030. No scale or north are provided.

It is clear that the error occurred during fieldwork. The surveyor registered the incorrect class for that node. After identifying the error, I edited the segments (leaving the node in place) by moving the last few vertices of the segments using the *topology edit tool* and changed the class directly in the attribute table (Figures 4.42 and 4.43). The final result shows the node and segments very similar to the field observations (Figure 4.44).

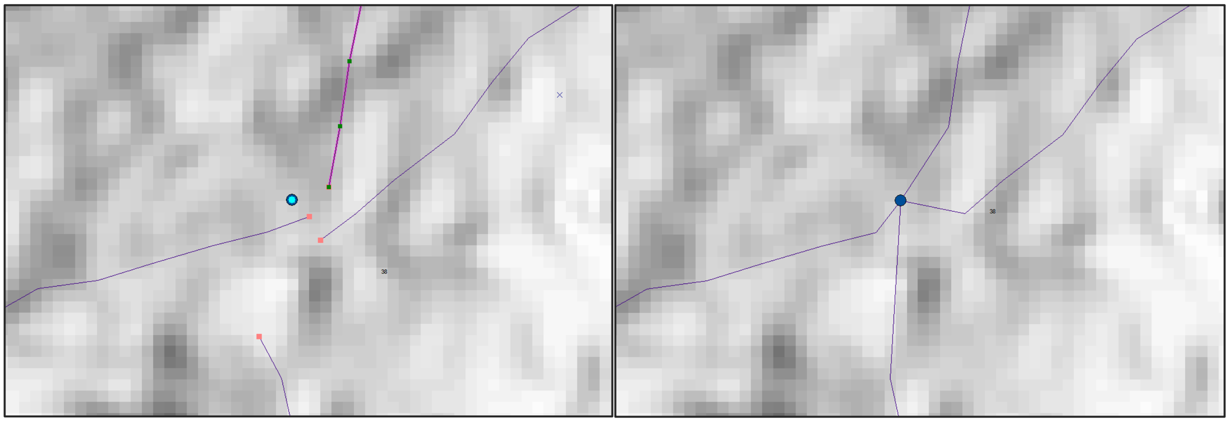


Figure 4.43. Before (left) and after (right) correcting segments. Red boxes represent error in the topology. No scale or north are provided.

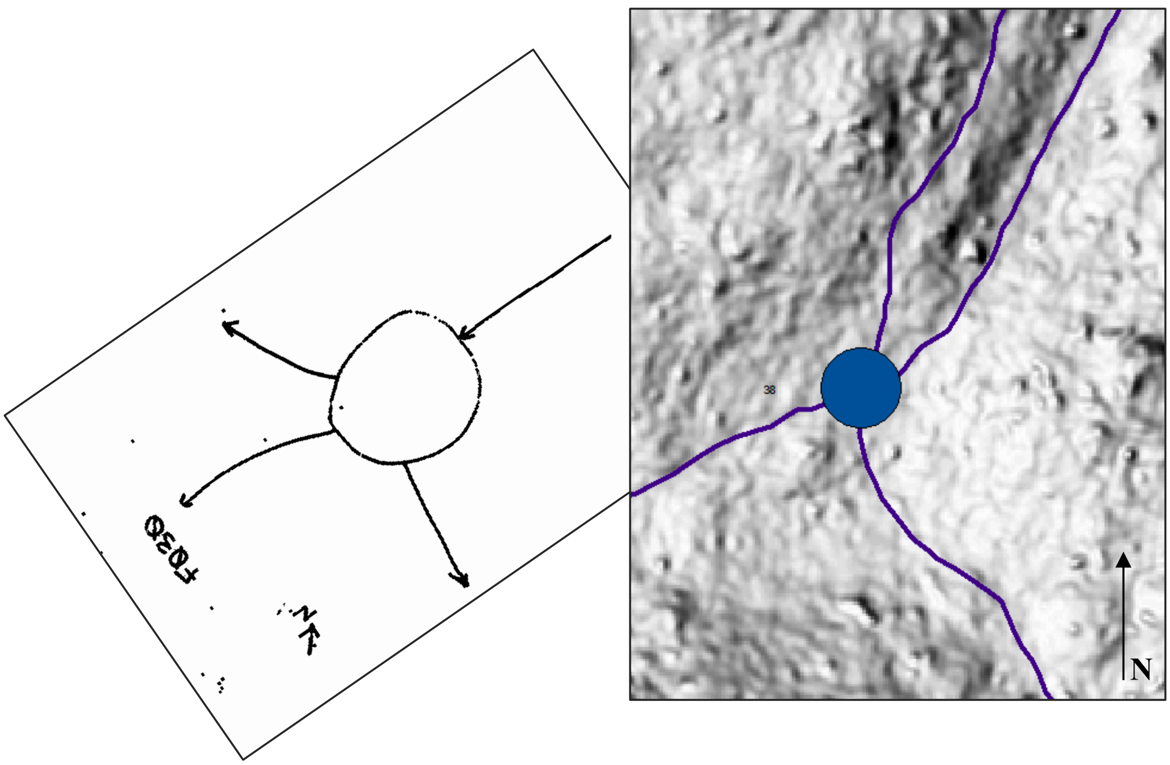


Figure 4.44. Corrected N2F030 with symbology adjusted to reflect better the size of the Node (Large). The sketch has been orientated to show similitudes. No scale is provided

Several other examples of topological errors were found during the post-processing, including lines that were intercepting and duplicated segments and nodes. Sometimes, editing these errors was complicated and unclear, particularly because the test would split intersecting segments creating parts that were not connected even if they were part of the same feature. On such occasions I merged separated parts of the same segment, but this meant to carefully check that original attributes were kept for such features.

Deleting false roads

As mentioned before, not all linear, flat surfaces are ancient roads. Some features resembling roads might actually be modern cattle trails, or rain drainage corridors.[46] Although this is easier to distinguish in the field, it was still possible to distinguish these during the digital extraction of the roads. For example, when available, architecture features provided a good reference for differentiating between ancient roads and cattle trails.

In the example below, segment S8X647 located in the SW corner of Tile 63 seems to run across a possible complejo and through two pronounced slopes —both up and down (Figure 4.45). As observed during fieldwork, ancient road segments usually follow the topography and natural features, unless they are wider than 4 m. They also have gradual slopes. Segment S8X647, was identified and extracted through image analysis, however, upon inspection did not match the topological, visual, and spatial criteria set for road identification in Angamuco (Table 4.8.).

[46] See assumptions and considerations of the network in section 6.1.1.

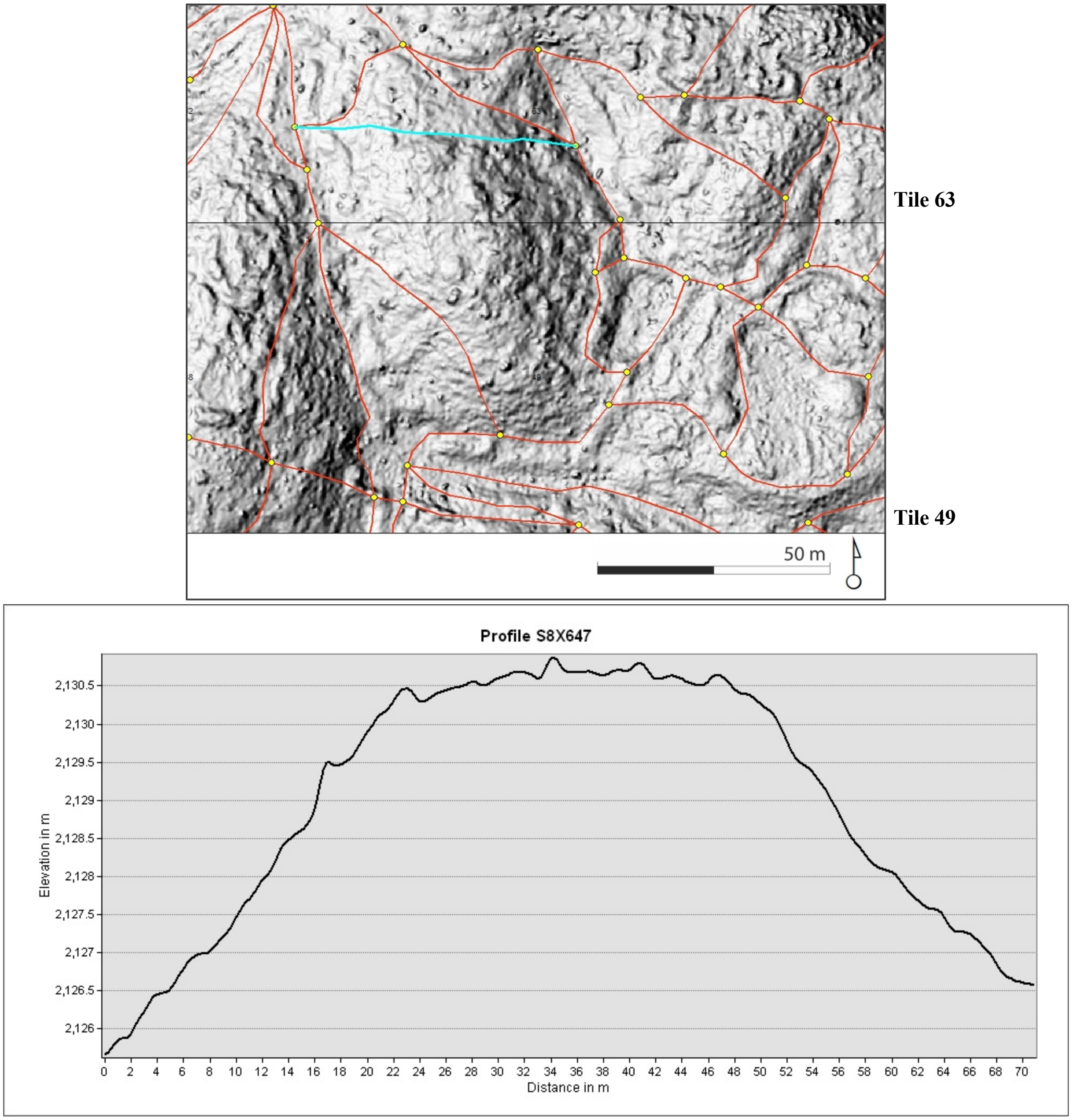


Figure 4.45. Top: detail of Tiles 63 (up) and 49 (down) on multidirectional hillshade image showing S8X647 in blue. Red lines are other segments, yellow dots are nodes. Below: Profile of same segment.

A detailed inspection of the nearby architecture shows that in fact, this segment cross through an *edificio compuesto* (multi-room building) (Figure 4.46).[47] Thus, the slope, the architecture, and the spatial location of this segment did not support the classification of this

[47] An exploration of circulation and connectivity inside complejos is discussed in section 7.3.1.

segment as a road segment. This type of inspection was done manually for every tile after image analysis was completed.

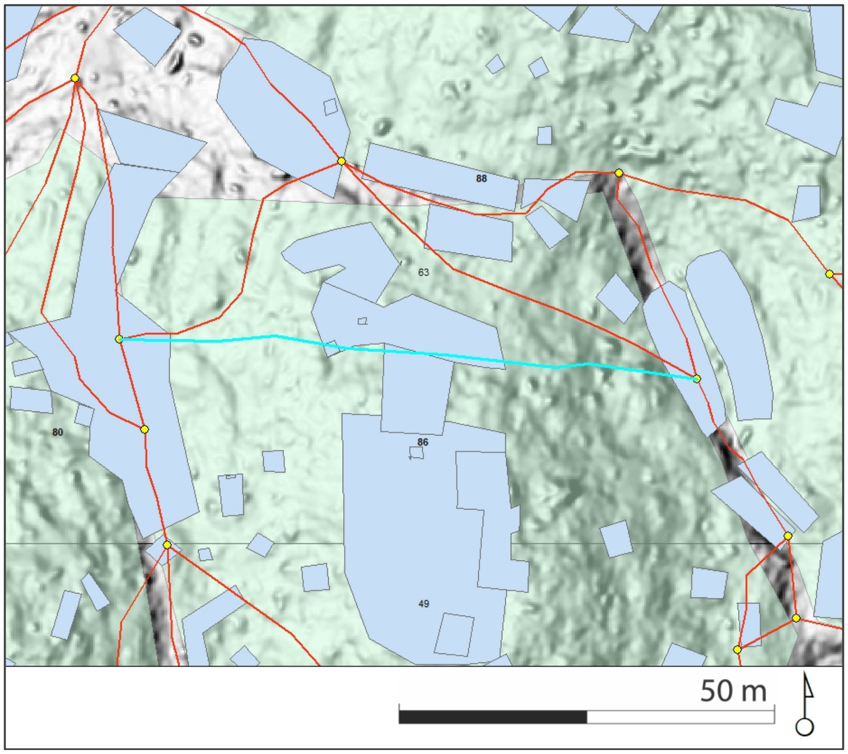


Figure 4.46. Detail of segment SX8647 (in blue). The green polygons represent complejos, yellow dots are nodes, and blue polygons are architectural features. Note: some of the features are open plazas which often served as large nodes and allow segments to run through. Architecture here is not symbolized by type.

Eliminating B-nodes

Eliminating B-nodes was the last task of post-processing. B-nodes were created to help mappers find a stopping point for their feature extraction when reaching the end of their area of analysis (tile). Every mapper had their own code and set of tiles. When a segment continued into an adjacent tile that was not assigned to them, they cut that segment at the tile perimeter and added a B-Node (Figure 4.39 and 4.47). The use of B-nodes was considered to be a necessary step to guarantee the data integrity of the road segments but it also added an additional factor that needed to be dealt with in order to generate the final network.

All B-nodes were merged into a new shapefile but needed to be eliminated for the final road network of the site. The following are the conditions and rules created to eliminate B-nodes:

1) All B-nodes between tiles would be deleted if two segments in either adjacent tiles had already been identified/digitized;

2) When B-nodes only connected one segment (the segment does not continue pass that tile) then B-nodes are converted into simple nodes (nodes class 1-segment);

3) All B-nodes at the boundaries of DEM will be left as is (B-nodes then marking the end of the site or network).

Using these criteria, I corrected all B-nodes from the image analysis. In sum, a total of X B-nodes remained from the 271 originally created.

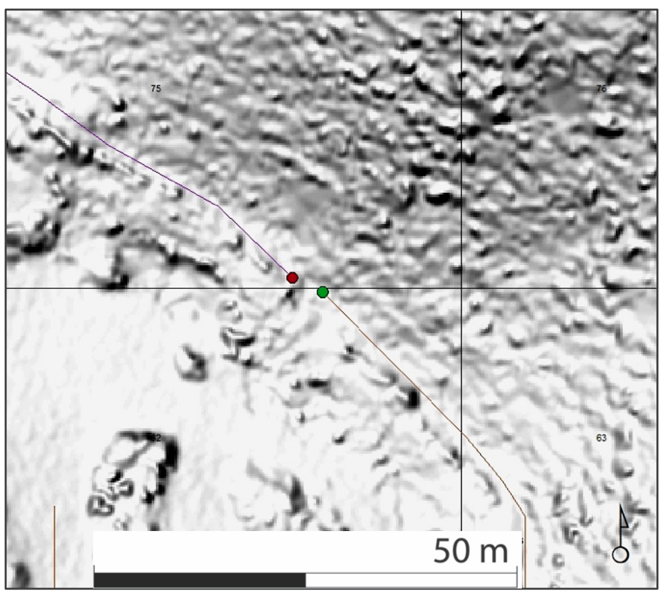


Figure 4.47. Left: example of two B-nodes (red and green) that would connect the same road segment between tiles 62 and 75. These two nodes were eliminated, and the segments were merged into one.

4.6. Brief summary of road identification process

The road identification process began with the design of the fieldwork and it took about 16 months to complete. This process included road identification in the field of a sample of ~14% of the total area of Angamuco (Stage 1). The digital identification for 100% roads of the site, post-processing, and the data standardization (Stage 2) were performed at the DigAR Lab at UW.

The fieldwork helped confirm some original assumptions about roads, but more importantly it helped identify the physical characteristics of segments, nodes and other features that resemble roads (like modern cattle trails, water drainage corridors, etc.). An important contribution of the fieldwork was finding evidence of architecture at roads. Another important result of fieldwork was the possibility of developing a node and segment typology.[48]

The digital road identification process back in Seattle took significantly more time than originally planned. There are many areas of improvement for the image analysis and road extraction process. The most interesting observation is that the network expands throughout the entire surface of the site.

In sum, the work during Stage 1 and 2 was necessary for identifying and preparing the network for spatial and network analyses.

[48] See chapter seven

CHAPTER FIVE: Laboratory Analysis

Construction and Temporality of Roads

This research focuses on exploring how pedestrians created, moved, and interacted with the movement infrastructure in Angamuco. Emphasis has not been on considering only a few unique and fragmented examples of specific roads but rather taking a more comprehensive examination of the entire road network. Nonetheless, to study urban movement phenomena it is necessary to consider evidence of different types and scales. For example, to consider general trends of traffic pattern is important to see the road network in its entirety, and in contrast, individual roads can show evidence of both synchronic road modification events as well as diachronic histories of road re-use. Understanding the historical and cultural contexts of Angamuco and the immediate area —chronology, basic social organization, economic practices, the available resources, etc.— are fundamental to study of the urban life of the city.

In order to study the formation processes and use of the road network, I combined traditional archaeological approaches, such as ceramic analysis, stratigraphic excavations, absolute dating, and computational methods as described in chapter six.

This chapter is centered on the archaeological investigation of the construction techniques and temporality of a sample of roads in the network. I begin this section with a description of the work performed during a single fieldwork season, its results, and its subsequent laboratory analyses. First, I present the results of the excavation of nine road segments in the site. Particularly, I concentrate on the stratigraphy and the evidence of construction and modification of roads overtime. Second, I discuss the results of the ceramic analysis of ~1,400 fragments recovered through the excavation at these units, the most relevant finds, and the deposit patterns. These are compared to the general ceramic profile for Angamuco (as well as the region) developed by Anna

S. Cohen and LORE-LPB. Third, I examine the radiocarbon determinations. While the radiocarbon sampling was large for this site[1], consisting of nine samples, roads proved to be settings for high bioturbation and contamination and only a few samples returned positive chronological results. Still, some of the results obtained expand the absolute chronology we had for the site by providing two unique examples of Early Postclassic events linked to the roads.

The general conclusions on this chapter are that radiocarbon results, stratigraphy, and ceramic analysis point towards the Middle Postclassic period as the most significant moment of extensive landscape transformation at the site.

5.1. Temporal sequence and use of roads

One of the goals of this dissertation is to identify the ways in which the evidence obtained from and related to the roads —such as architecture of roads, topology of the network, and material deposits— could help reconstruct temporal sequences of urbanization of Angamuco. Before fieldwork began, it was assumed that roads were contemporaneous to their adjacent architectural structures, but it was not entirely clear if their usage could be associated directly to these structures (Fisher et al., 2011, 2019a). Roads are the quintessential palimpsests, making it difficult to identify periods of use from materials collected from surface. With that in mind, my goals for excavation at roads were centered on the following questions:

Were roads built? Is there evidence of construction and planning? If so, are the construction techniques complex? What amount of human effort was involved in these constructions? How large were the construction projects? Could they have been built by a few community members,

[1] Before this dissertation, a total of 17 C14 samples had been collected and analyzed for the site including two field sessions of LORE-LPB (~6 months of excavation) and Anna S. Cohen's dissertation work.

or is there evidence for some central planning requiring a larger political state-like structure? Is there evidence of modification events over time? Can material deposits and construction styles suggest different uses for such roads, such as high vs. low traffic, or ceremonial vs. conventional? Can we identify temporal sequences?

The excavation and ceramic analysis turned out to be the most effective methods for associating roads with periods of inhabitation of the site, and for describing the chronology of construction events. Trenches were the most effective excavation strategy for understanding roads diachronically. As a result, I identified two important periods of built environment modification —Early Postclassic and Colonial periods— despite the challenge that represented the lack of a comprehensive ceramic chronology for Angamuco.

As discussed earlier in chapter three, the LPB was first occupied by smaller sociopolitical settlements and eventually complex urban centers with monumental architecture, mortuary customs, and unique ceramic styles and technologies until the formation of the Purépecha Empire. This has been corroborated by geoarchaeological analysis of the ecological transformations in the basin, architectural styles, funerary and osteological research, and most importantly ceramic analysis (Beekman, 2009; Cohen, 2016; Haskell & Stawski, 2017; Pollard, 2003; , 2008). A similar development process has also been observed at Angamuco. The LORE-LPB model originally suggested that its residents slowly settled in the upper zone of the site and eventually moved to lower areas once the lake basin receded and the Purépecha Empire was formed (Figure 3.2).[2] Excavation and analysis from LORE-LPB and Cohen's doctoral research from 2014 to 2016 made some adjustments to this model. In general, the site observed three main phases of settlement. The

[2] See chapter three

chronology for the first one is not entirely clear but is likely to have begun somewhere around the Early Classic period (~150 BCE–500 CE) and probably saw a slow, long, and steady period of settlement in all areas of the site. Settlement was most likely much heavier in the upper zone of the site and adjusted to the fluctuating lake levels that modified the site boundaries. Ceramic evidence of the Loma Alta and La Joya phases in the lower Angamuco and sunken plaza complexes (traditional of the Classic period) have been documented in the upper zone of the site.

The second and third settlement phases occurred around the Early Postclassic (~1000 CE) and Late Postclassic (~1350 CE) periods (Figure 5.1). The results of ceramic analysis, stratigraphy, and radiocarbon from this research shed light on the Early Postclassic (Pre-Purépecha) transformation moment and help demonstrate the significance of the Early Postclassic period for the site. Additional data reveals a fourth and final remarkable period of changes in Angamuco's spatial configuration during the decades that followed the conquest of the Purépecha Empire that initiated the colonial period in the basin (mid 1500s CE).

The following three sections (5.1.1., 5.1.2., and 5.1.3.) describe in detail the evidence for spatial modification during the Early Postclassic and Colonial periods.

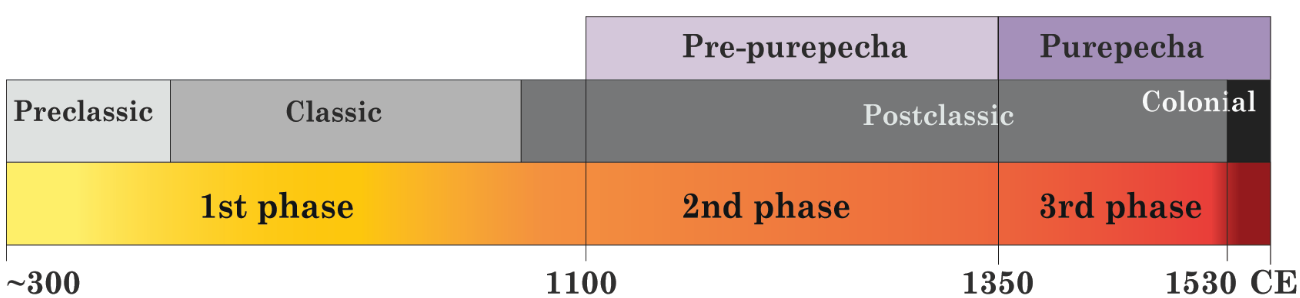


Figure 5.1. Simplified timeline of the urban development/occupation of Angamuco

5.1.1 Stratigraphy and road construction techniques

Examples of road excavations are scarce in the archaeological literature but served as good reference on how to approach the aforementioned features. The majority of these examples focus on the physical dimensions of architectural features —width, depth, and length— and the chronology through analysis of ceramics and radiometric methods to identify construction, modification, and abandonment, as well as how roads are associated to nearby architectural features (see examples in: Bolles & Folan, 2001; Erickson, 2001; Keller, 2006; 2018; Lipo & Hunt, 2005; Matteazzi, 2017).

The fieldwork targeted nine segments corresponding to two different types of locations: three segments were located at intersections, and the rest were located at the center of road segments (Table 5.1). Within the above mentioned research areas, two locations were selected for excavation based on the following criteria: 1) they presented a good state of preservation, 2) they showed evidence of architecture on surface —ramp, curb, platform—, 3) there were easy to access for excavation (Figure 4.25 and 5.2).[3]

I used a mixed excavation strategy that included six rectangular trenches of various dimensions, and three 1 m x 1 m test units. A summary of the structures, features, and deposits that my team uncovered, and the stratigraphic interpretation are presented below (Table 5.1), organized by area and unit. For detailed description of stratigraphy see Appendix D.

[3] See section 4.4.2.

UNIT	AREA	TYPE	DIMENSIONS	LOCATION	SURFACE DESCRIPTION
U1A01	A	Cross section	4 x 1.5 m	Road intersection	At base of ramp
U1A02	A	Cross section	5 x 1 m	Road intersection	Possible superposition
U1F01	FG	Test unit	1 x 1 m	Middle of road	Major road
U1F02	FG	Test unit	1 x 1 m	Middle of road	Road
U1H01	H	Cross section	0.5 x 1.5 m	Middle of road	Near site entrance
U1H02	H	Test unit	1 x 1 m	Middle of road	Near site entrance
U1I01	I	Cross section	4 x 1.5 m	Middle of road	Between buildings
U1I02	I	Cross section	4.5 x 1.5 m	Road intersection	Raised road/ramp
U1I03	I	Cross section	8 x 1 m	Middle of road	Raised road

Table 5.1. Description of excavation units

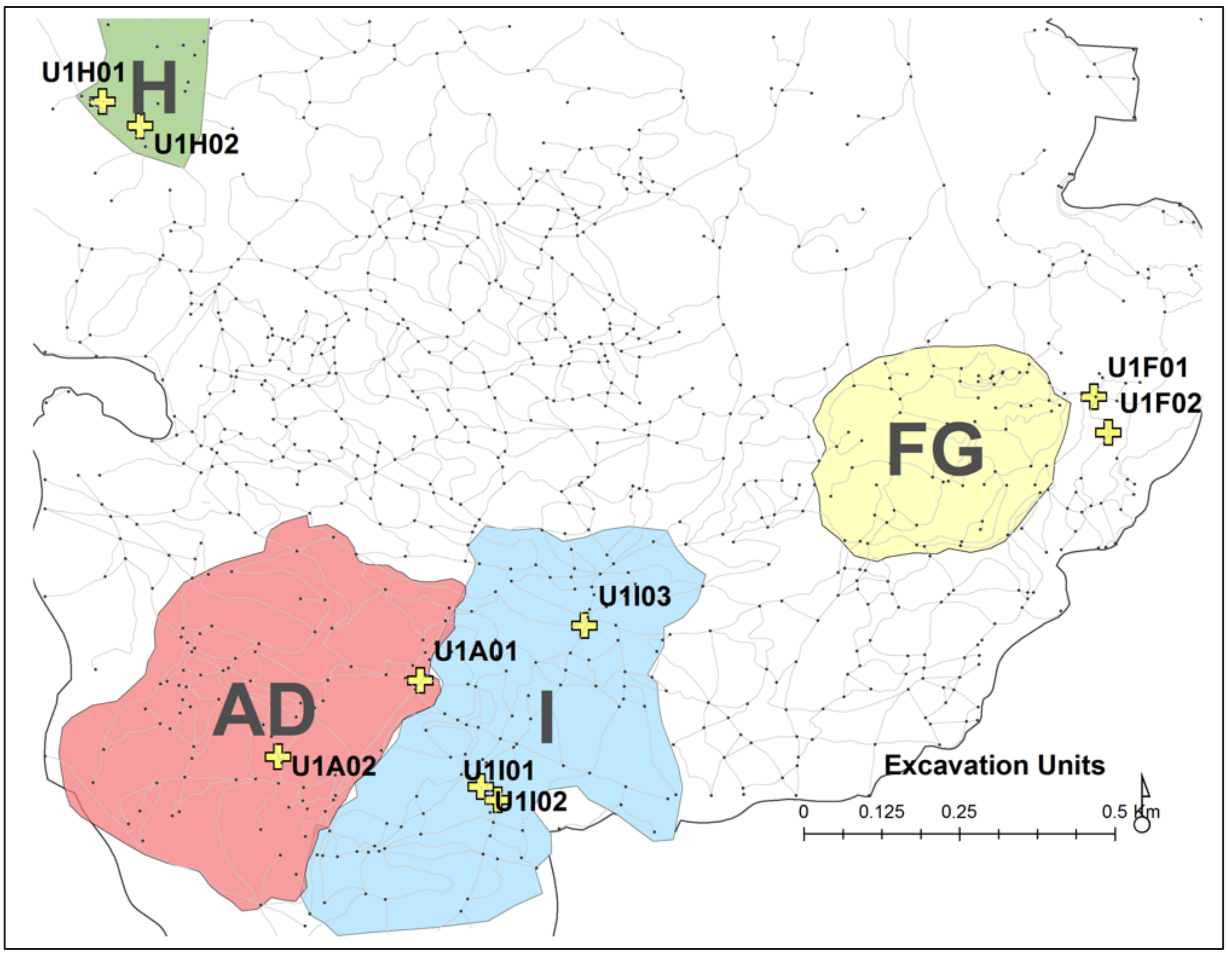


Figure 5.2. General location of excavation units.

<u>Area AD</u>

Area AD[4] covers most of the SSW region of Lower Angamuco zone going from the SW edge of the site to the south to the escarpment. This region is characterized by five N-S elongated ridges that form elevated areas for housing and other features. These ridges are delimited by valleys with a series of wide and flat road segments (*caminos*[5]). Several elite and ritual features located within area AD were tested between 2013 and 2014 (Fisher et al., 2014; 2016), such as: El Palacio complex, an area of elite rooms and plazas (area A); a semi-public and multicomponent building (ED 5128) and other associated non-elite buildings (area B); the grand plaza and Yácata complex (area C); and a set of platforms and elite rooms (area D). But it also includes hundreds of elite and non-elite residential buildings, terraces, patios, and other ritual buildings, including an I-shaped ball-game court that have not yet been excavated. Two roads in area AD were selected for testing.

Unit U1A01

Location of unit

Unit U1A01 was placed on segment S1059 at the base of a ramp that connects one of the aforementioned flat, wide, and long *caminos* that at the time of excavation were considered to be major roads. Unit U1A01 is situated at an important juncture between areas with seemingly different urbanization patterns, and more importantly, two different styles of roads (a large flat road and a paved ramp connecting to smaller roads). Specifically, segment S1059 ends at plaza node N1A051. To the north of the node, a 5 m-wide paved ramp connects this large sunken plaza to a series of narrower segments as part of an elevated and rougher topography (Figure 5.3). The unit was excavated as a cross section trench across the base of the ramp cutting through two curbs

[4] Includes areas A, B, C, and D from LORE-LPB excavations.
[5] See typology of segments in section 7.1.1

(*banquetas*[6]) at both ends of the walking surface and visible on surface. The unit was 4 m x 1.5 m. A stone pavement was visible on the surface, but that did not become clear until the end of the first level.

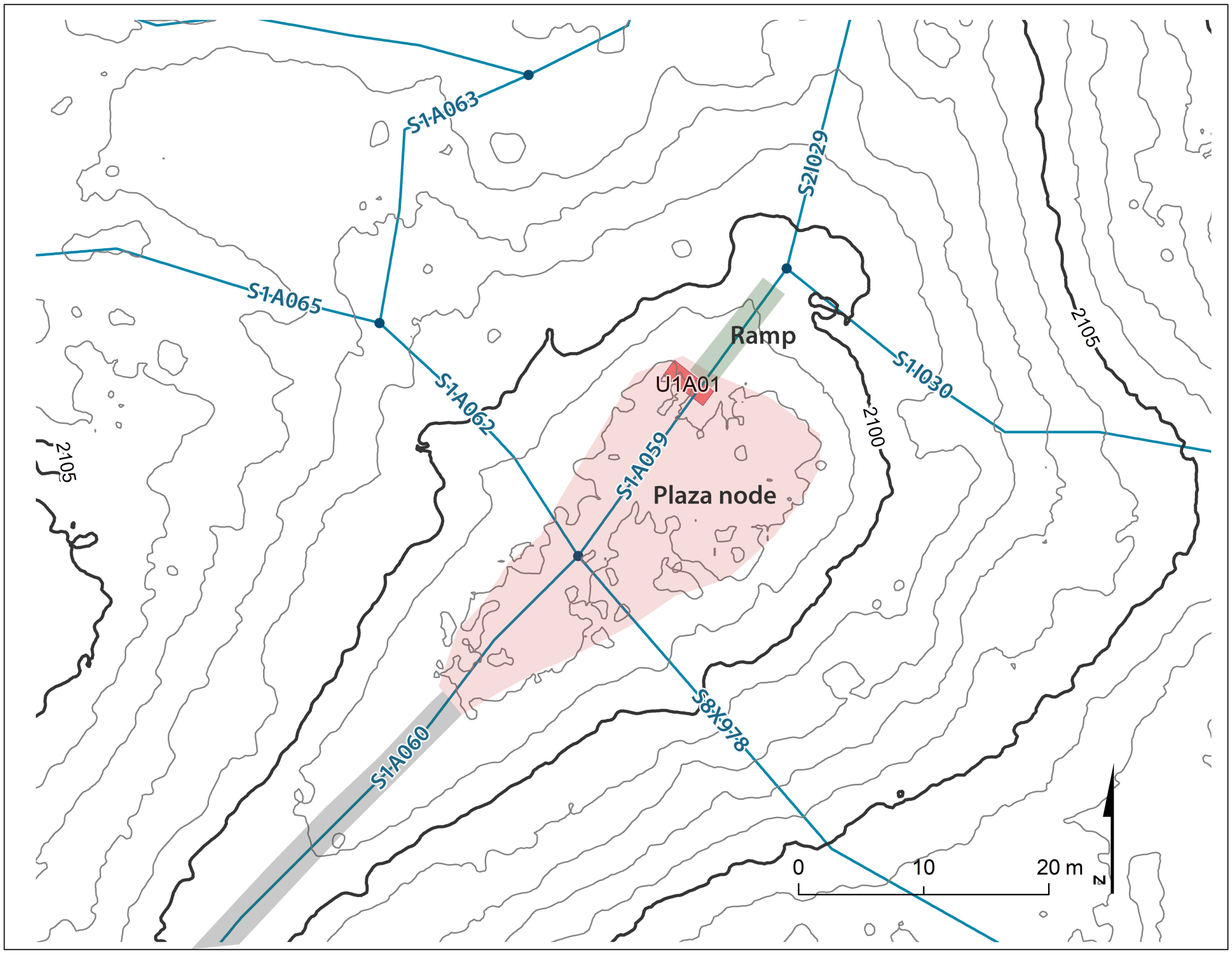


Figure 5.3. Planview sketch of U1A01 location. In red, unit U1A01. In light red, a suggested contour for the plaza node. In green, the ramp. In gray, a major road. Segments and nodes are in blue. Contour lines show elevation values of every meter (gray) and every 5 meters (black) in masl.

[6] I use the term *banquetas* to refer to an alignment of rocks on one or both sides of the road segment, similar to a curb for a sidewalk that defines the lines of a car street. *Banquetas* are described and illustrated in detail in chapter seven.

Stratigraphy

The stratigraphy of this unit reveals several events of modification and evidence of planning and construction (Figures 5.5 and 5.7). In sum, this ramp's construction consists of three major components.

1) *Banquetas*: Two stone alignments composed of medium to large basalt rocks placed on the surface without mortar (~50 cm wide) on both sides of the road.

2) An earlier *paved stone platform* (or earlier road) located in the center of the unit (level 3), also composed of medium to large size basalt rocks and narrower than the road creating gaps between it and the *banquetas* (excavated as feature A-01) (Figure 5.4).

3) A *pavement* of small basalt rocks with a higher-than-usual concentration of obsidian debitage that filled the area between the two *banquetas* above and around the stone platform.

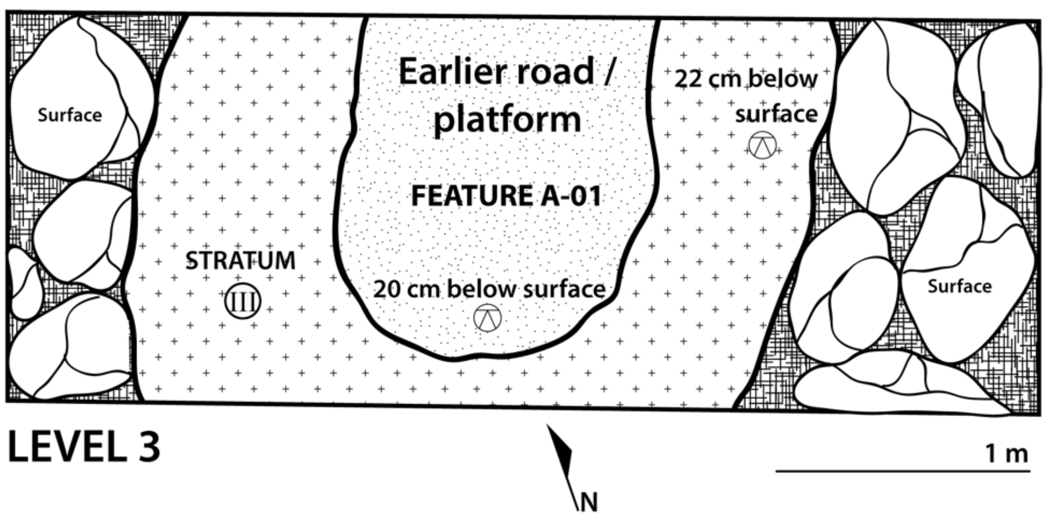


Figure 5.4. Planview of level 3 of U1A01 showing the extent of feature A-01 or earlier platform.

A total of 40 radiocarbon samples were collected, but only three (from strata II, III, and feature A-01) were chosen for analysis.[7]

[7] See radiocarbon determinations in section 5.1.3.

Interpretation of construction events

First, the flat surface of plaza node N1A051 was created by filling a naturally formed valley with nearby sediment possibly placing offerings during this process as it is observed with the discovery of a *laja* in strata V.[8]

The stone ramp leading to the northern road was constructed during a later episode. At that time, a narrow stone platform was constructed connecting the ramp to the plaza. There are two possible interpretations for the use of this narrow stone platform: a) it served as the first road connecting to this ramp that eventually was covered for a modification and expansion event of the same road in a later time, or b) it was part of S1059 road's foundation.

The *banquetas* were built as narrow walls (~20 cm tall) right after the stone platform. These narrow walls were used to retain the fill/pavement of small stones that were placed between them. With the *banquetas* holding the pavement in place, the entire road would likely have been elevated above the natural surface, and with a stronger structure in the center, it would likely have been higher in elevation in the middle and sloping downhill toward the *banquetas*. Both of these features would have been effective at preventing water from accumulating in the road during seasonal rains. It is possible that the high pedestrian traffic in this location demanded a stronger structural design.

Discussion for the construction events of this unit is expanded in chapter seven as evidence of landscape modification.

[8] A large stone *laja* was found at the bottom of the unit but was not fully excavated due to time constrains. *Lajas* are very important and have been observed in Urichu (Pollard & Cahue, 1999) and Angamuco (Cohen, 2016; Fisher et al., 2016) as architectural components, generally found as walls or tops for stone cases of offerings and burials.

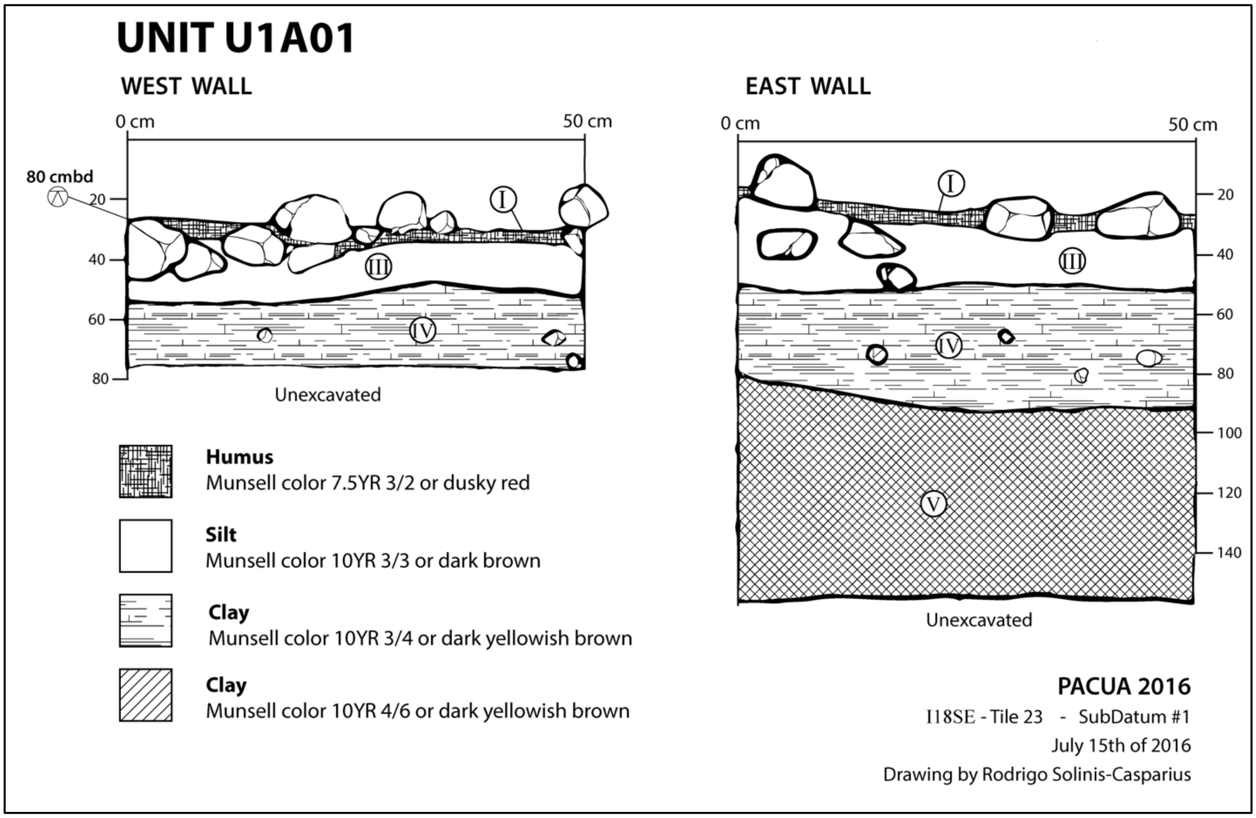


Figure 5.5. Profile of east and west walls U1A01

Figure 5.6. Photos of the unit before excavation. Unit dimensions are highlighted with yellow lines. A contour of the paved ramp has been also highlighted with red. Image on the left is a view from below, the base of ramp (facing NE). Image on the right is the ramp viewed from above (facing SW).

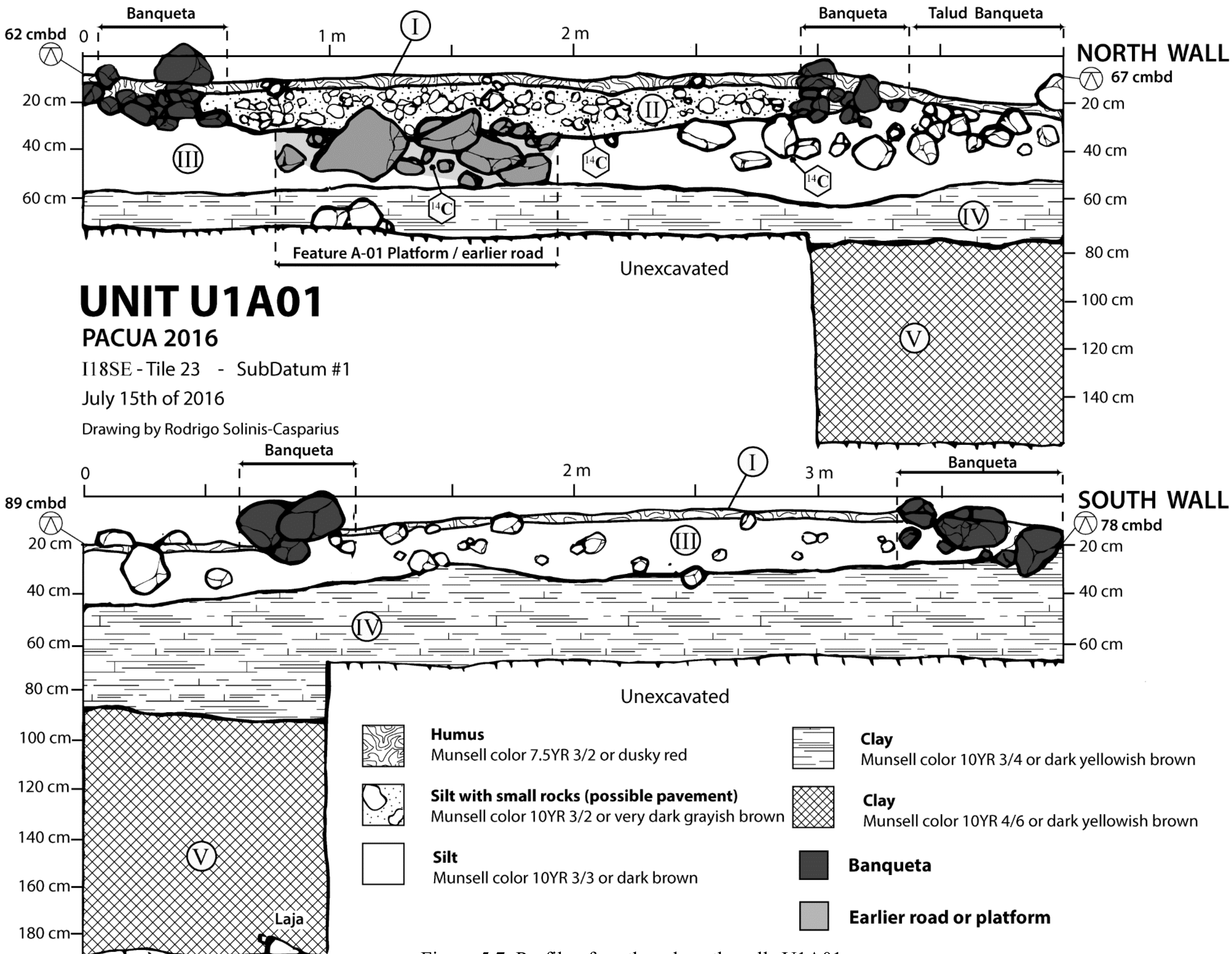


Figure 5.7. Profile of north and south walls U1A01

Figure 5.8. Photos of the unit's ongoing excavation. Left image shows how the ramp connects to the area of buildings complexes (facing NE). Right image shows how the ramp connects to a plaza node and the *banquetas* on the surface (facing SW).

Figure 5.9. Still picture of the 3D photo-model created for feature A-01 showing the two *banquetas* on the sides and the earlier road/platform in the center. All 3D models can be found in the Appendix B.

Unit U1A02

Location of unit

Unit U1A02 was placed at a small node (N1A011) between segments S1A013–S1A012, and S1A017 with the expectation to capture what was first identified as a superposition between these two roads. Segment S1A013–S1A012 is a medium size road about 2 m wide on a gentle slope and limited by two *banquetas* on each side. On the surface, the *banqueta* on the east cuts segment S1A017 that runs in an angle semi-perpendicular to S1A013–S1A012 on a bank (similar to a terrace) and parallel to major road S1A041–S1A014 just below the terrace. About 5 m down the slope from the location of the unit, S1A013 meets this major road —flat, wide, and located in a valley that runs south-north toward the escarpment (Figure 5.10 & 5.13). The unit was excavated as a 5 m x 1 m cross-section trench capturing both segments and oriented 51º east of magnetic north. The goal of this excavation was to investigate how two segments meet at a small node and confirm the superposition of S1A013–S1A012 over S1A017.[9] In topological terms, a road segment placed on top of another would represent a later event.

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[9] The superposition principle refers to a spatial relationship in which a linear feature rests on top of another earlier linear feature.

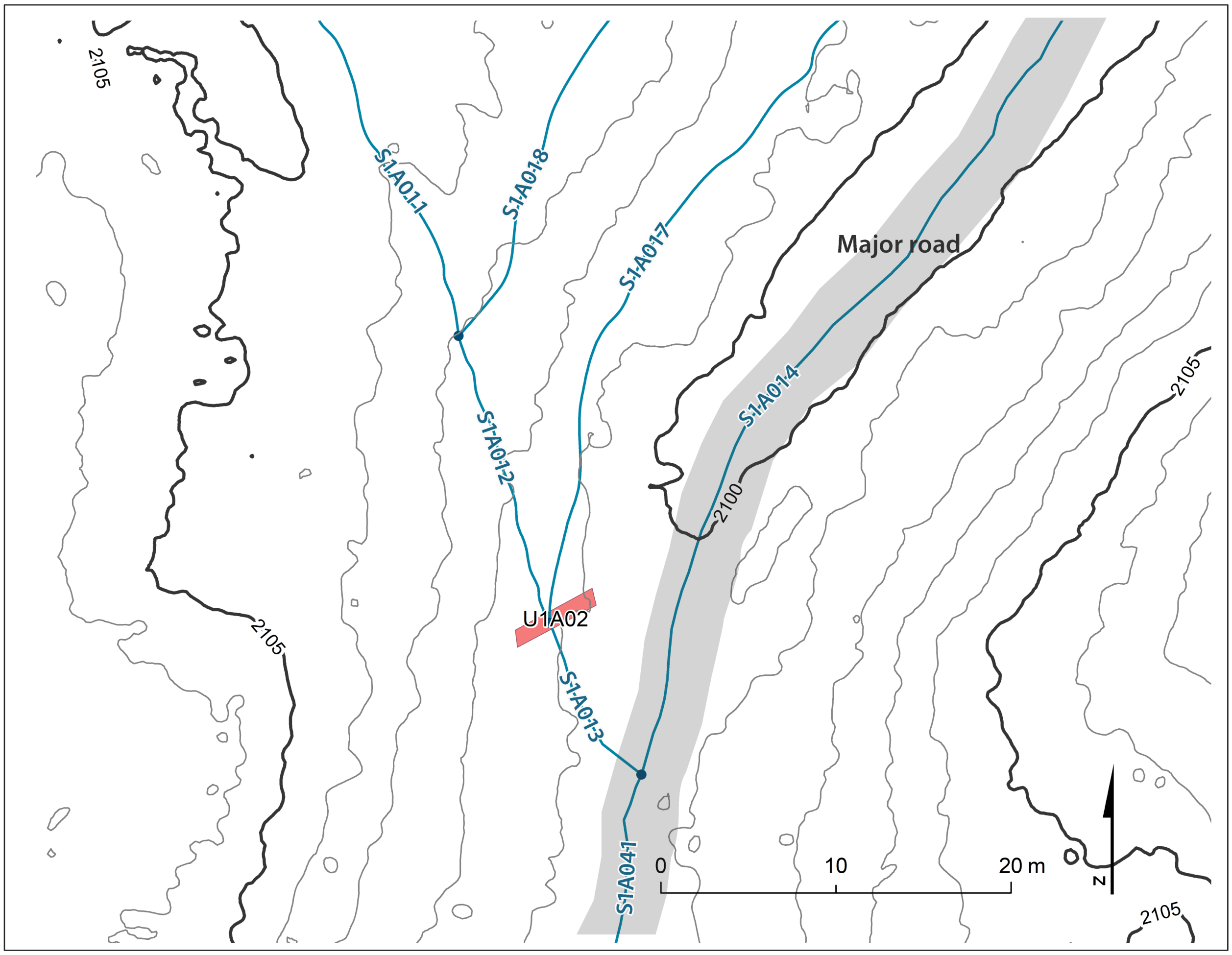

Figure 5.10. Planview sketch of U1A02 location. In red, unit U1A02. In gray, a major road. Segments and nodes are in blue. Contour lines show elevation in masl of every meter (gray) and every 5 meters (black).

Stratigraphy

The stratigraphy of this unit reveals several events of modification and planning (Figures 5.11 and 5.12). In brief, this road's intersection consists of four major architectural components.

1) *Banquetas:* Built through two different construction styles. S1A013–S1A012 shows clear construction of banqueta-walls that helped shape the road. The *banqueta* on the west side is an alignment of large size stones stacked on each other and following the natural topography of the adjacent mound. The opposite *banqueta* was built following a similar construction technique observed at the Palacio rooms in 2013 (Fisher et al., 2014): the foundation and side walls were

created with two alignments of medium size stones, and then the gap between these two alignments was filled with gravel and a mix of sediment. On top of this *banqueta*-wall, a simple alignment of large stones was placed on top (covering the gap) to create the *banqueta* on the surface.

2) Sendero S1A017 was built as a terrace with one retention wall (*talud*) to the east that was exposed at one time but was eventually covered with sediment. At the two edges of this terrace, two simple alignments of medium size rocks resting on top of the terrace (on the surface) create the ~1 m wide road.

3) A combination of large and medium rocks and sediment was placed at the intersection of S1A013–S1A012 and S1A017 to create a blockage (Feature A-02).

4) A thin layer of highly compacted silt on S1A013–S1A012 provides the clearest evidence of the sediment that composes walking surfaces of roads.

Features

Feature A-02 represents the possible fill or intentional blockage between S1A017 and S1A013–S1A012. It is not entirely clear if S1A017 originally extended into S1A013–S1A012 and was then blocked. I suggest two hypotheses: a) S1A017 was deliberately blocked by dumping a mix of small stones and sediment (that almost looks like pavement) at the juncture point of both roads after S1A013–S1A012 was built, or b) this is a small ramp attempting to visually connect both roads. Feature A-02 was intentional (that is, a clear interruption of the sediment sequence) and showed the highest density of artifacts of any stratum in the unit. Feature A-02 was excavated in one level. Once this feature was excavated, the banqueta-walls for both road segments (features A-03 and A-04) were more clearly defined.

Feature A-03, also the eastern wall of S1A013–S1A012, was first exposed in level 2 of the unit and continued being defined as the excavation continued. It did not show a good state of conservation or a sophisticated construction system. However, it is a good example of *banqueta*-wall. It is defined at the bottom by two alignments of larger rocks. The center void of about 50 cm deep was filled with other medium to small size rocks. The banqueta-wall was well defined in both sides.

Feature A-04 is the retention wall for S1A017 facing the major road S1A014. In the part exposed to this unit, a different sediment (stratum V) was observed, which was most likely the result of accumulation of organic soils from rains and erosion, etc. The southern half was excavated in search of clearer evidence of construction style and materials. Very little materials were recovered, and construction is less sophisticated than A-04.

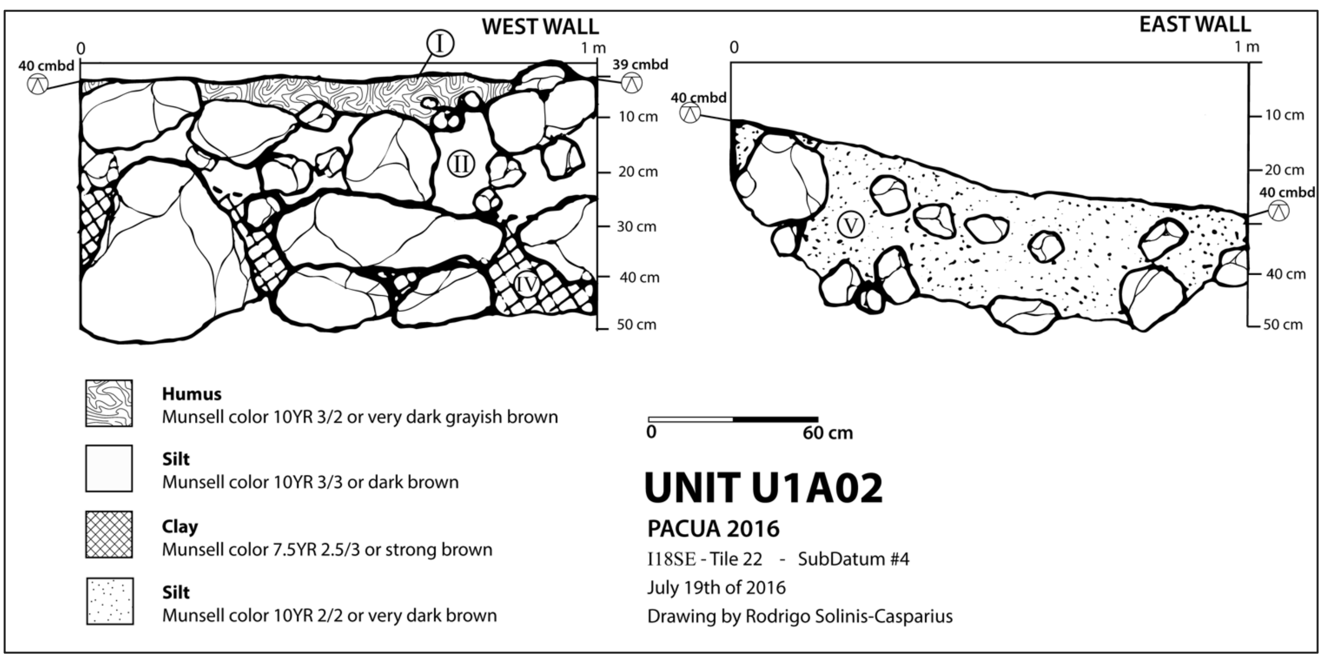

Figure 5.11. Profile of east and west walls U1A02

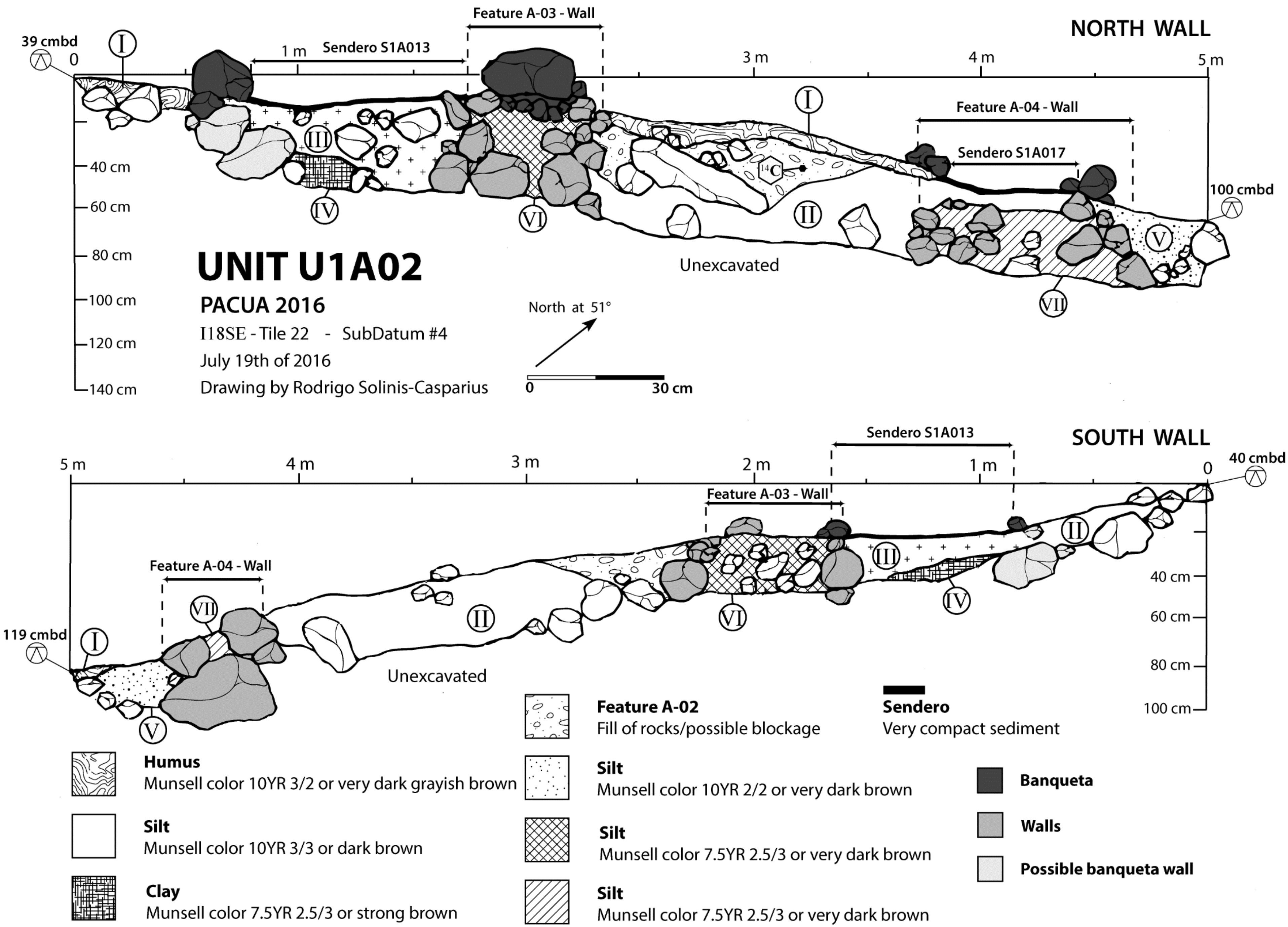

Figure 5.12. Profile of north and south walls U1A02

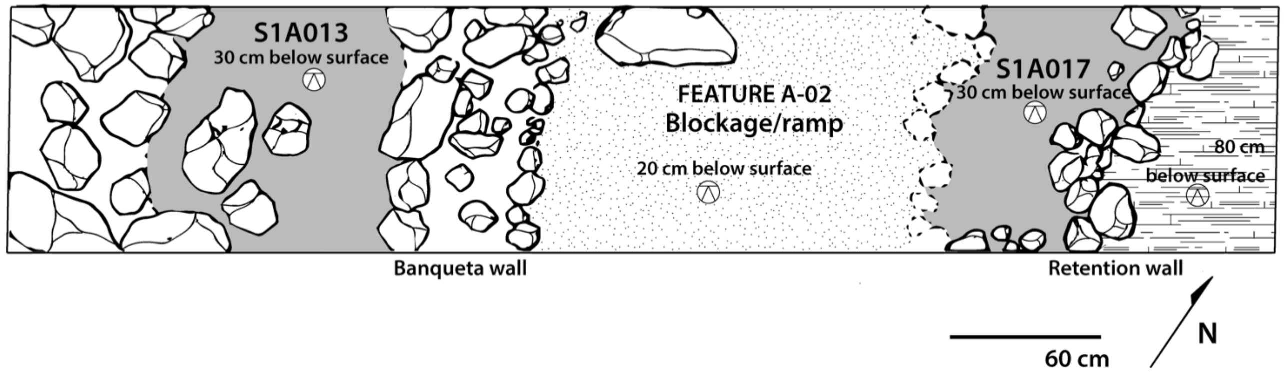

Figure 5.13. Planview of U1A012. Level 5, showing both roads, the blockage/ramp, and banqueta wall.

Interpretation of construction events

Road S1A017 (~1 m wide) was built on a hillside that was adapted by digging out sediment to create a terrace and was reinforced with a retention wall (*talud*) of medium size stones. At a later time (after some deposits had accumulated) two alignments of rocks were placed on the surface to delimit the walking surface. Either as part of that event or a subsequent one, high pedestrian traffic compacted the topsoil.

Road S1A013–S1A012 (~1 m wide) is located on a moderate slope that connects major road S1A041 to a series of other smaller roads and *complejos* on a higher topography to the north, and cuts S1A017 almost perpendicularly. The natural topography may have helped define where to build this road. Either as part of a modification event of a natural downslope corridor, or even a modest trail, or as the first attempt to create a road in this location, a ditch ~40 cm deep was excavated to build a foundation/wall 30–40 cm tall for a *banqueta* but only for the eastern edge of S1A013–S1A012. Most likely, immediately after the foundation was erected, the ditch was filled creating a flat surface for the road. High traffic may have helped compact the topsoil.

A blockage or ramp extends from the outer side of the eastern *banqueta* of S1A013–S1A012 almost entirely until the east retention wall of S1017. In other words, it blocks and covers across the entire sendero S1A017 in an angle (Figure 5.13). Road S1A017 and its east retention wall did not show many materials, but I suggest one of the following three scenarios: a) S1017 is older and S1A013–S1A012 was superimposed later; b) S1A017 was contemporaneous or older than S1A013–S1A012 but an accumulation of rocks was placed to visually signal a blockage; c) S1A017 connects S1A013–S1A012 and the "blockage" is actually a ramp to help access the larger and more important road S1A013–S1A012.

Figure 5.14. Photos of the unit before excavation. Unit dimensions are highlighted with yellow lines. A contour of road S1A013 is also highlighted with red. Image on the left is a view from below S1A013 (facing NW). Image on the right shows both *senderos* (facing NE).

Figure 5.15. Photos of the unit facing west and showing feature A-02. In the foreground, the retention wall for S1A017. Left image shows the blockage/ramp as it started appearing at the end of level 4. Right image shows how the blockage extends almost covering S1A017 entirely.

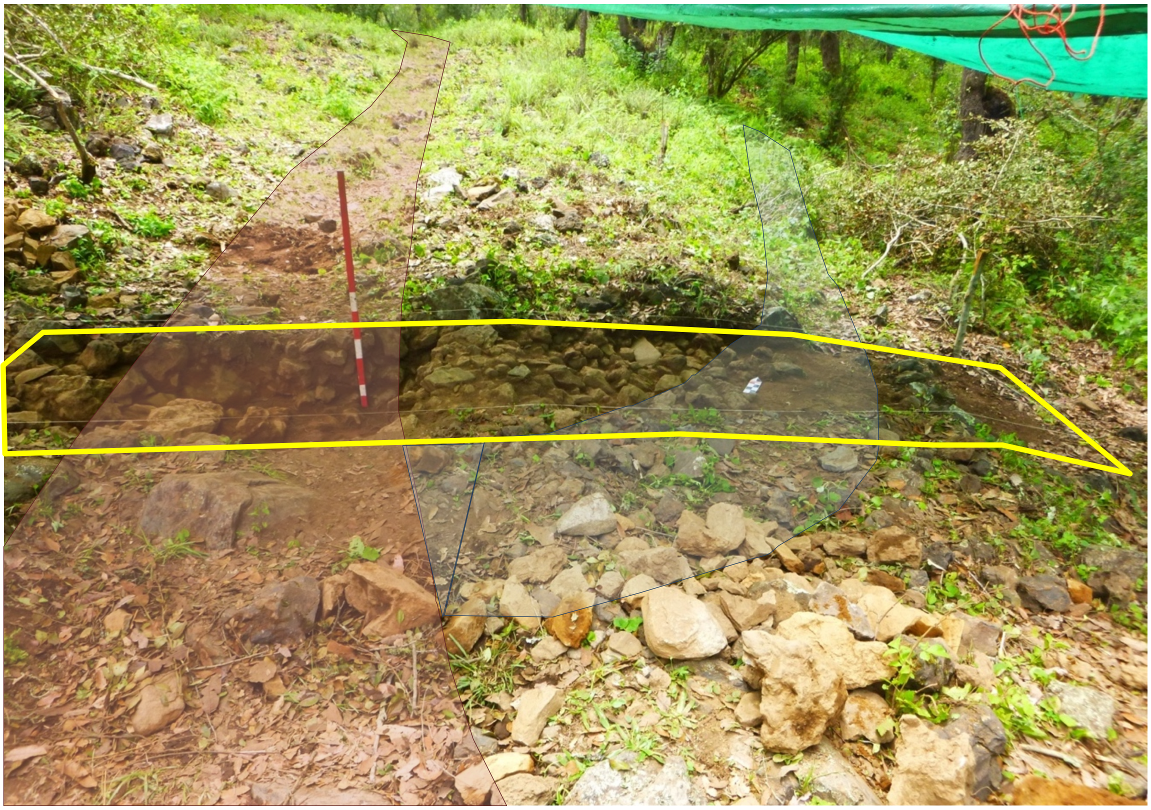

Figure 5.15. Photo of the unit at the end of level 5 (facing NW). Unit dimensions are highlighted with yellow lines. A contour of road S1A013 is also highlighted with red, and S1A017 in blue.

Area FG

Area FG[10] covers most of the ESE region of the site, partially covering Lower Angamuco but mostly on the Upper zone divided by the escarpment. This area constitutes 1–2 neighborhoods with mixed residential and ritual spaces. It is considered the southern edge of the malpaís slope and overlooks the Cerro Colorado. To the southern part of this area (area F) is a *complejo* containing a proto-yácata (MO 9858), circular feature F1, and other rooms that have been examined, reaffirming elite residence (Cohen, 2016; Fisher et al., 2016). Area G is another series of *complejos* immediately northeast of area F with more residential and commoner rooms, terraces, and patios.

[10] Areas F and G from LORE-LPB excavations.

In general, area FG shows a good level of conservation for architectural features. More importantly, Entrance 7 is located here, which is one of the two entrances that connect Upper and Lower Angamuco to the water reservoir to the SE. Two locations were selected for testing near Entrance 7.

Unit U1F01

Location of unit

Unit U1F01 is a 1 m x 1 m test unit placed in the center of segment S2F043 (Figure 5.16 & 5.18). This road is about 2 m wide and ~60 m long on a slope (gaining ~8 m) connecting Entrance 7 to the lower Angamuco area. This ended up being classified as a major artery of the network,[11] located at the lowest part of the escarpment (or where the escarpment recedes). The south side of the road faces a cliff and is marked with an alignment of rocks on the edge (a *banqueta*) and a retention wall down the cliff face. About 1 m going west from the unit (in the direction toward Entrance 7[12]) there are two stone steps that cross the entire width of the road. To the north, the unit faces the hill.

It is possible that a cross-section would have helped understand the massive modification for the construction of this road, however I decided to excavate only a test unit in the center due to the time constraints. Ultimately, this decision resulted in relatively inefficient road excavation. It is difficult to capture architectural features or construction elements in roads with a 1 m^2 area of excavation and there are less chances to collect material deposits. However, some general conclusions can be drawn from this unit.

[11] See chapter six.
[12] See discussion of Entrances to site in section 7.3.2.

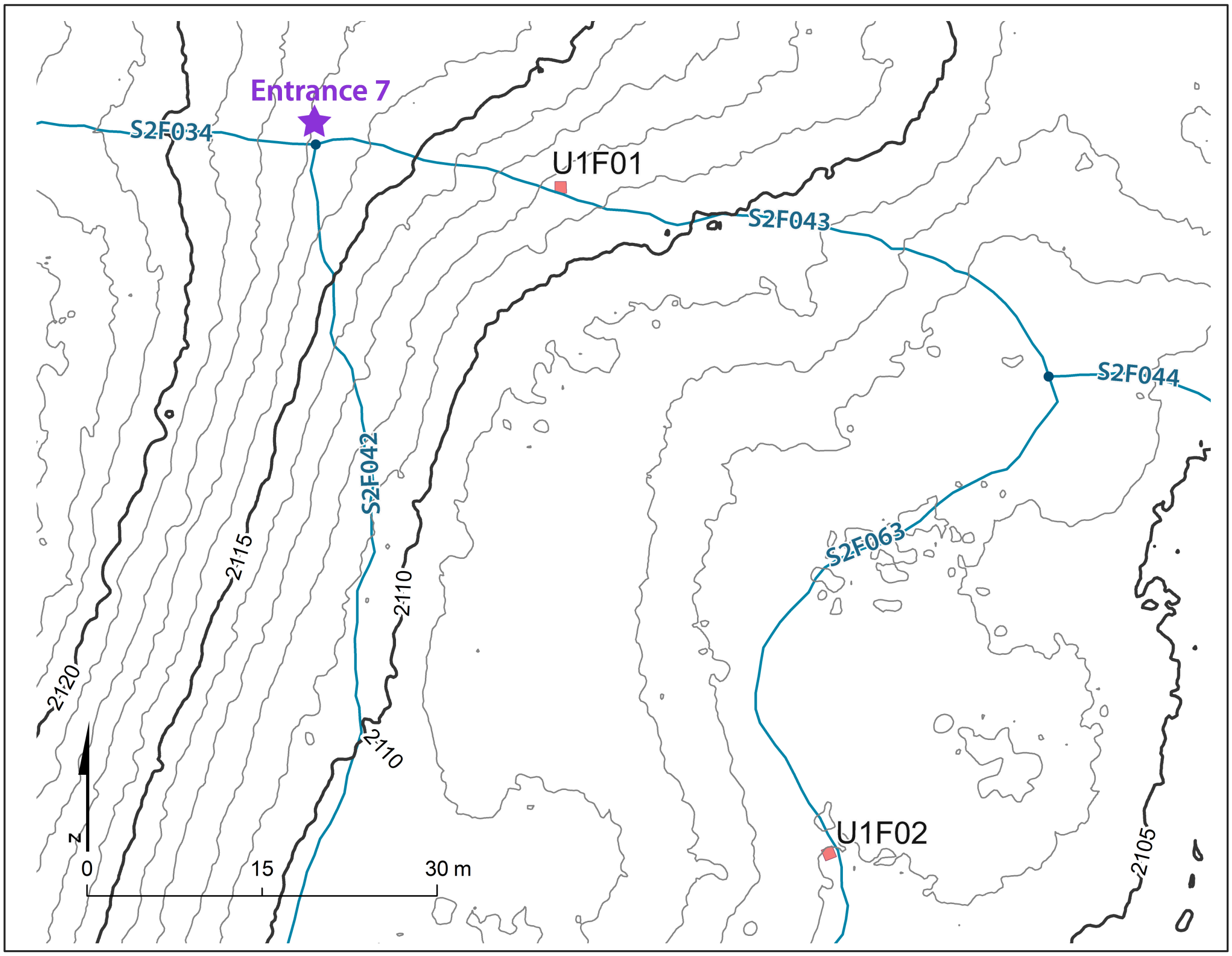

Figure 5.16. Planview sketch of U1F01 and U1F02 location. In red, units U1F01 and U1F02. Purple star represents Entrance 7. Segments and nodes are in blue. Contour lines show elevation values of every meter (gray) and every 5 meters (black).

Interpretation of stratigraphy

The stratigraphy of this unit is very simple, as it contained three strata and only one possible construction event (Figure 5.17).

The top strata are natural post-habitation deposits. A possible walking surface for the road (not pavement) is described as compacted grayish silt with fewer rocks on the top but supported with a natural deposit of medium size rocks directly below. Most likely, all the modifications for this road occurred at the surface level and to the sides of the road (that were not excavated). Not much of that activity can be observed at the center of the road, other than suggesting the possibility that the actual road surface is about 10 cm below the modern organic deposits.

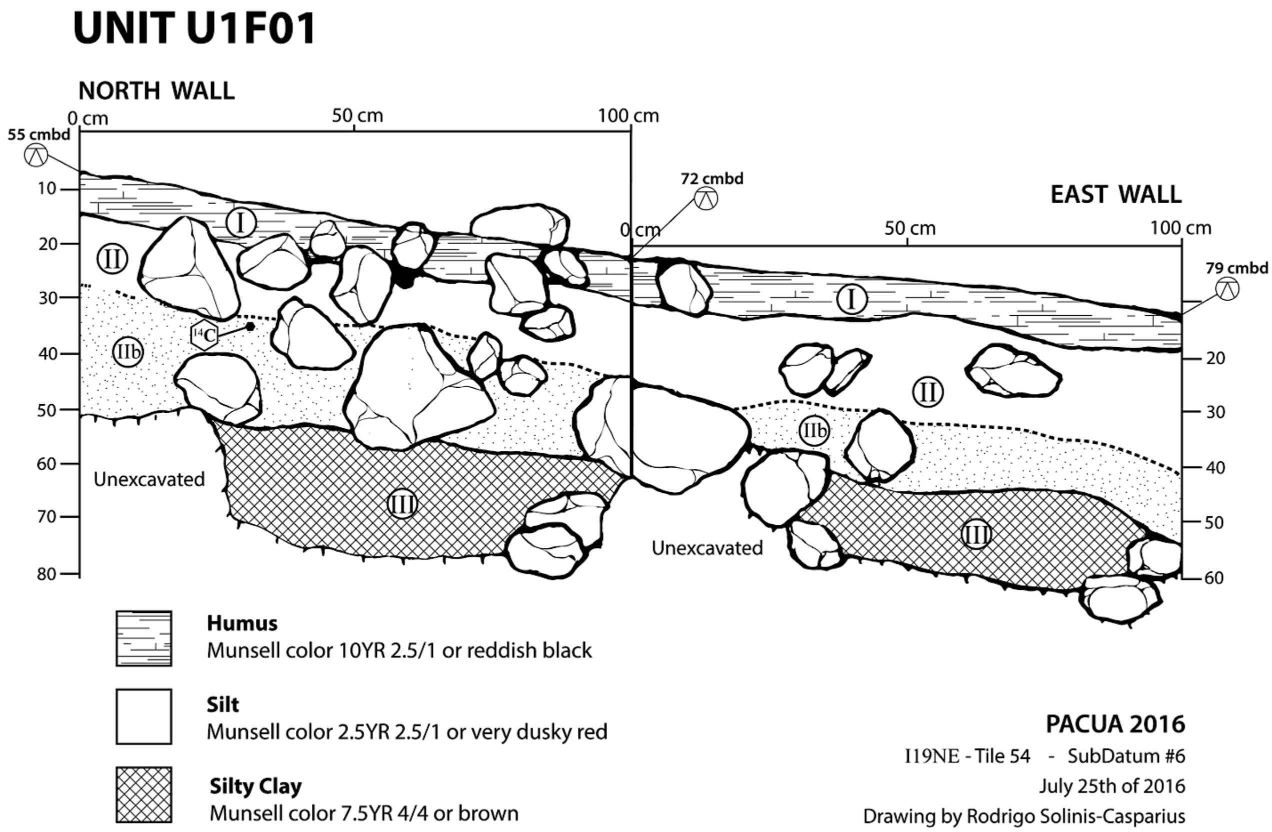

Figure 5.17. Profile of north and east walls of U1F01.

Figure 5.18. Photo of middle of level 4 showing the rocks directly below the compact silt or walking surface of U1F01.

Figure 5.19. Photos of location and ongoing excavation of U1F01. Left: unit seen going downslope on S2F043. Right: facing west or going upslope toward Entrance 7.

Unit U1F02

Location of unit

Unit U1F02 is a 1 m x 1 m test unit placed in the center of segment S2F063 (Figures 5.16 & 5.21), which is a flat major road in the lowest part of the FG area. This road connects to S2F043 (same road as U1F01) to the north, and to an open space (plaza/patio) to the south through a series of habitational *complejos*. There is an alignment of stones similar to a *banqueta* on the west side of this road, and an access to residential rooms and houses to the east. A possible pavement/walking surface was observed on the surface of this road. This unit provided a high density of materials, and much deeper deposits than U1F01.

Interpretation of stratigraphy

The stratigraphy of this unit is also very simple, as it contained four strata and only one possible construction event (possible pavement) (see Figure 5.22).

Strata IIb composed of medium size rocks might represent a walking surface, similar to what was observed in U1F01, either prepared with a foundation similar to a pavement that would have given the walking surface more structure, or as a first walking surface that eventually was covered by another silt deposit. The clay layer directly below (III) could correspond to an occupation before the surface was used for a road.[13]

In sum, this unit is an example of roads lacking architectural modification other than the erosion and compaction created by normal pedestrian traffic. If this surface was used as a road at a later time, then it is possible that this area (and perhaps other similar areas) were modified. Unfortunately, the non-diagnostic materials[14] and the lack of clear structures make these interpretations difficult to argue. A better example of this can be found in unit U1I01.

Figure 5.20. Photos of unit U1F02. Left: end of level 2 showing possible walking surface. Right: end of excavation. Note the layer of medium rocks in the north wall and the lack of these rocks in stratum IV.

[13] See unit U1I01.
[14] See Section 5.1.2 in this chapter

Figure 5.21. Photos of unit showing sendero S2F063 in red. Left: facing south towards an open plaza/patio. Right: facing north, in the direction of sendero S2F043.

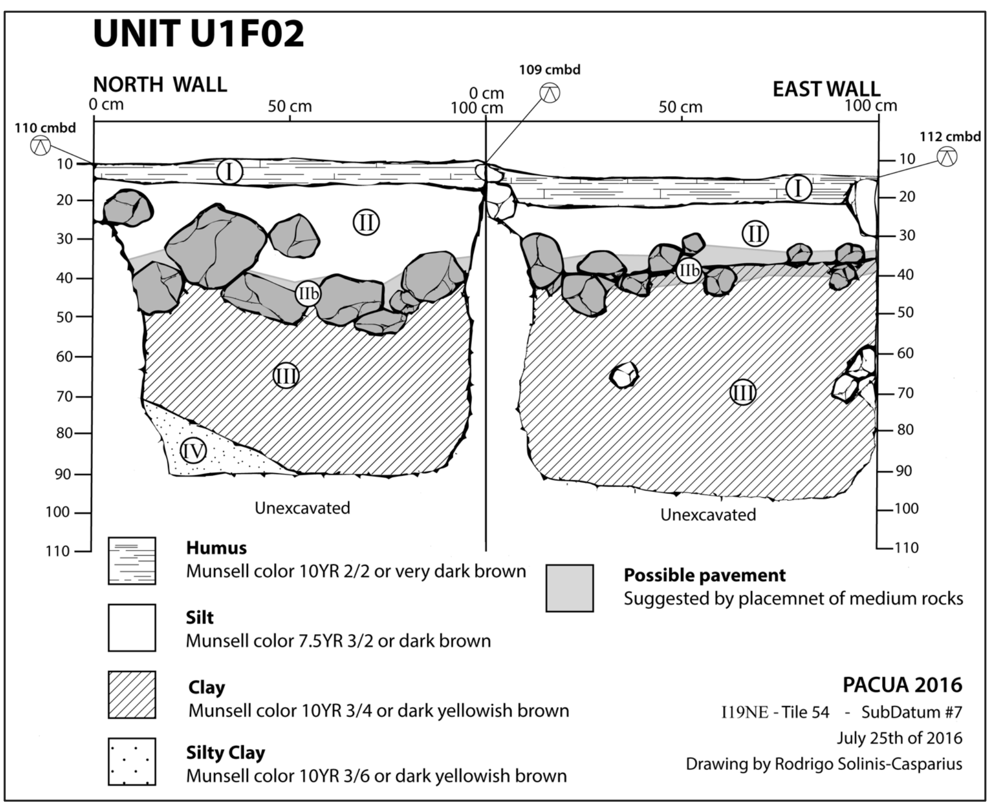

Figure 5.22. Profile of north and east walls U1F02.

Area H

Area H covers a small section of Upper Angamuco by the WSW edge of the escarpment. The entire area presents *complejos* with a mix of residential and elite buildings. The most relevant feature in this area is Entrance 2. It is possible that Entrance 2 was one of the most important gates between the site and the lake Pátzcuaro to the west. This Entrance is situated in a straight line 10 km east of the last capital of the Purépecha Empire (Tzintzuntzan) (1350–1530 CE).

Unit U1H01

Location of unit

Both units U1H01 and U1H02 were located along the two opposite major roads that lead toward Entrance 2 (on top of the escarpment) (Figure 5.23). Unit U1H01 was placed on a narrow road (S1H009) that runs on an east-west steep slope. The unit was placed as a 1.5 m x 1 m trench in the middle part of road S1H009. The road runs parallel to a retention wall that forms a terrace to the north. To the south, another retention wall gives stability to the road facing the cliff-slope. There is a stone step 3 m to the west of the unit (see Figure 5.24). To the east of the unit the road goes upslope connecting to Entrance 2, which is also the node that connects to road S1H006–S1H007 where unit U1H02 is located. Road U1H09 has a very steep slope and the hill face is very close, and with the narrow width of ~1 m, it does not leave much room for more than two people to walk side-by-side. For reasons that are discussed in chapter seven, this road is considered a later road, perhaps used during the Late Postclassic or the Colonial period.

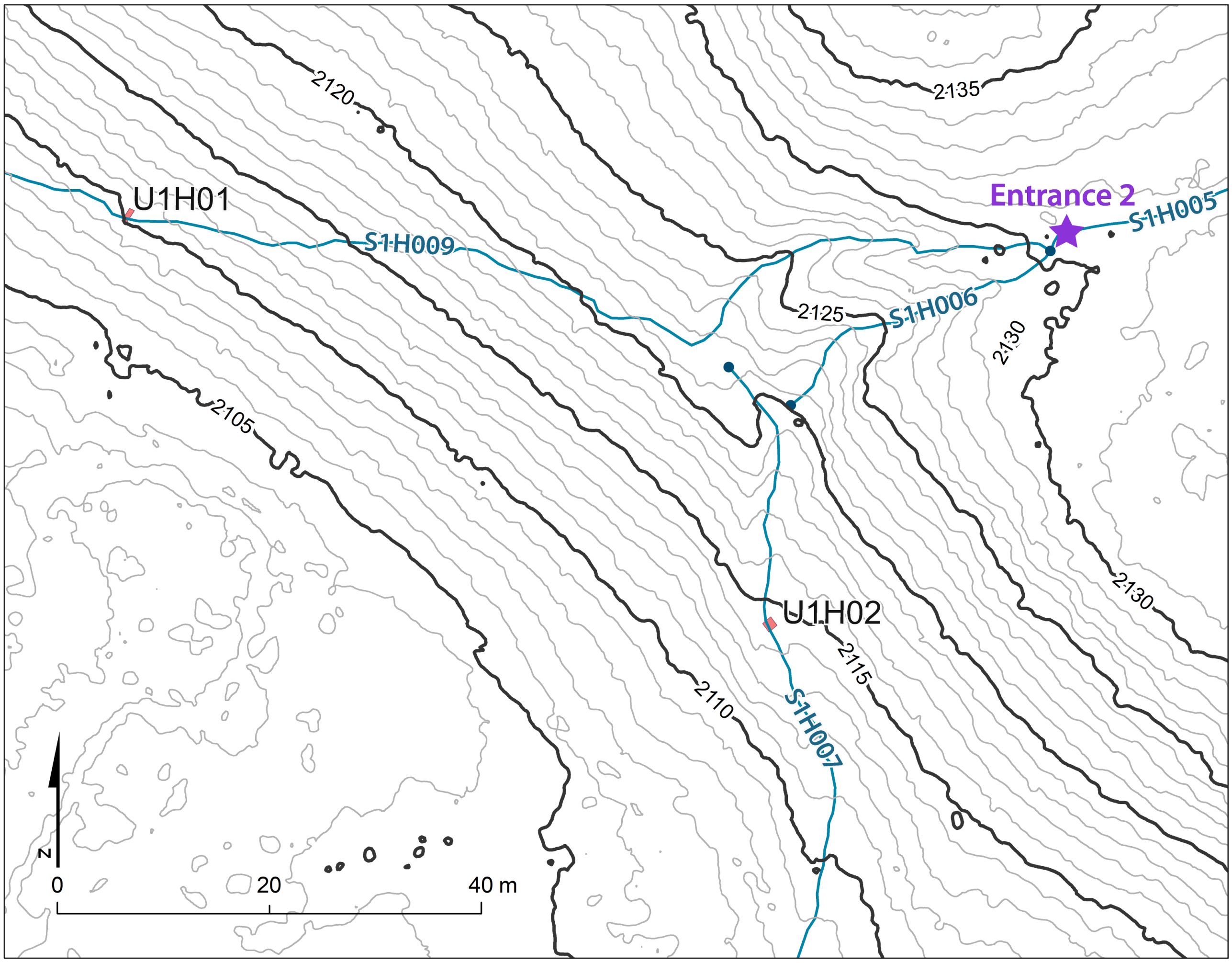

Figure 5.23. Planview sketch of U1H01 and U1H02 locations. In red, units. Purple star represents Entrance 2. Segments and nodes are in blue. Nodes do not connect roads, demonstrated by clear evidence of blockage. Contour lines show elevation values in masl of every meter (gray), every 5 meters (black).

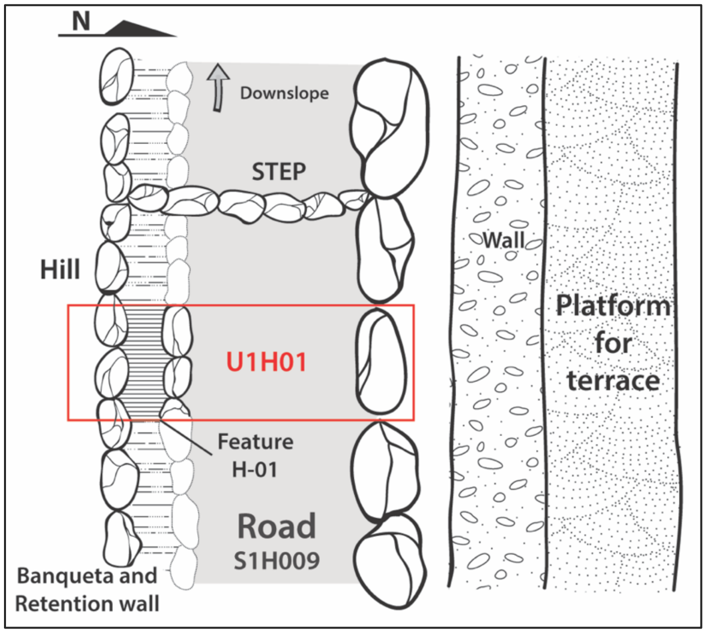

Figure 5.24. Simplified planview sketch of unit U1H01 showing nearby architectural features and construction system. Not to scale.

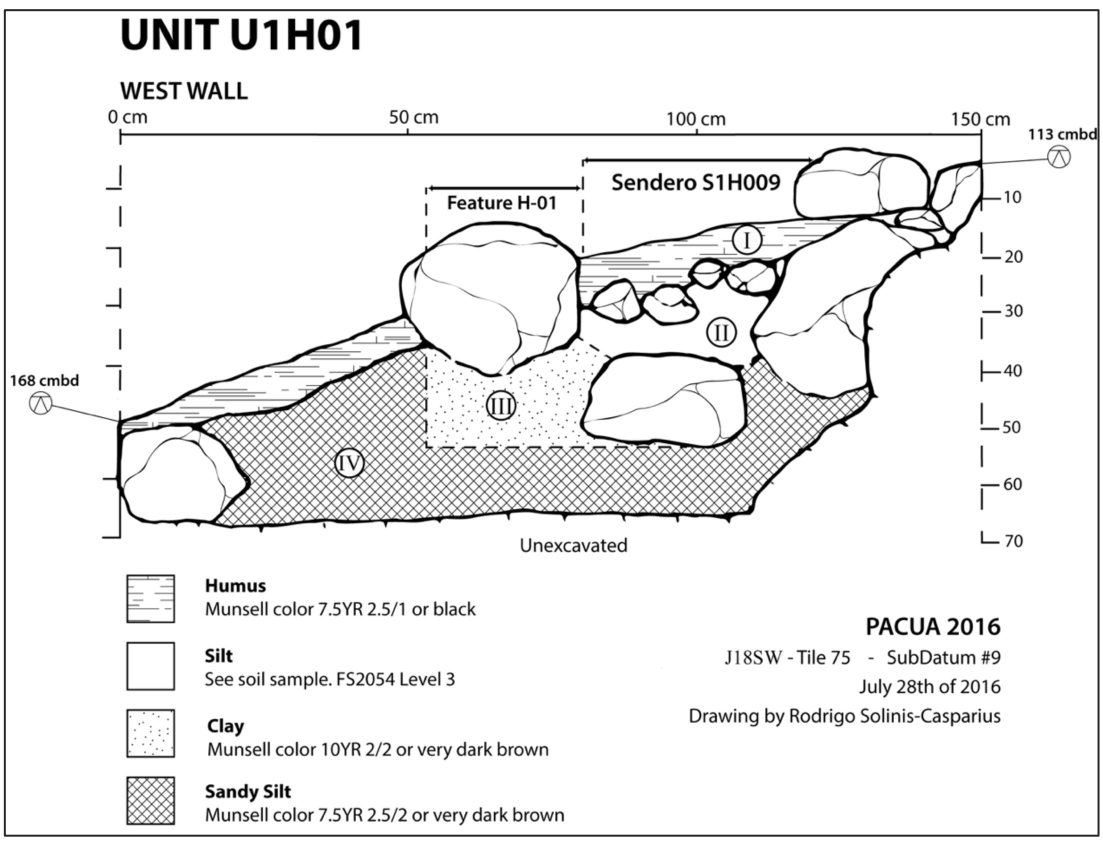

Figure 5.25. Profile of U1H01

Interpretation of stratigraphy

Four strata were observed in the stratigraphy of this unit including evidence of modification of the surface for creating the road (pavement) (Figure 4.25). The unit covered two stone alignments (*banquetas*) in the south and north.

Although this was a relatively small and shallow unit (only the area between *banquetas* was excavated), it was possible to observe the construction system of road S1H009. This road has an average width of 2 m although it was especially narrow by the excavated area.

Overall, the construction or series of modifications for this road are monumental and were most likely achieved through the support of a state structure or the involvement of a greater community. Fortunately, a large number of ceramic fragments were collected (>50), confirming that this was a massive operation during the Middle Postclassic period.[9] As part of the preparation for this road, residents built a parallel terrace with its retention wall for stabilizing the cut in the hill. This terrace could have also been used for growing food or as a decorative landscape element as this road leads toward an important entrance to the site (Entrance 2). The retention wall also served to delimit the road. Both, the stone wall and terrace would have been taller than an average pedestrian (~2 m). The road was limited with a simple *banqueta* (one alignment of medium size rocks) on its north side, and to the south with a double *banqueta* (two alignments of medium size rocks filled with gravel in between). The inner alignment of the double *banqueta* was not exposed on the surface but probably helped reinforce the *banqueta* as a whole. This double *banqueta* served as the retention wall facing the hill of the escarpment (opposite to the terrace). All the rocks were placed without the use of mortar. Inside the *banquetas* is an unsophisticated pavement, perhaps to prevent sediment from washing down with the rain, given the slope.

[9] See ceramic analysis below.

One last possible interpretation is that the gap between the retention wall and the simple *banqueta* was actually part of the road, now covered from the collapse of wall and accumulation of sediment, and that both simple and double *banquetas* were part of a system for the retention wall facing the cliff (Figure 5.24).

Figure 5.26. Photos of unit U1H01 before excavation. Left is facing west or downslope and shows the step directly below the unit. Right shows some of the stone wall to the north of unit and the retention wall. Unit limits shown in yellow lines.

Figure 5.27. Photos of unit U1H01 during excavation facing east/upslope. Missing a medium size rock (here recreated digitally in red lines). Left: shows both alignments of the double *banqueta*. Right: shows the step directly below the unit and the face of the retention wall towards the cliff at the edge of the road.

Figure 5.28. Left: photo of the stone wall. Only part of it is exposed due accumulation of sediment and collapse. Terrace is above stone wall. Right: the stone wall in background and the retention wall for the hill in foreground.

Unit U1H02

Location of unit

Unit U1H02 was placed as a 1 m x 1 m test unit in the middle of camino S1H007. As mentioned before, this road splits from entrance 2 (on top of the escarpment) towards the south cutting through the escarpment (Figure 5.23). In other words, S1H007 mirrors S1H009, however, I believe the former was a later access road to Entrance 2 that was eventually modified and then blocked.[10] It is clear from excavation that S1H007 actually underwent a massive construction process. S1H007 is about 80 m long, although the road itself (together with S1H006) was as long as S1H009 from the base of the escarpment to Entrance 2. Segment S1H007 is wider than S1H009, averaging 3 m and flatter. U1H02 faces the escarpment cliff to the west, the hill to the east and Entrance 2 going upslope to the north.

The test unit strategy used here was useful in order to understand the construction technique of the road; however, very little material was recovered. The unit was laid out on

[10] See chapter seven for further discussion of this feature.

magnetic north, which made excavation easy, but in retrospect was not the best choice since this does not reflect a perfect cross-section of the road.

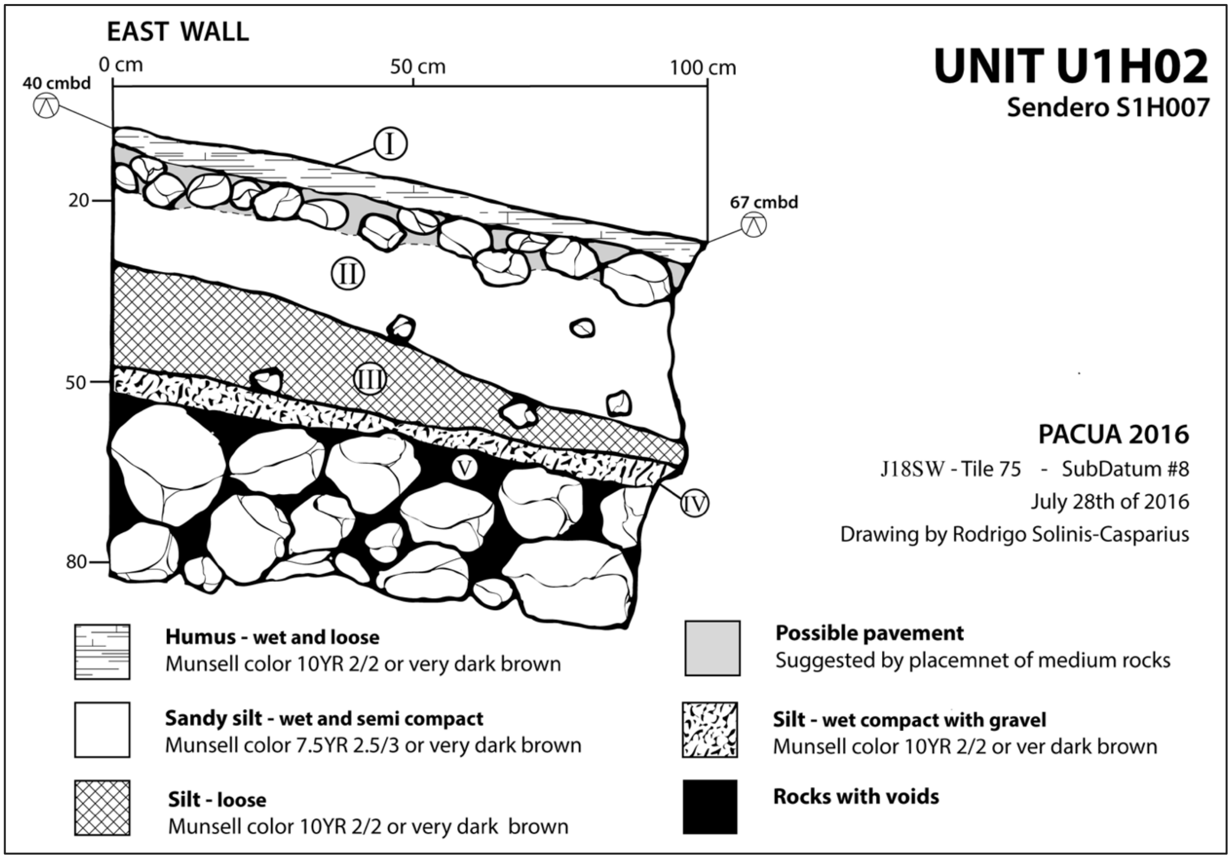

Figure 5.29. Profile of U1H02

Interpretation of stratigraphy

A total of two possible walking surfaces (layer between I and II; and strata IV) with clear stratigraphic transitions were observed in this unit. The surface was relatively clean with no large trees on the road surface and minimal loose rocks that had fallen from the hill face.

The unit showed two construction events that helped shape and create a monumental ramp or platform for the road. The excavation did not reach the end of the platform (fill) (strata

V). I suggest that people in Angamuco cut the natural topography of the escarpment to create the massive platform. To gain control of the slope and protect the integrity on the road, the void created with this cut was filled using medium to large rocks without any sediment to pack them (strata V). A layer of compact silt was placed on top to cover the fill and the surface as well (strata IV). It is not clear if this surface was used as a walking surface or if it was immediately covered with the next layers of sediment. I suspect that it was used as a road surface for a while but not for an extended period of time. At some point, more road modification included adding two different types of sediment for a total of 30 cm. Pavement was later created for walking. In sum, the fill layers were all clearly distinguishable from each other.

Overall, construction for this road was a large, multi-stage building process that probably involved large numbers of well-coordinated people. All of the sediment throughout the unit was within the same Munsell color range (very dark brown), and the only differing points between layers were changes within texture or rock prevalence. Most likely all the material for these events came from the same sources, or all events were relatively contemporaneous. For these reasons, U1H02 exemplifies —with more clarity than the other units in the study— the construction methods for monumental roads within the site.

Figure 5.30. Photos of U1H02 on S1H007 road. Left: photo facing uphill (direction) toward Entrance 2. Right: facing downhill (direction). Unit shown in yellow lines. Road shown in red lines.

Figure 5.31. Left: photo of the pavement after it was encountered at level 2. Right: end of the pavement as it was being excavated at the end of level 3.

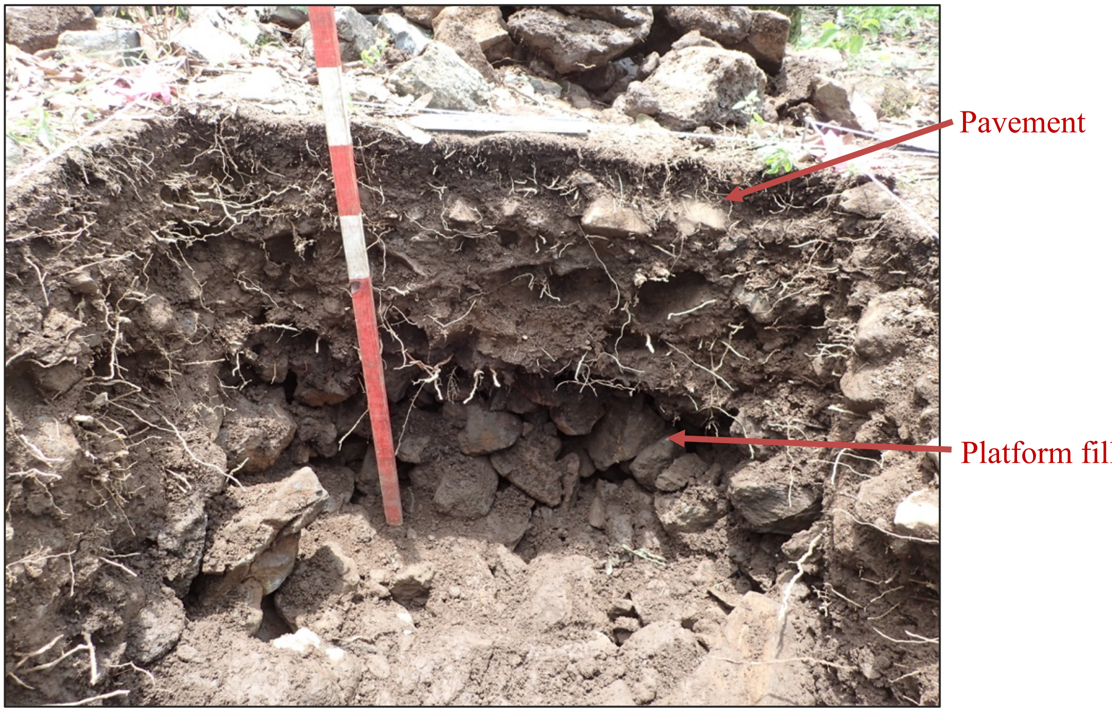

Figure 5.32. Detail of the profile of east wall, revealing the pavement and the fill.

Area I

Area I is located east of area AD covering the central-south side of the site. It is also an area with varied topographic elements; where valleys were used for major roads that were separated by ridges from areas of residences, and uneven plateaus that serve for *complejos*. In total, over 1,000 architectural structures (including residential, religious, and utilitarian) have been estimated in this area alone. The largest road (in width and extension) observed in the site crosses through this area and serves as the best example of a formal entrance connecting Lower and Upper Angamuco (Entrance 1).

Three locations were selected for excavation in this area: the first two (U1I01 and U1I03) at major roads and the third (U1I02) at a narrower segment that passes through residential architecture. They all showed evidence of modification overtime and produced diagnostic ceramics.

Unit U1I01

Location of unit

The location for unit U1I01 was chosen as an example of a raised road adjacent to a sunken plaza (Figures 5.33 and 5.34). Segment S1I029 is a major road running south to north towards the escarpment in the lower and center-south of the site. This road runs alongside a tall ridge (to the east) but is not entirely flat. The road is composed of several segments including S1I029 and S1I021, and parts of it are flat, straight, and paved, while other parts are curved and sloping. The road is about 2 m wide with at least one *banqueta* created with a simple alignment of rocks. The road runs parallel to another major road that is formed by segments S3I025, S3I024, and S1I019, and that also crosses through some elevated topographic features but remains flat and straight for the most part averaging 2 m in width.

Both roads (S1I029 and the road formed by the three aforementioned segments) are connected by a smaller road (S1I020) that crosses through a residential *complejo* (unit U1I02), and then descends through a slope to end at a small sunken plaza/patio where unit U1I01 is located. These major roads join about 100 m north of the connecting road (S1I020). As I mentioned before, road S1I029 lays flat and straight as it approximates the sunken plaza/patio (node N1I015), and it is at this point that the road is raised through a paved ramp and leads into a platform in which another flat and elevated segment of the road continues (Figures 5.34 & 5.35).

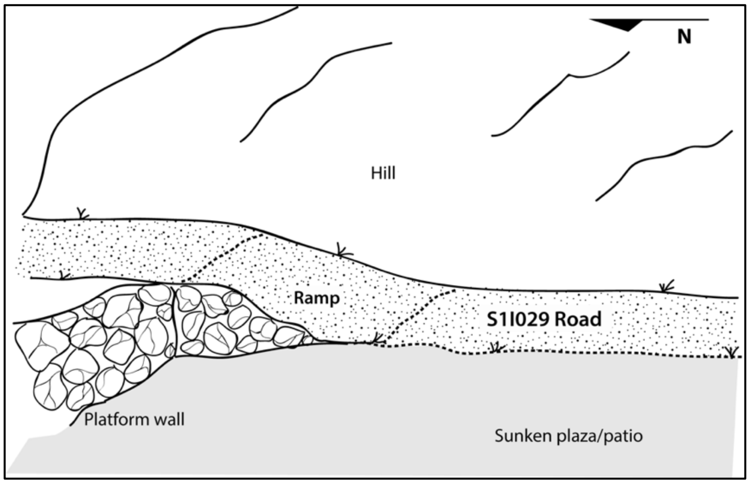

Figure 5.33. Sketch of location of U1I01. Not to scale.

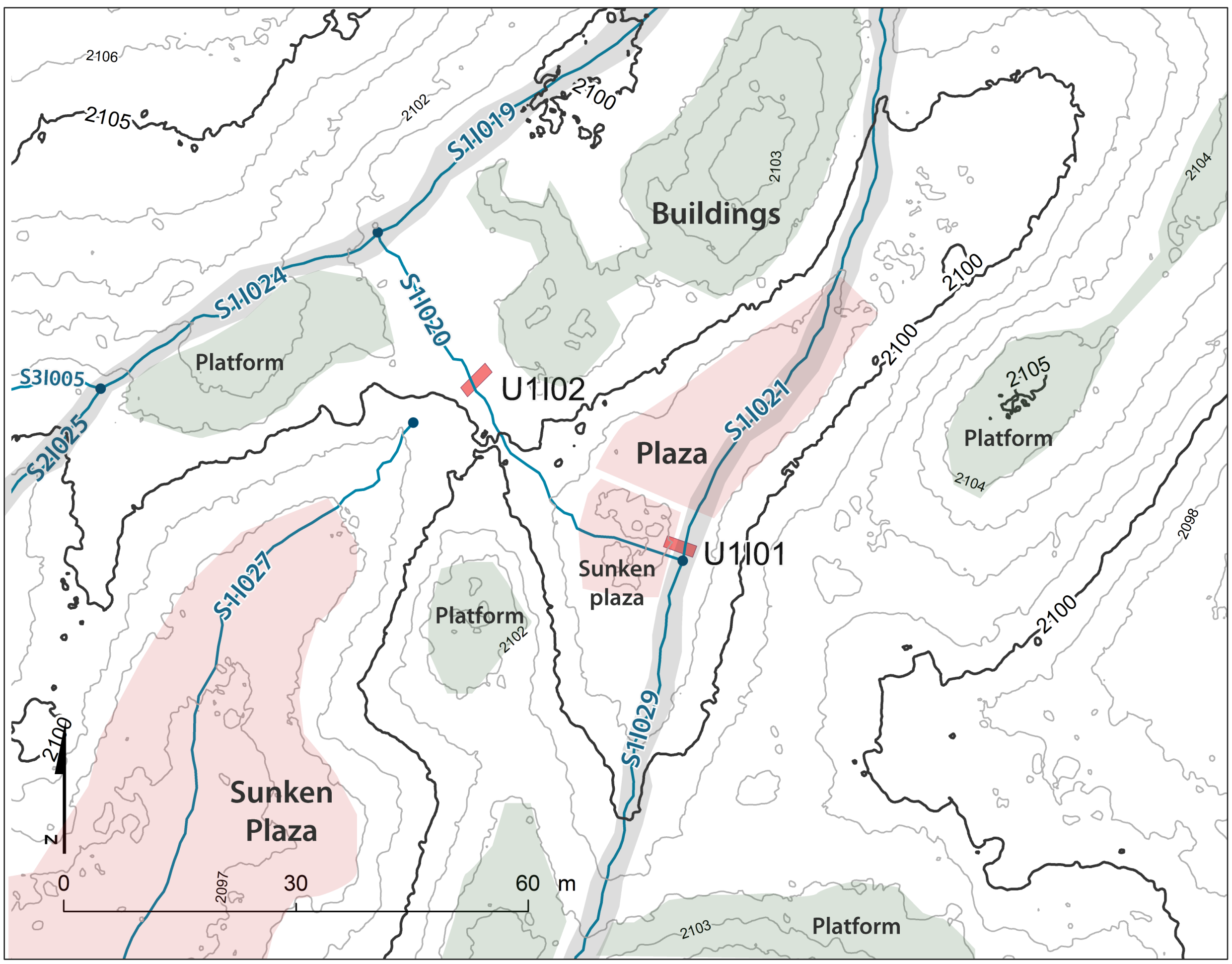

Figure 5.34. Planview of general location of units U1I01 and U1I02. In red, units. Segments and nodes are in blue. In light red, sunken plazas. In green, residential structures. Major roads in gray. Contour lines show elevation values in masl of every meter (gray) and every 5 meters (black).

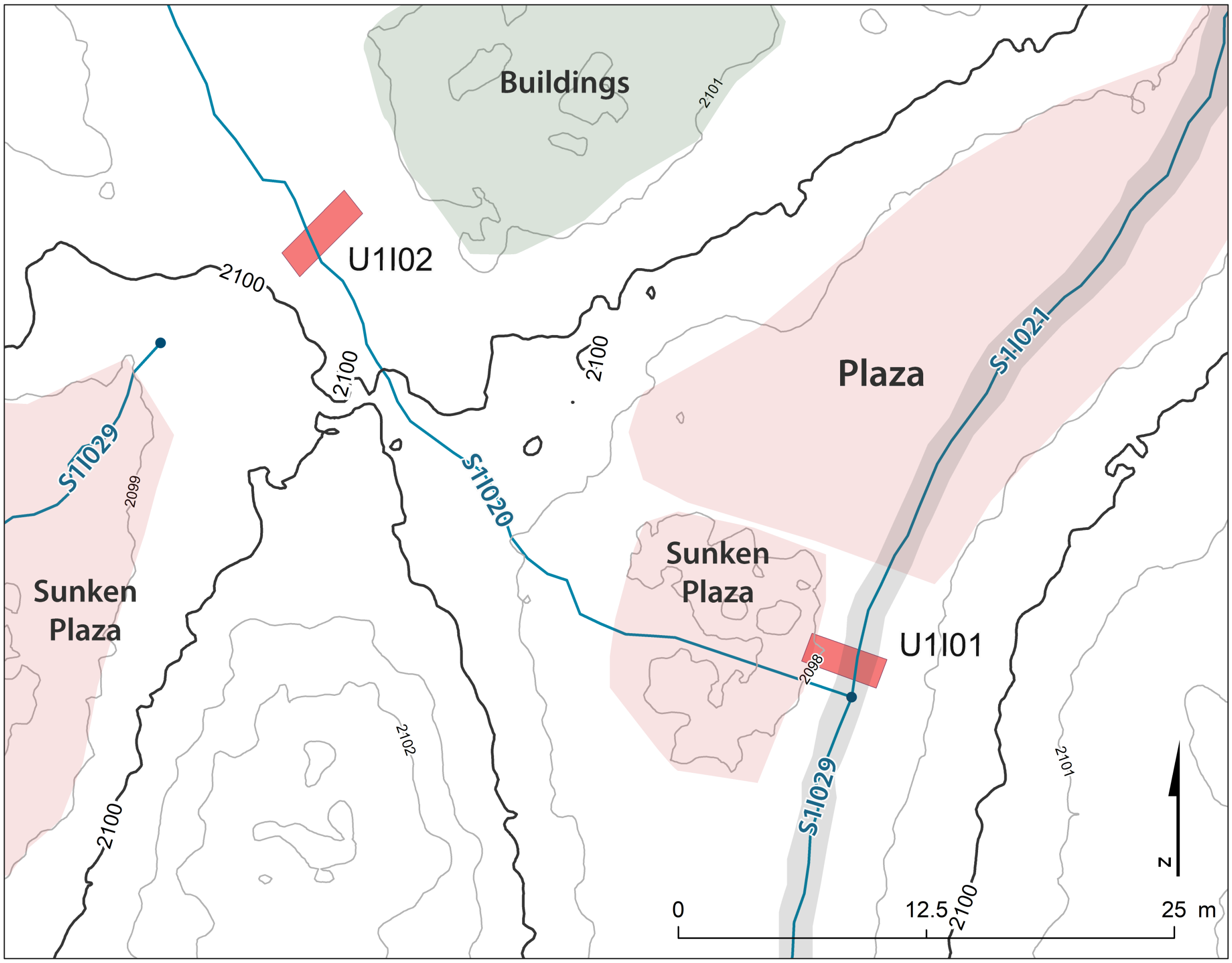

Figure 5.35. Detailed planview location of units U1I01 and U1I02. In red, units. Segments and nodes are in blue. In light red, sunken plazas. In green, residential structures. Major road in gray. Contour lines show elevation values in masl of every meter (gray) and every 5 meters (black).

Unit U1I01 was placed as a long trench of 4 m x 1.5 m in an attempt to capture the construction system and chronology of the road/ramp and its relationship to the sunken plaza/patio. As the excavation proved (Features I-03 and I-04), this was a monumental construction event that would have needed the cooperation and coordination of several members of the community. The sunken plaza/patio creates a secluded space probably used for members of the immediate community and not necessarily as a public space but more as an area of interaction,[11] however the road itself was heavily transited by many pedestrians on a daily basis.[12] Two C14 samples were sent for analysis from this unit, however they unfortunately came back with indeterminate dates.

Features

Features I-03 and I-04 refer to two construction events for the ramp. Feature I-03 is described as an exterior wall ~1 m wide with a *talud* facing the sunken plaza and is made out of large rocks at the bottom and medium-to-small rocks toward the top. Inside this Feature, I-04 is an internal wall ~50 cm wide and is formed by more packed medium-to-small rocks and silt.

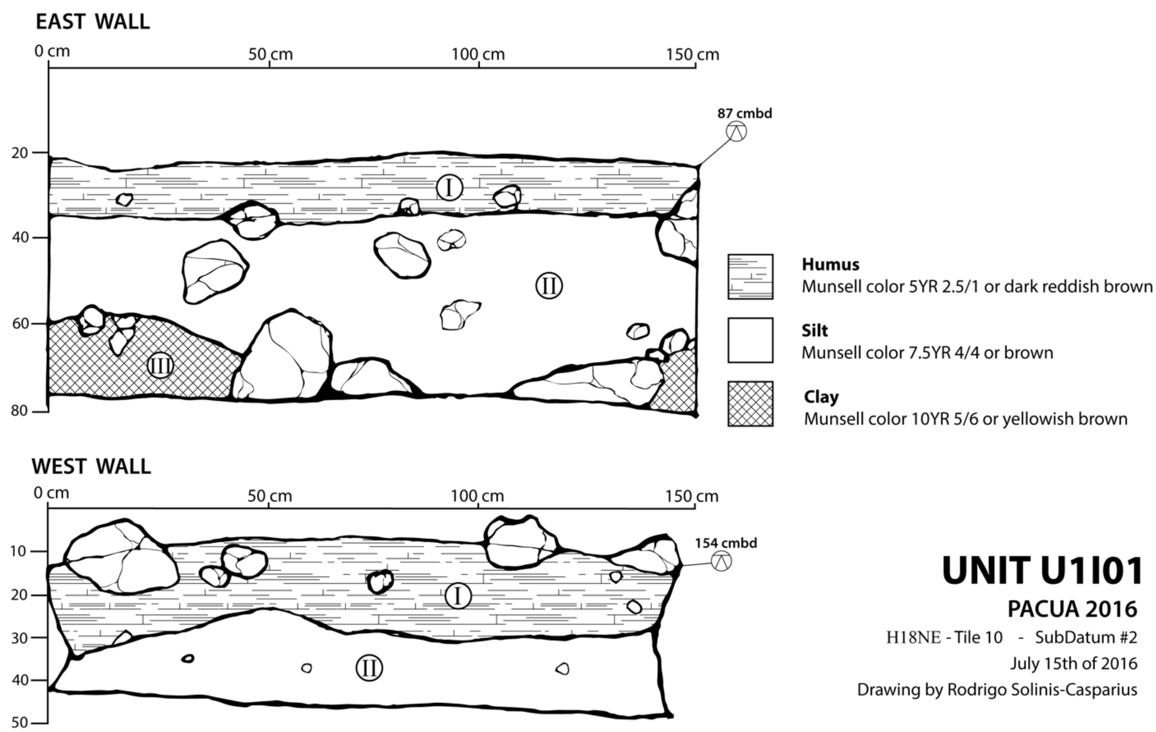

Figure 5.36 Profile of west and east walls of U1I01.

[11] See Social interaction afforded by movement in section 7.5.
[12] See network analysis in chapter six.

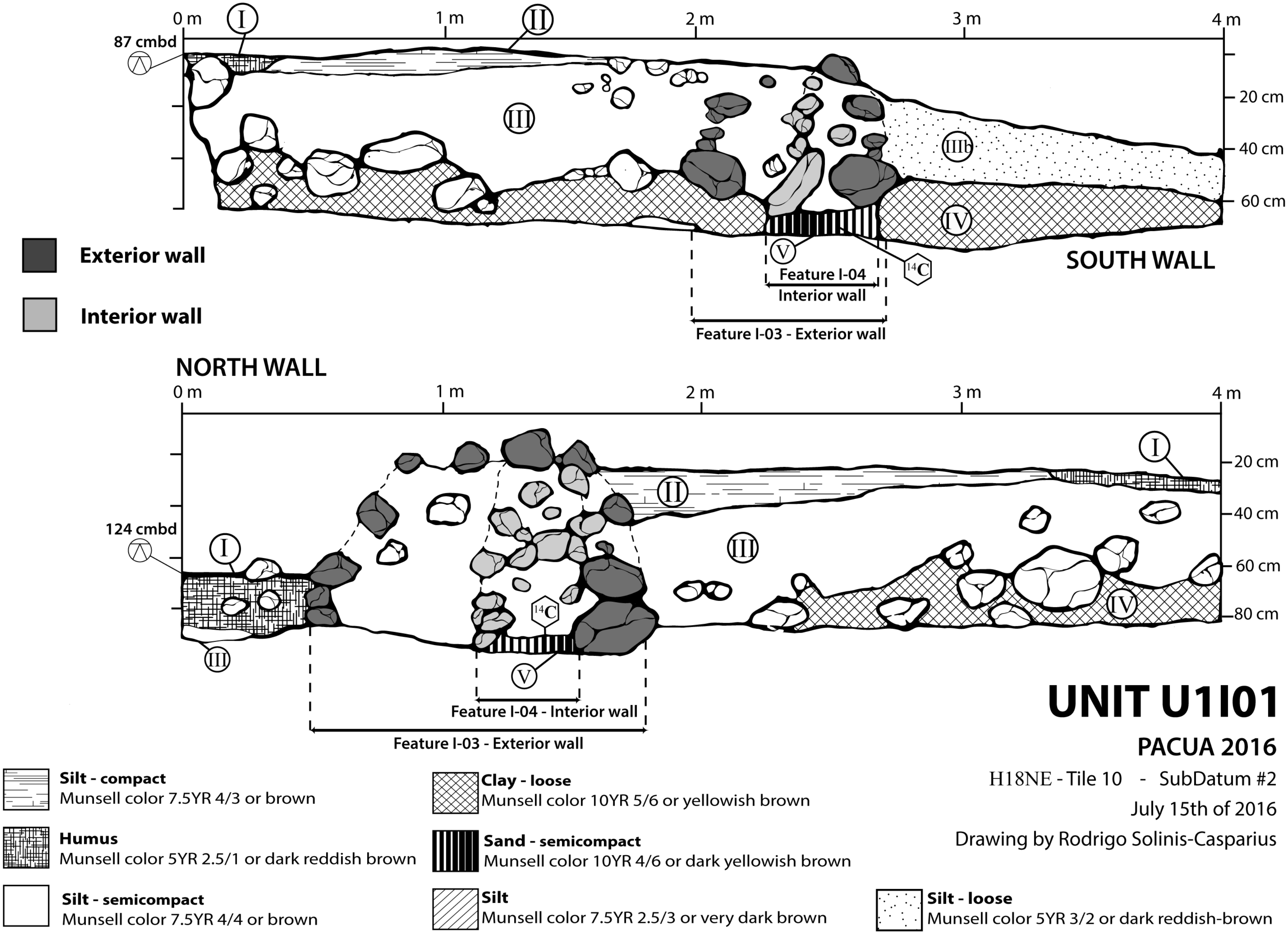

Figure 5.37. Profile of north and south walls of U1I01.

Interpretation of stratigraphy

In total, two construction events were observed in this unit, both of which related to the construction of the ramp and its *talud*.

Unit U1I01 is another example of the construction technique used on an elevated road but showing a different style ramp than unit U1A01. This is not only illustrative of the diversity of landscape modification of the site, but also of how construction of roads takes advantage of the topography and natural features —in this case, connecting two naturally-formed valleys.

I believe that an existing naturally-sunken area was further modified by digging and therefore creating a clear differentiation between the sunken plaza/patio and the elevated platform. Road S1I029 was then delineated by adding a ramp that would connect these two areas. In order to build this ramp, first a foundation was prepared by digging through the natural clay layer (strata IV) and tamping down a semi-compact fine sand (strata V) only for the width of the foundation of the wall (interior wall). Then an inner wall was erected using larger rocks in the base and smaller rocks towards the top, creating a wall 50 cm thick. The construction of this wall consisted of two parallel alignments of medium size stones arranged in rows, with mud filled with small stones used as a mortar.

Probably as part of this construction event (contemporaneously) an outer layer of rocks (the exterior wall) reinforced the foundation of the wall and acted both to delineate the edge of the road and as a retention wall for the ramp. The ramp was then filled with a mix of the same semi-compact sediment found in the excavation of the sunken plaza (strata III) and was then covered with another layer of silt that was compacted either deliberately or through sustained pedestrian traffic. I cannot suggest a clear interpretation for the presence of the *talud* and whether it was an important construction element —other than perhaps aesthetic— or the result of further modifications of the sunken plaza.

The last construction event was the placing of a wide (30–40 cm) alignment of medium and small rocks (*banquetas*) on both sides to delineate the road and make it more formal. No evidence of rocks acting as pavement were found in the excavation.

Figure 5.38. Photos of U1I0I on S1I021 road. Left: facing north toward elevated platform. Right: facing south; to the right, the sunken plaza/patio. Road highlighted in red, and platform wall in blue.

Figure 5.39. Photos of U1I0I during excavation. Left: facing west, showing outer wall. Right: facing northwest, showing outer wall and sunken plaza/patio in the background.

Figure 5.40. Photos of U1I01. Left: alignment of inner wall. Right: facing east, showing outer wall. *Talud* in foreground.

Figure 5.41. Photos of U1I01. Left: facing south, showing the profile of the road (outer wall not yet excavated). Right: the two *banquetas* at the end of level 1.

Unit U1I02

Location of unit

Unit U1I02 was located in the same area as U1I01 and laid out as a 4.5 m x 1.5 m trench directly on sendero S1I020. Such a location was chosen in order to capture a medium size road within a residential area. S1I020 is a road that connects major roads S1I019 and S1I029, the former on a higher elevation and the latter down a slope (Figure 5.34). This road crosses through an elevated edge with a steep slope to the west. The steep slope runs into a plaza and passes through complejo 19, a group of structures that have been described as residential houses by LORE-LPB in 2011. It is at this particular point in the road, where a narrow passage extending between residential structures to the north and the edge of the slope to the south, that unit U1I02 was placed. Additionally, the center-south part of the unit showed a large build-up of rocks on the surface, which seemed like a retention wall or a possible blockage on the west side. It was not possible to see architectural features associated to this road from the surface. For these two reasons I selected this location to set up the unit. In general, this unit provided a clear example of the reuse of space and how roads emerge with time as needed to define spatial configuration.

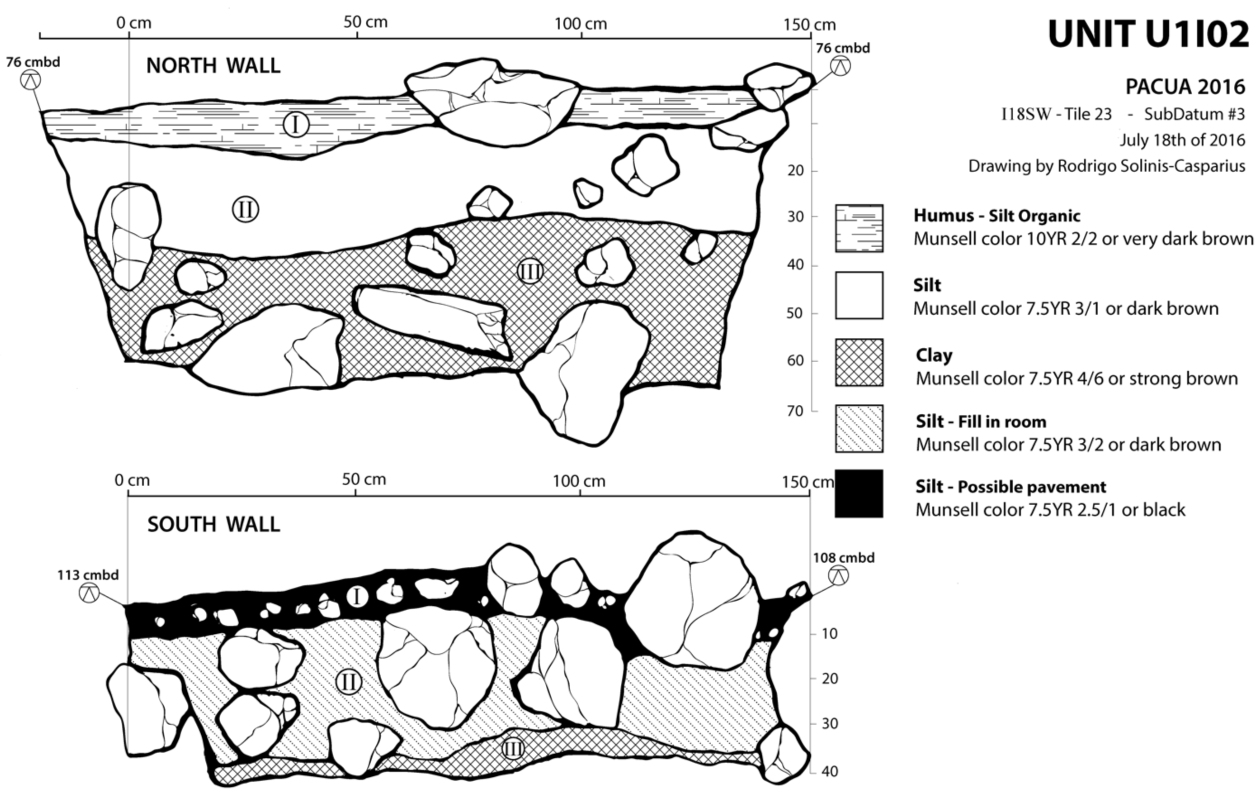

Figure 5.42 Profile of North and South walls of U1I02.

Interpretation of stratigraphy

The stratigraphy for this unit was complex given that the excavation unexpectedly uncovered an earlier residential structure below the road (Figures 5.42 & 5.43). In total, three construction events were observed (retention wall, *banquetas*, and an earlier room) in addition to another clear example of a road walking surface.

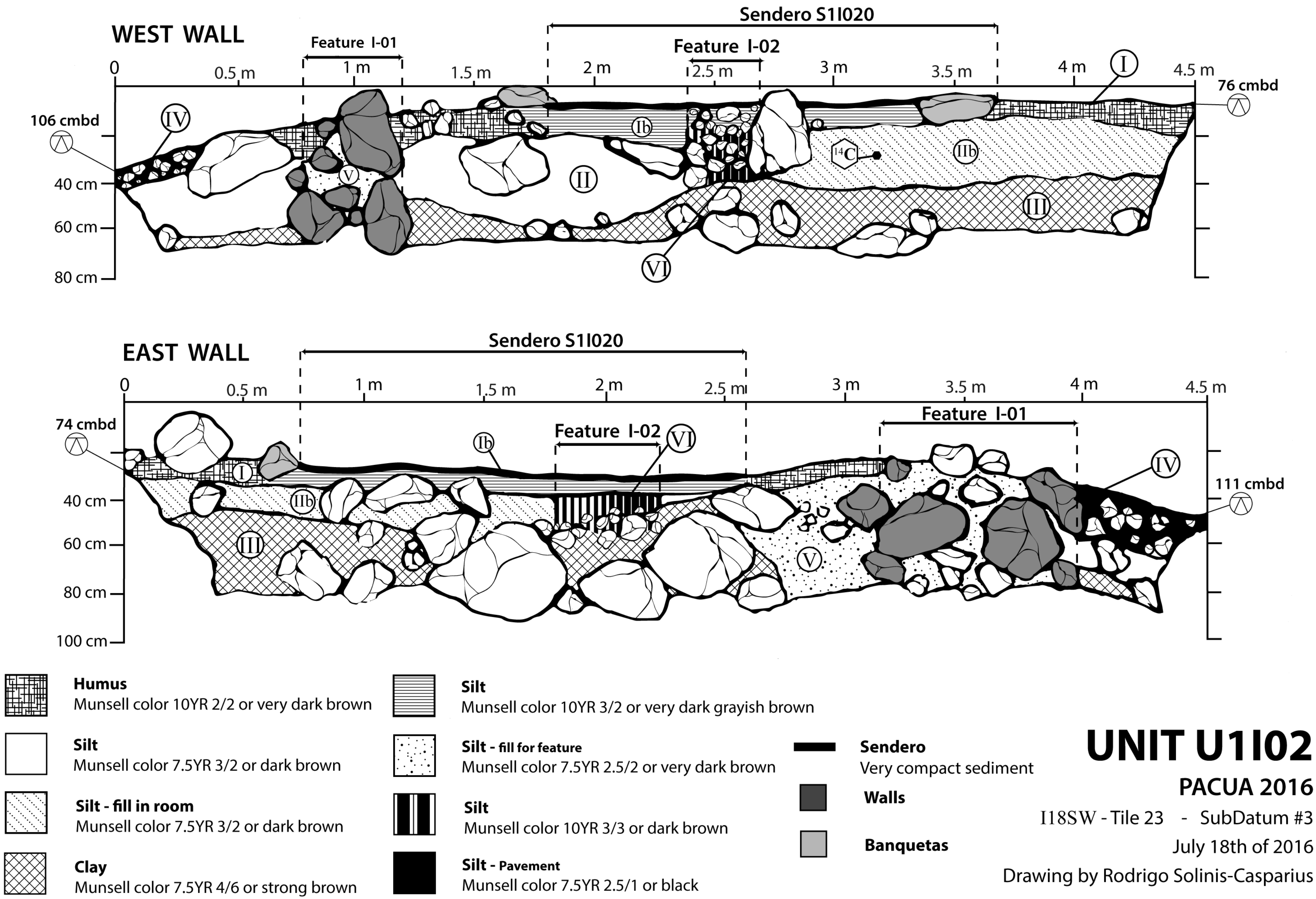

Figure 5.43. Profile of West and East walls of U1I02

Unit U1I02 presented the largest density of ceramic material of any other unit in the project. This is because the unit included excavation of a road and an earlier room below it. Sometime during the Early Postclassic period, the natural stratigraphy of the area (I-II-III) was disturbed, revealing the construction of the following features: on the north end, the foundation of a wall (Feature I-02) for a room described as a well-defined alignment of large rectangular rocks (>40 cm), and on the south end, another alignment of larger rocks (Feature I-01) part of a retention wall used to protect the surface and the structures from the natural slope just 1 m to the south. What was first described as pavement on the south side of the unit (just outside the retention wall) may have been the surface of a step, that may have been followed by many other partially or completely deteriorated steps aiming south down to the plaza. Eventually the room was abandoned and covered and used for a road delineated by a simple *banqueta*. Effectively, the width of the road was defined by placing boundaries directly onto the surface, which was enough to create a new road that with time and use compacted the sediment.

Figure 5.44. Photos of U1I02 on S1I020 road. Left: facing east towards unit U1I01. Right: facing north, with area of structures and residential *complejo*.

Figure 5.45. Photos of U1I02. Left: facing north, showing the retention wall in foreground and *complejo* in background. Right: facing south showing the alignment of an earlier room.

Figure 5.46. Photos of U1I02. Left: facing northeast with detail of earlier room, Feature I-02. Right: facing northwest with same feature in background and retention wall in foreground.

Figure 5.47. Photos of U1I02. Left: detail of the pavement for a step. Right: detail of the step.

Unit U1I03

Location of unit

Unit U1I03 was one of the most interesting and revealing excavations of this project. The unit is located on the elevated road S2I009, one of the largest and more important roads of the site that connects the lower and upper zones from the southernmost to the northernmost points in the city, forming a central axis. This road (causeway) is flanked by hills and structures in its southern section, and averages 6 m wide until it crosses a sunken road that follows the escarpment (S2I003). At this location, a raised platform about 3 m high extends to the base of the grand ramp of the site. On this platform, road S2I009 has clear retaining walls on each side that run straight toward the ramp, where they end. The ramp is long and paved and has one switchback climbing over 17 m until it reaches the top of the escarpment at Entrance 1 (Figure 5.48). A unique and noteworthy feature about this ramp is that it has a massive wall that serves as a sort of handrail, measuring 1.5 m in width and reaching as high as 1 m overall. This ramp and Entrance 1 are an essential artery and point of connection between Lower and Upper Angamuco. Past the grand ramp, the road continues again as a main artery and is flanked by hills, ridges, and architectural structures until the northern edge of the site.

Unit U1I03 is located at the base of the grand ramp, immediately north of node N2I006 where road S2I009 is met by segment S2I005 running from the east. S2I05 is a narrower segment that branches to the northeast from N2I003 and passes through the unit via a small stone ramp that provides access to the *causeway* from the east. The purpose of this excavation was to gain understanding about one of the most obvious and major examples of road construction and modification. For that, I chose to excavate this road as a trench cutting across the causeway in its entirety. The unit as a whole was 8 m east–west by 1 m north–south, oriented 4 degrees east of magnetic north, and took about 2 weeks to be excavated.

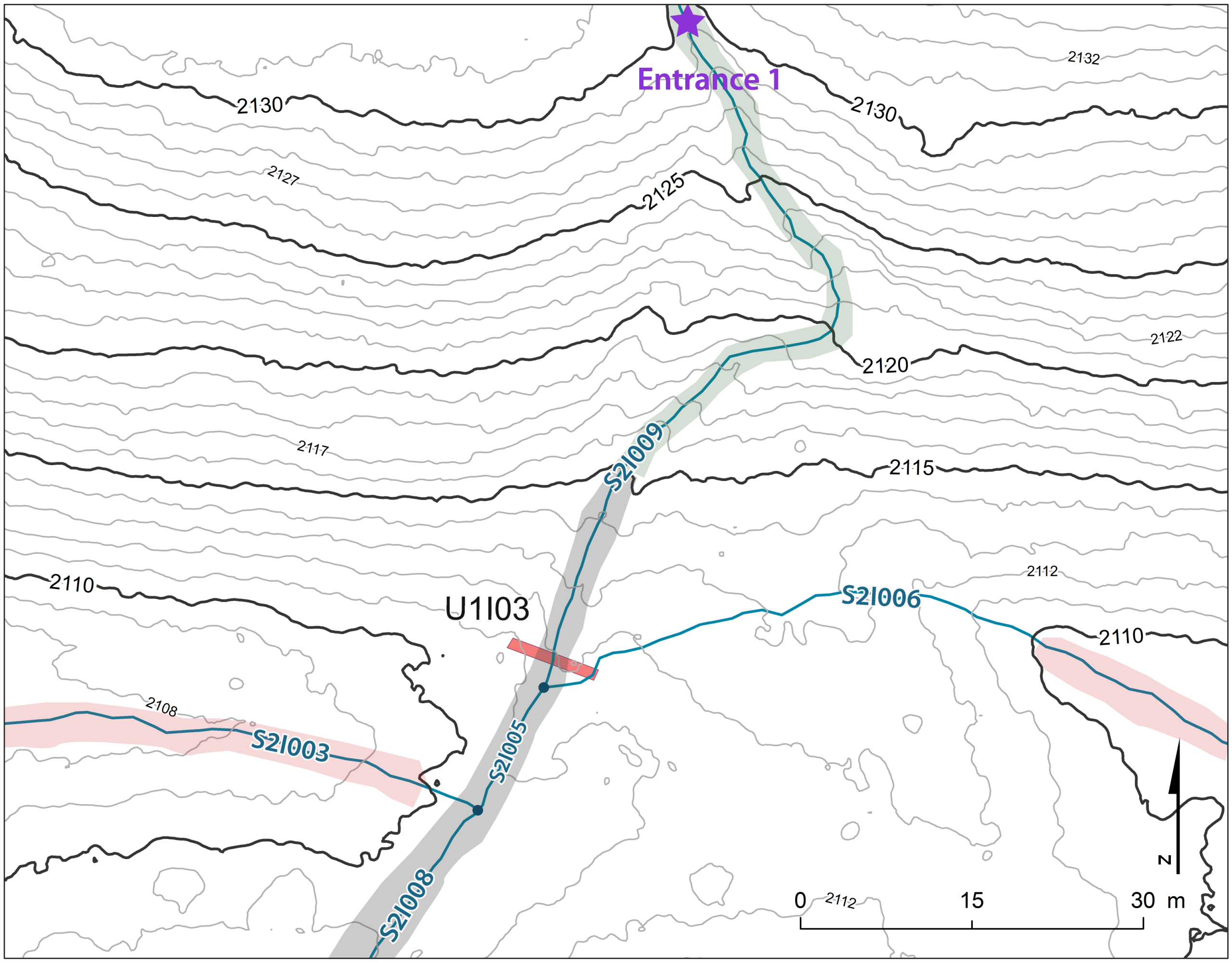

Figure 5.48. Planview location of unit U1I03. In red, unit. Segments and nodes are in blue. In light green, the large ramp toward Upper Angamuco. In light red, sunken roads. Elevated road section in gray. Contour lines show elevation values in masl of every meter (gray) and every 5 meters (black).

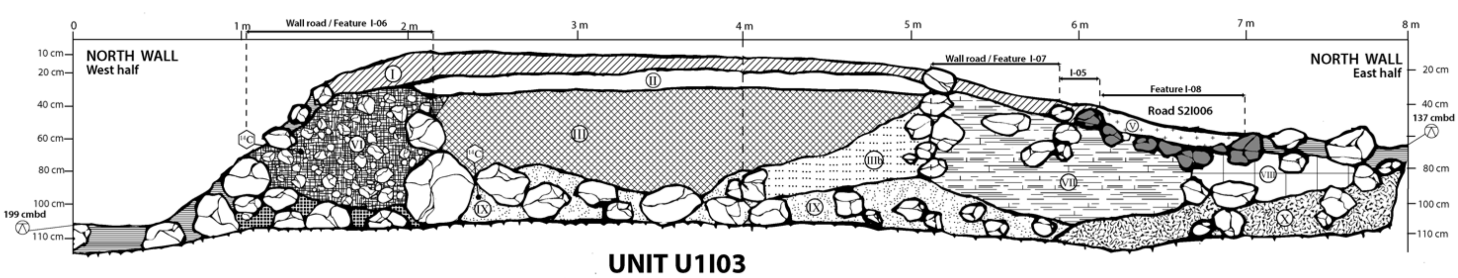

Figure 5.49. Simplified profile of north wall. For details see Figure 5.52.

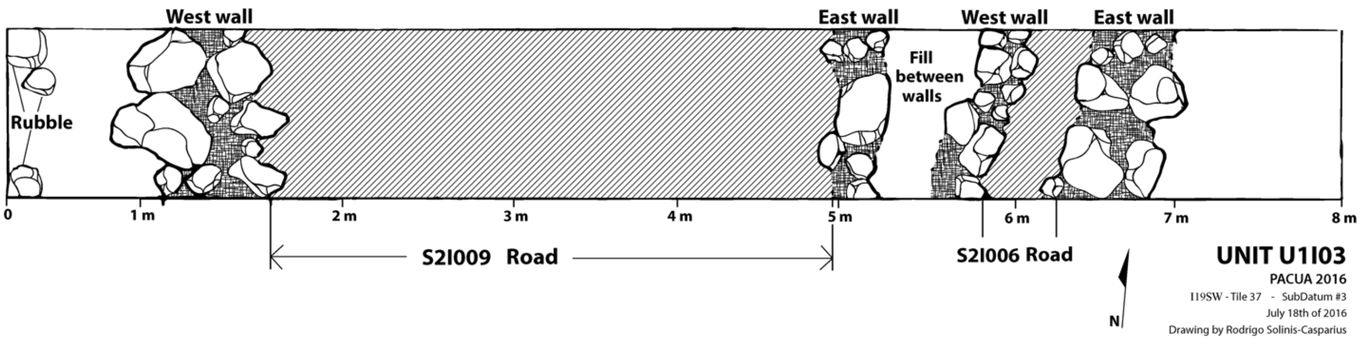

Figure 5.50. Planview map of unit U1I03 (level 7), showing the two roads with their respective walls.

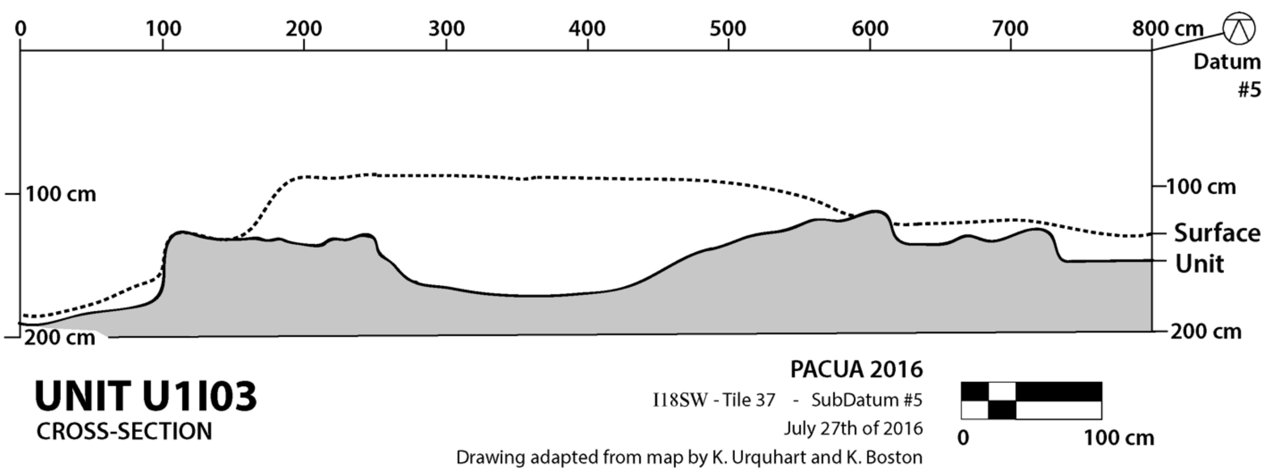

Figure 5.51. Cross-section of unit showing the profile before (dashed lined) and after (gray) excavation.

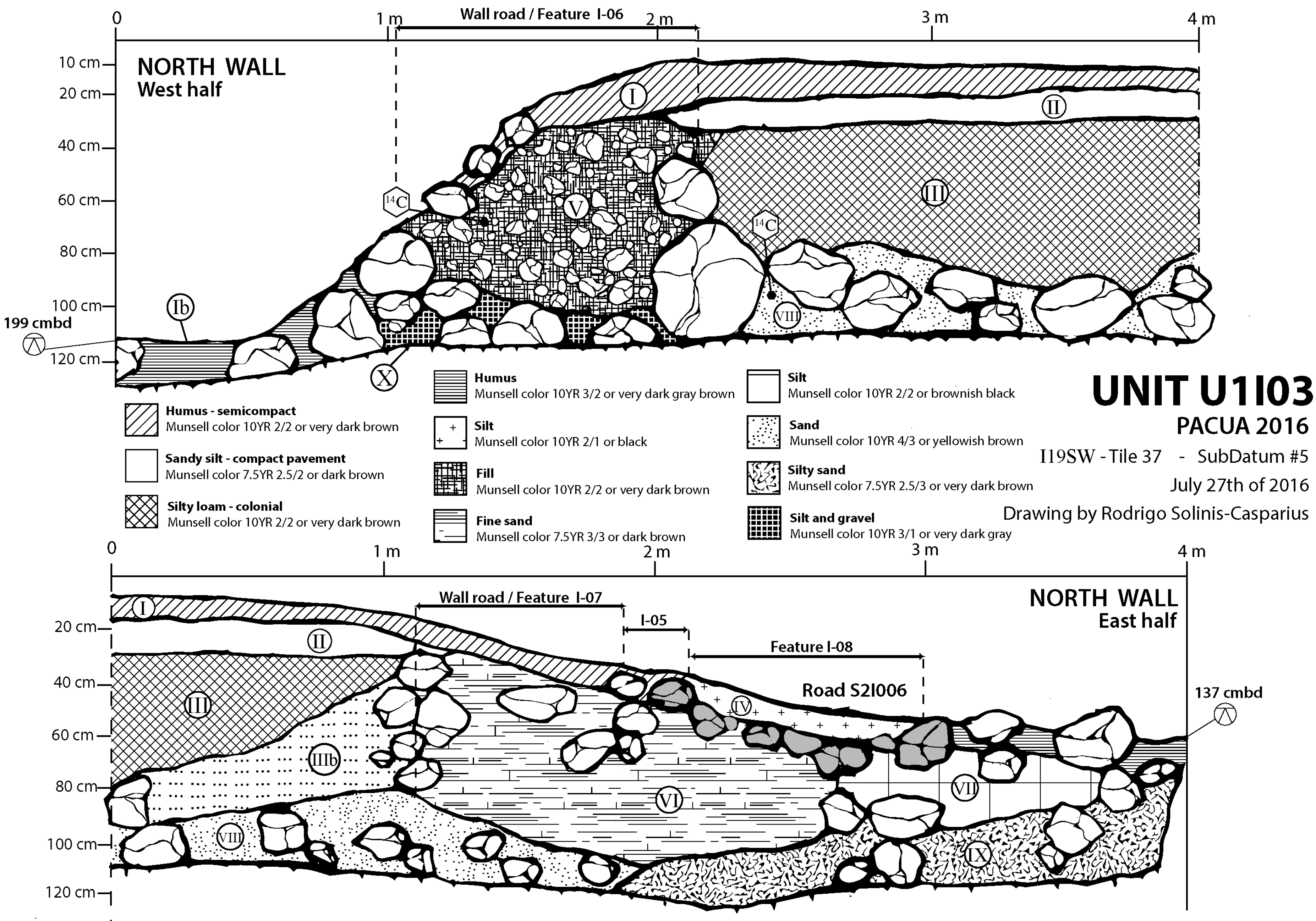

Figure 5.51. Profile of North wall of U1I03

Interpretation of stratigraphy

The stratigraphy of this unit is very complex with a total of 10 strata and 3 construction events observed. More importantly, these massive construction events most likely took place at the very end of the Late Postclassic period or during the first decades of the Colonial period (post-contact).[13]

The general stratigraphy for S2I009 road is complex, and because we observed several episodes of construction and modification, the strata numbering is markedly different from the strata of other units in this study and skips sections and stratum numbers.

Surprisingly, unit U1I03 showed that landscape transformations and modifications of the roads continued even after the Spanish conquest of the Purépecha Empire. Here I present the chronology of constructions events revealed during excavation, although a more in-depth discussion of this unit and its full chronology are presented in detail in chapter seven.

Given its prime location —center of the site— I expected to find evidence of very early construction and use. Unfortunately, we did not excavate down to the sterile layer and it is possible that we may have missed some important evidence of usage during the Middle Postclassic period or earlier.

I believe that a stone platform with yellow sand (stratum VIII) was constructed first or that this stratum corresponds to the remains of an older road that was used as the foundation/fill for a platform. In either case, this platform lies beneath the base of the retention walls on either side of road S2I009, road S2I006, and other archaeological features, indicating an earlier construction. On the surface of this platform, two walls that helped define the elevated road and served as retention walls were constructed on both sides. The west wall is more vertical and mirrors construction techniques found at other parts of the site with large faceted stones and a

[13] Based on colonial ceramic fragments. See ceramic analysis in this chapter.

rubble core. The east wall appears to be a simpler stack of stones. At least one fill deposit was placed against the east retention wall, using the same sediment as the associated wall (stratum IIIb). It is unclear why two different kinds of sediment were used or why two different construction techniques were used for the two walls. It is possible that these two walls were constructed at different times, or with different purposes in mind. I suggest that the fill deposit against the east retention wall dates back to the construction of the wall itself and possibly represents an earlier fill episode.

Above the east retention wall, and probably as part of the latest modification events, a much simpler road was constructed (S2I006). This modification served as an access ramp from the road traveling east along the base of the escarpment and was probably needed after the massive construction of the causeway. A black sediment deposit between the retention wall and the ramp indicates that this ramp was a later addition and was not part of the original retention wall. Therefore, the east retention wall was likely not constructed differently in order to accommodate the ramp, unless an earlier version of the ramp existed there and was not preserved to the present day.

Once both walls were erected, the void between them was filled with a large deposit of brown silty loam (stratum III) that evened out the surface of the below platform. Stratum III also served as the foundation for the *causeway* (stratum II), the last element in the construction of the pavement. Stratum II is a mix of sand and gravel to make a hard (compacted) pavement.

Strata I forms the modern road surface and dates back to the Colonial period, as evidenced by the presence of colonial era sherds. It is not clear if this means that the whole road dates to the colonial period or if the brown fill deposit was added later. I suggest that the brown deposit is a later construction considering the yellow platform that lies beneath the retention walls, which indicate that it was built before the retention walls were put in place. Additionally, the presence of other strata of fill at the bottom of the brown deposit may be remnants of earlier construction episodes. Moreover, it is somewhat improbable that the comparatively small colonial occupation of Angamuco would build a massive roadway up the escarpment, although it does seem plausible for them to have modified or repaired an existing road, especially to allow for the occasional use of wheeled carts and horses to traverse it after the bulk of the site was abandoned after conquest.

Figure 5.52. Photos of U1I03. Left: planview of eastern section of unit showing the *banquetas* and road S2I006 at end of level 2. Right: facing north, a profile of end of level 4 by west side of unit showing the top layer and the walking surface for the *causeway* in lighter brown.

Figure 5.53. Photos of U1I03. Left: facing north before excavation showing the raised *causeway* on its way toward the grand ramp. Right: after end of level 1, top of eastern wall in foreground, and sunken road S2I003 in background.

Figure 5.54. Photos of U1I03 during excavation. Left: R. Solinís and K. Boston drawing unit profile. Right: J. Urrutia and M. Acosta carefully placing boulders inside unit during backfill.

Figure 5.55. Photos of U1I03 facing east. Left: before excavation. Right: after cleaning surface debris.

Figure 5.56. Photos of U1I03. Left: photo facing east with detail of west wall. Right: facing west.

Figure 5.57. Photos of U1I03. Left: end of excavation facing west. The light-colored sediment is stratum IX. Toward the center, the earlier platform or stratum VIII. Right: facing east, end of excavation with west wall in foreground.

Figure 5.58. Still of photogrammetry model of level 2 showing the shape of the raised *causeway*. Toward the right the two *banquetas* clearly demarcate road S2I006 (in blue). A 3-D version of this model is included in the Appendix B at end of dissertation.

Brief summary of stratigraphy

In sum, all the excavation units showed different evidence of active engagement in the shaping and construction of roads and access to roads (ramps), as well as evidence of modification over time. These excavations produced cultural materials and radiocarbon samples that help locate these construction events in time (at least in sequence). They also demonstrated that the density of cultural materials within roads is generally quite low. More importantly, road excavation provided evidence that roads —just like other public structures— are features that were created, maintained, and planned in community, most likely requiring the hard work of several tens of people at a time, and other times fewer people but sustained work over longer periods of time; all this, even with the common but unsophisticated architecture style of Angamuco (Table 5.2).

UNIT	AREA	EVIDENCE OF CONSTRUCTION	EVIDENCE OF MODIFICATION AND RE-USE	LEVEL OF SOCIAL ENGAGEMENT FOR CONSTRUCTION
U1A01	A	Yes	Yes	Massive – urban
U1A02	A	Yes	Yes	Moderate – community
U1F01	FG	Yes	No	Massive – urban
U1F02	FG	Yes	No	Moderate – community
U1H01	H	Yes	No	Moderate – community
U1H02	H	Yes	No	Massive – urban
U1I01	I	Yes	No	Moderate -community
U1I02	I	Yes	Yes	Massive – urban
U1I03	I	Yes	Yes	Massive – urban

Table 5.2. Description of excavation units and the level of social engagement for construction.

5.1.2 Ceramic Analysis

The ceramic traditions at Angamuco are only beginning to be understood. The most comprehensive study and analysis for the ceramic materials of the site was done by Anna S. Cohen as part of her dissertation in 2016 (Cohen, 2016), in addition to the INAH *informes* by LORE-LPB (Fisher et al., 2012; 2014; 2016). Unfortunately, the complex but limited ceramic sample from this site has not provided a typology that can be easily associated with social status, function, or chronology. There are, however, several other studies in the LPB and the extended area that have produced similar vessel forms, decoration, and manufacture styles to those observed at Angamuco and that serve to define traditions and locate them in general time periods (Fisher, et al. 2019b).

In chapter three, I discuss how the study of ceramic typologies has been the core line of evidence to understanding the chronology of the LPB area. This work has been made possible through the contributions of several researchers over more than eight decades. Of those, the most influential work specifically within the lake Pátzcuaro basin has been done by Helen Pollard and Shirley Gorenstein (Gorenstein and Pollard, 1983; Pollard, 1993; 2008). In sum, these studies have centered on identifying ceramic assemblages found in association with other materials, such as architecture, burials, lithics, and metals (e.g., Gorenstein and Pollard, 1983; Kelly, 1947). These assemblages are known as "cultural traditions" and are only interpreted as phases once they have been sequenced. They have typically been named after the sites where a larger abundance of those ceramic styles has been recovered, and when possible, associated to absolute dates. While some of these traditions are similar and overlapping within other areas of Michoacán, the most accepted chronological ceramic typology for the LPB region is comprised of seven to eight of these traditions, starting around 500 BCE and lasting until the conquest of the Purépecha Empire in 1530 CE.

These traditions or phases of the LPB are comparable to the conventional periods of cultural development for the rest of Mesoamerica —Preclassic, Classic, and Postclassic— and describe social, political, and urban development in addition to ceramic manufacturing and stylistic practices.[14] However, these ceramic traditions expand beyond a unique cultural phase at the LPB. Thus, one ceramic tradition is not unique to any one cultural development phase exclusively. For example, variations of polychrome decoration or the *polychrome type* (that is, more than two paint colors over an orange-slip on jars, bowls, and other vessels) are found in sites of the LPB only after the Late Urichu phase around 1100 CE, and then expand from Late Urichu to the Tariácuri phase that starts around 1350 CE. While this style is usually associated with the formation and expansion of the Purépecha Empire (Tariácuri phase) it actually describes ceramic traditions from a period of time some centuries earlier (Pollard, 1993).

Apart from this polychrome type, several other diagnostic types have been observed throughout the LPB, however, only 12 of them have been identified at Angamuco (see Table 5.11).[15] According to Cohen (2016) many other local styles must have emerged at Angamuco during the different settlement periods, but those have not yet been fully identified. In table 5.3, I have simplified the LPB chronology and included the most diagnostic ceramic styles with a confirmed presence in the site of Angamuco (following Cohen, 2016).

In this section I present a summary of the ceramic styles observed during this project's excavation and ceramic analysis. First, I explore the findings in general and compare the variation of non-diagnostic materials in the eight units that showed ceramic fragments. Then, I

[14] See chronology of the area in chapter three.
[15] A more detailed description of the diagnostic materials for Angamuco can be found in chapter 5 of Cohen's dissertation.

describe how diagnostic materials were identified and how they helped me reconstruct a temporal sequence of architectural modification of roads for eight of the nine excavation units. Finally, I discuss two noteworthy ceramic findings at different road contexts.

	YEAR	PERIOD	PHASE	ANGAMUCO SUPPORTING DATA	DIAGNOSTIC CERAMIC TYPES
	+ 1700 1600 1530	Colonial	Early Colonial	Last date documented from ceramics	
	1400 1350	Late Postclassic	Tariácuri	C14, architecture, metal and ceramics	FR, PB, DR, FRG, RPB, RO, DRG, WR, P, IA
	1300 1200 1100	Middle Postclassic	Late Urichu	C14, architecture, metal, obsidian, and ceramics	FR, PB, DR, FRG, PB, RPB, RO, DRG, WR, POB, P, IA, BNP
CE	1000 900	Early Postclassic	Early Urichu	C14, architecture, and ceramics	FRG, PB, RPB, RO, DRG, POB, IA, BNP
	800 700 600	Epiclassic	Lupe/ La Joya	C14, architecture, and ceramics	PB, RPB, POB, IA
	500	Early to Middle Classic	Jarácuaro	No documented evidence	RPB, IA
	240 300 250		Loma Alta	Earliest date documented through C14	RPB, IA
	200 100 0	Preclassic			
BCE	100 200 300 400 500		Chupícuaro		

Table 5.3. Chronology of the Lake Pátzcuaro Basin and Angamuco. Modified from Beekman, 2014, Cohen 2016, Fisher et al. 2003, Haskell & Stawski, 2017, Pollard 2008.

5.1.2.1 The ceramic collection

As already mentioned, excavation units were laid out following specific goals of the project. Each unit was chosen to explore different types of roads and thus, they all have different dimensions and configurations. However, they were all excavated following the same protocol: arbitrary 10 cm levels or until a clear natural/cultural layer change was reached.[16]

During excavation, pre-sorting, and ceramic analysis, all materials with an area smaller than 1 cm^2 were discarded unless there was clear evidence of decoration, or they were part of a diagnostic form (e.g., lip, base, support, etc.).

During pre-sorting analysis (field lab), all samples were washed, curated, and re-bagged. Each FS bag was then pre-sorted, further separating each material bag into preliminary general classes —part of vessel and decoration— and all information gathered was then entered in the artifact database (Table 5.4).

After pre-sorting, all samples were organized in boxes by excavation unit with an additional box for all survey materials. In total, we had 187 FS bags (0001-0129 and 2000-2057) with 166 FS bags consisting only of ceramics.

Finally, during lab analysis (fall of 2016), all the pre-sorted bags —a total of 1,253 ceramic fragments— were further studied through attribute analysis approach (see below) with the goal of identifying diagnostic materials. Below, I present a summary of the observations from non-diagnostic and diagnostic materials.

[16] Details on the excavation methods, including mesh size, FS protocol, and other sampling are described in chapter four.

	DESCRIPTION	EXAMPLE	CODES
ID	FS Number	FS0005	FS + Number
Internal Code	Code including type/class	PA.C.FS0005.1.2	Project two-digit code + C (for ceramic) + FS number + Code per class
Count	Total amount of pieces per class	12	
Weight	Weight per class in grs with up to 1 decimal	67.5	
Sherd Type	Sherd type or part of the object	Body	Sherd type/part descriptor
Sherd Type Code	Code #	1	Body = 1 Element = 2 (includes rim, support, handle, base) Special = 3 (Pipe, spoon, figurine) Indeterminate = 4 (not clear) Other = 5 (anything else not in this list)
Class	Class of sherd	Undecorated	Class descriptor
Class Code	Code #	2	Decorated = 1 (paint, slip, appliqué) Undecorated = 2 Other = 3 (Anything that does not fit in previous categories)
Comments	Any special comments on the collection (e.g. polychrome, complete figurine, etc.)	Very small cylindrical piece-possible miniature	
Record Date	Date of pre-sorting	6/6/2016	
Marked	How is marked in the sherd (same code for all sherds of same class and type) Drop the first digits of the FS	5.1.2	

Table 5.4. Pre-sorting classification.

5.1.2.2 Non-diagnostic materials

One of the most significant results from this project is that roads generally have a low density of material deposits. The nature of the function of a road, their generally shallow stratigraphic deposits, and their architectural configuration are not suitable for a high accumulation of ceramic, lithic, or other cultural objects. Thus, the small sample of materials collected from excavation limits the kinds of analyses that can be performed in this research.

Despite the small number of sherds, however, the cultural materials analyzed are still useful, primarily in providing enough information to suggest the sequence of use, and construction events of roads.

In sum, of the nine excavated units, eight presented ceramic fragments of various decoration styles, manufacture styles, raw materials, sizes, thicknesses, and forms. About 22% of this sample (n=272) could be associated to a known diagnostic type for Angamuco (see diagnostic section below in Table 5.5). For the remaining materials (n=971) could not be associated to social and chronological contexts.

	DIAGNOSTIC CERAMICS	%	NON-DIAGNOSTIC CERAMICS	%	TOTAL
Total fragments	272	22	971	78	1,243

Table 5.5. Counts and percentages of the ceramic materials from excavation.

The density of materials is low but consistent within units of the same area, with two exceptions: unit U1I02 and U1A01. Unit U1I02 uncovered an infrastructure related to a road and the remains of an earlier room. A large amount of cultural deposits found in Angamuco, regardless of their function (domestic or public) or social status (commoner or elite), are rooms or housing structures, such as houses and palace chambers (Cohen, 2016, Fisher et al., 2016). The two strata related to the room in unit UI102 (stratum VI or the wall for the room, and stratum IIb or the fill of the room[17]) together represent ~50% of the materials of the unit. At the end of stratum IV, we excavated a 1 m x 1 m test pit to explore the rest of the stratigraphy. It was through this final excavation —stratum V— that we found the largest concentration of materials (42% of the total for the unit). As discussed earlier in this chapter, stratum V is considered part

[17] See UI102 stratigraphy earlier in this chapter.

of the construction of a plaza, therefore it may not necessarily relate directly to the road construction per se, but instead to a larger construction event in the area.

	AREA AD		AREA F		AREA H	AREA I			
	U1A01	U1A02	U1F01	U1F02	U1H01	U1I01	U1I02	U1I03	MEAN
Area (in m²)	6	5	1	1	0.75	6	6.75	8	
Volume (in m³)	5.6	3.15	0.55	0.7	0.53	4.32	4.25	8.4	
Total ceramic fragments	484	81	17	20	54	33	487	67	
Adjusted ceramic count	277						282		
Density (n/m³)	86.43	25.71	30.91	28.57	101.89	7.64	114.59	7.98	**50.46**
Adjusted density (n/m³)	49.46						66.35		**39.81**

Table 5.6. Counts and densities of materials per unit. Adjusted counts and densities for units U1A01 and U1I02 do not include materials found in room and platform fill.

The density of ceramic finds per square meter[18] is relatively the same found in other units of same areas of the site, although this measurement should be taken with caution since all units represent different construction events, time periods, and use of roads. Most noteworthy however, is that the density of materials is consistently low compared to other units representing habitational or public settings and burials excavated in the site. For example, a non-elite room excavated in 2014 in area F presented an average of 1,300 ceramic fragments, whereas roads excavated in the same area presented an average of only 19 sherds.

Overall, the density of materials found in excavation units at Angamuco is not very high compared to other sites in the region (e.g., Carot, 2001; Migeon, 2016; Pollard, 2001) having an average of over 190 sherds per m³ in every area, with the exception of area G. Excavations on

[18] Density of materials is calculated dividing the average number of fragments by the average volume of excavated units in meters (Schieppati, forthcoming).

road sections have yield, with the exception of area H, an average density of < 40 sherds per m^3 (Table 5.7 & Figure 5.59).

	PACUA (ROADS)				LORE-LPB (ROOMS AND PLAZAS)						
AREAS	AD	F	H	I	A	B	C	D	E	F	G
Volume (in m^3)	4.38	0.63	0.53	5.66	4.00	3.10	3.20	6.01	4.91	5.31	2.96
Total ceramic fragments	179	19	54	127	1357	685	633	1635	1460	1301	211
Density (n/m^3)	40.9	29.6	101.9	22.5	339.3	221	197.8	272.1	297.4	245	71.3

Table 5.7. Average count and density of materials per m^3 in each area of the site. On the left (gray) side of the table, all areas represent roads as part of PACUA project. On the right side, areas represent a combination of rooms, burials, and plaza excavation units as part of LORE-LPB project.

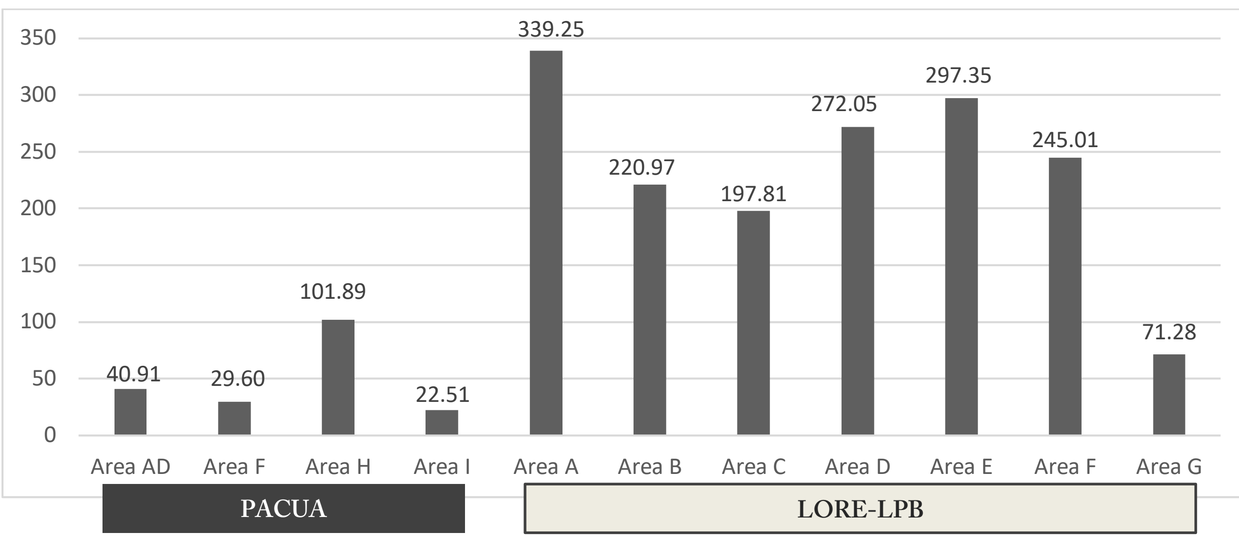

Figure 5.59. Comparison of average density of materials per m^3.

Thickness and *paste type* were recorded for all fragments, and both are here interpreted as evidence of technology. The biggest abundance of thickness occurs between 3.5 and 5.25 mm (n=550), although there are some examples of extremely thin (2.5 mm) and thick objects (15.75 mm) (Figure 5.60).

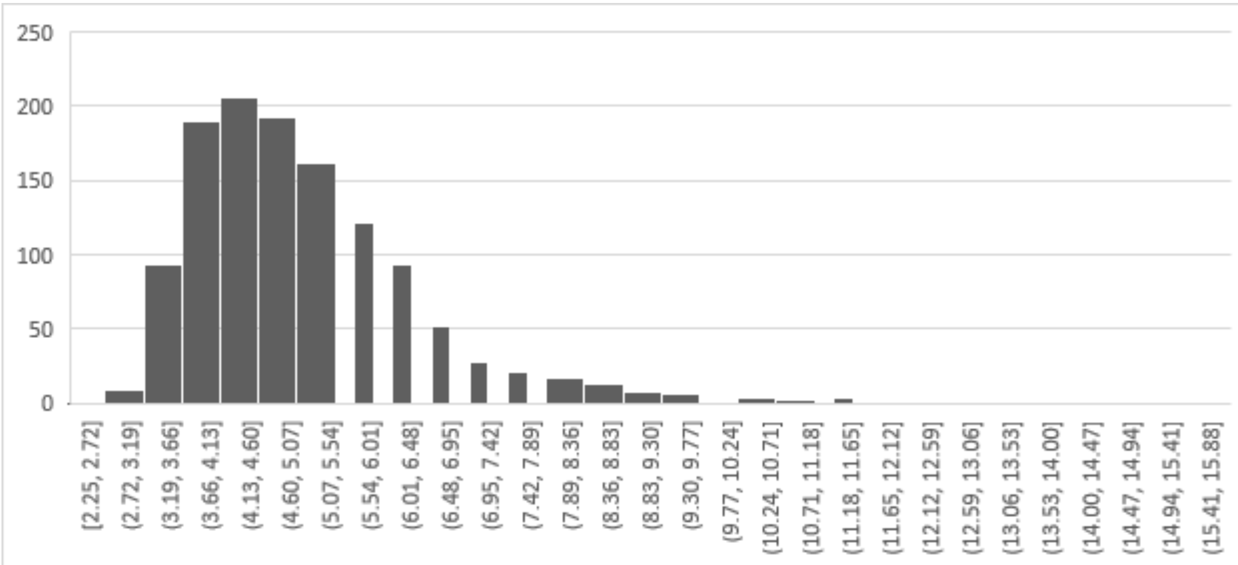

Figure 5.60. Distribution of sherds by their thickness. The X axis refers to thickness ranges (in mm) and the Y axis to counts of fragments.

Identifying the type of paste is important to understanding the uses of the ceramic objects from which social status and context of activities can then be derived. For example, since fine-paste fragments represent delicate and valued vessels of sporadic or ritual use, it is possible to associate them with an elite social status. In contrast, coarse paste fragments suggest a user population of commoners and activities associated to daily use (such as food or water storage vessels).

The paste type of the samples collected in road sections was grouped into three categories according to the diameter of particles (following Pollard, 1993): fine (<0.25 mm), medium (between 0.26 – 0.5 mm), and coarse (>0.5 mm). The vast majority of the sherds (71.5%) have a medium paste type, which closely resembles that observed at other locations throughout the site (Cohen, 2016) (Figure 5.61). Medium paste can be interpreted as evidence of mixed-use activities, which would be expected for roads of public use. Additionally, a distribution skewed toward medium paste but with a similar low presence of both fine and coarse paste fragments might suggest that these roads were not favored for ritual or primarily economic activities (e.g., agriculture, water transportation through vessels, or wholesale), and that these roads were used by both commoners and elite members of the Angamuco society.[19]

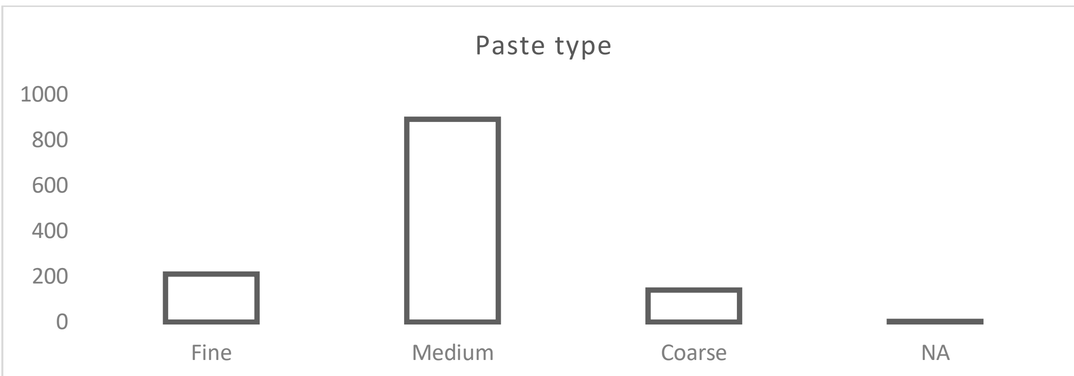

Figure 5.61. Summary of ceramic fragments by their paste type. Fine (17%), medium (71.5%), and coarse granular fragment (11%) from a total of n=1,251.

Unfortunately, these measurements alone (thickness and paste) are not diagnostic of known types for the area. Instead, *decoration* and *shape* of ceramic artifacts are the best indicators of socioeconomic and temporal contexts at the site. Most of the ceramic fragments for this research are small, ranging between 1 cm^2 and 2.5 cm^2, which make form identification complicated. Both rim (projected rim diameter by their curvature), and the curvature of body fragments were used to understand the ceramic forms of the assemblage.

Only 64 sherds in the sample represent rim fragments (Figure 5.62) that are convex (in-sloping rim that curves inward), straight (rim that does not exhibit change in the orientation from body), or out-sloping (rim that curves out from the body). Rim information alone however only helped discriminate 64 fragments as bowls, jars, miniatures, vessels, or incense burners.

[19] This interpretation can only be applied to the eight roads excavated in this project.

Additionally, the curvature of the body fragments was grouped into flat, incurved (probably closed forms), and outcurved (probably open forms) shapes (Figure 5.63). Of these two characteristics (rim and body curvature), it is possible to further identify a total of 87 forms for the assemblages described in Table 5.8 below.

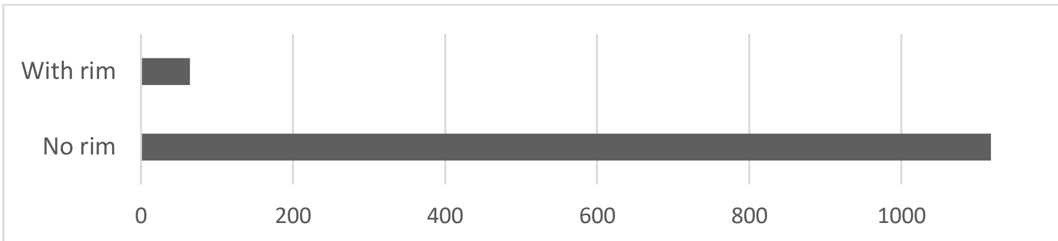

Figure 5.62. Summary of ceramic fragments that can be used to identify forms. With rim (n=64 or 5.5% of the sample) and without rim (n=1,117 or 93.5% of the sample) from a total of n=1,181.

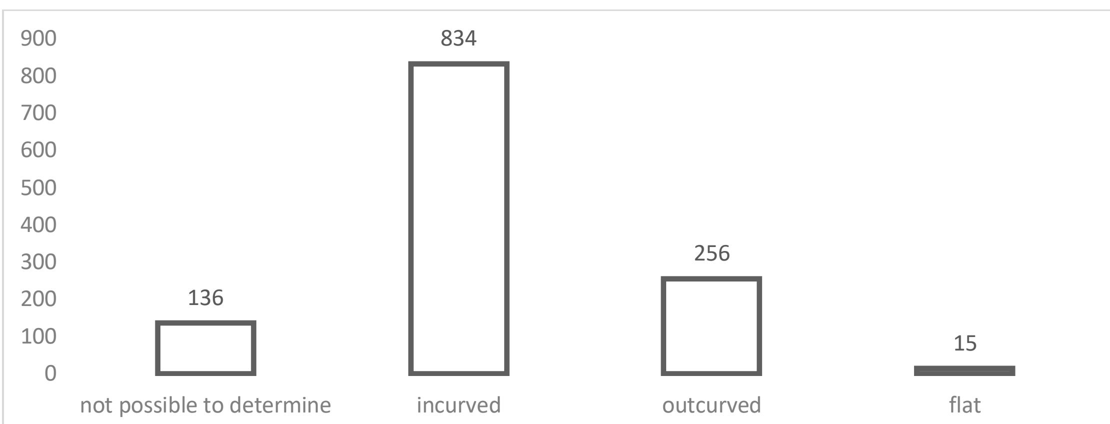

Figure 5.63. Summary of ceramic fragments by their form. Incurved (67%) can be interpreted as open bowls, outcurved (20.5%) as jars and vessels, and flat (1%) as plates from a total of n=1,241.

FORM	TOTAL
Bowl, composite silhouette	4
Bowl, convex wall	24
Bowl, everted rim	2
Bowl, incurved rim	7
Bowl, tripod	2
Jar, everted rim	22
Jar, incurved rim	7
Jar, incurved rim, (*tecomate*)	5
Plate, convex wall	2
Miniature	2
Other	10

Table 5.8. Description of forms of PACUA assemblage based on rim and body curvature. Total identifiable sherds is n=87, the remainder (n=1,154) cannot be associated to any of these specific forms.

Decoration was another important characteristic for identifying diagnostic materials in the sample. I considered a sherd decorated if it showed signs of any of the following either inside or outside of the vessel: slip, paint, incision, negative, or apliqué. Of all the fragments from this assemblage, ~78% showed one or more of these attributes (Figure 5.65). Although these decoration characteristics require a more detailed analysis, the large number of decorated objects further supports my interpretation of roads used by all social classes.

Decoration alone is not necessarily a diagnostic characteristic but can provide some general indication about the nature of the assemblage and chronology. For example, the application of one or more slips in the vessel fabrication has been observed for periods as early as the Late Preclassic in the lake basin (Hirshman, 2008) (Figures 5.64 & 5.65).

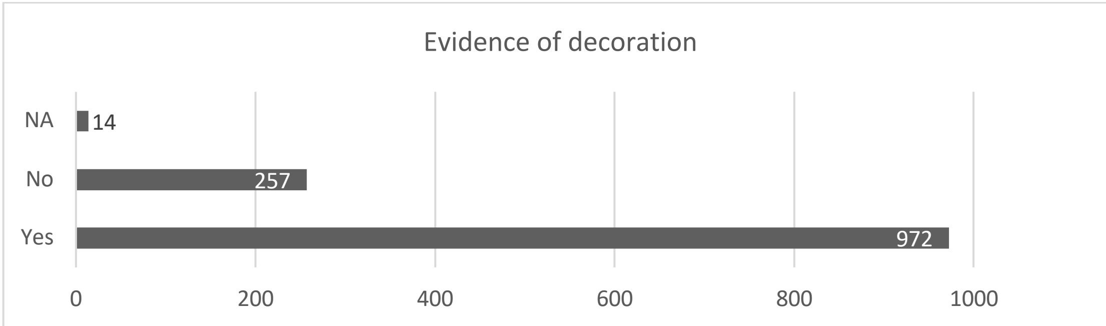

Figure 5.64. Summary of ceramic fragments by decoration. Decoration includes slip, paint, incision or apliqué. With decoration (78%) and without decoration (20.5%) from a total of n=1,243.

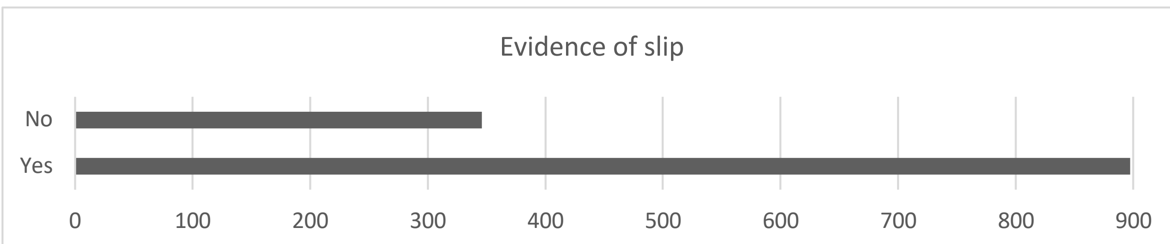

Figure 5.65. Summary of ceramic fragments by evidence of slip. This includes one or more slips (72%), or no slip (28%) from a total of n=1,243.

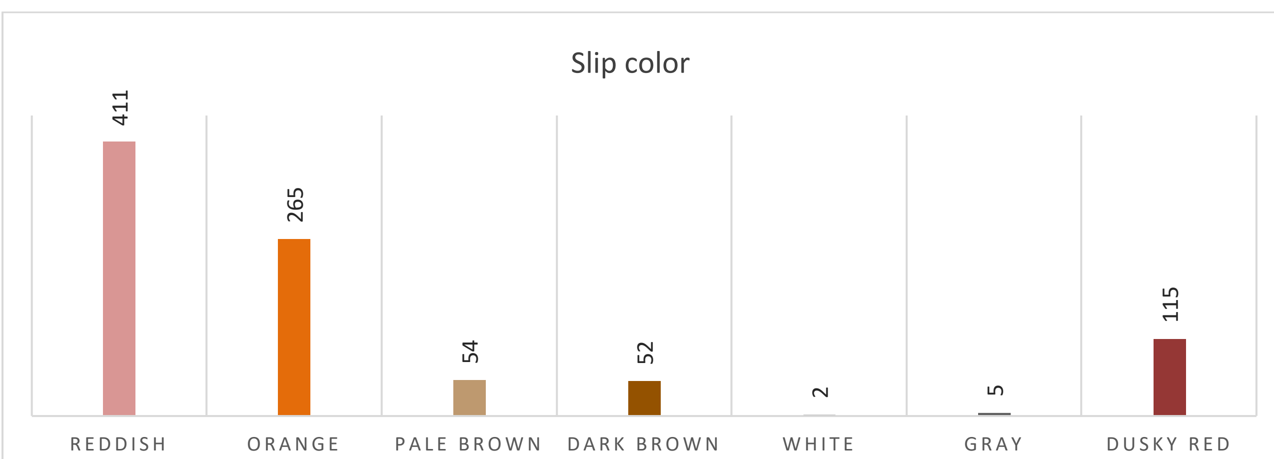

Figure 5.66. Summary of ceramic fragments by slip color description. Reddish (45.5%), orange (29%), pale brown (6%), dark brown (6%), white (0.25%), gray (0.5%), dusky red (13%), from a total of n=904.

In sum, the initial exploration of the ceramic assemblage for road excavation reinforces the idea that roads were used by many individuals of all social classes and for various activities. All units except units in area H showed a similar distribution of paste type and decoration presence (largest abundance of medium paste and decorated vessels).

Unit U1H01 did not show any evidence of fine wares in the fill or pavement of the road, an important observation given that this unit is located in one of the most important entrances to the site (facing the lake basin and directly facing the last capital of the Purépecha Empire). I believe that the absence of these materials is not related to the kinds of pedestrians that transited this road (non-elite), but instead reveals a combination of the following: a) the construction event of this road, i.e., constructed by lower class workers, b) the construction style, i.e., a paved road built on top of a thick layer of fill, with both fill and walking surface compact enough to prevent the deposit of newer materials, and c) the slope of the road, which would not allow for the accumulation of cultural deposits during construction or during use (e.g., very low density of materials above the fill layer might mean that materials would have washed out of the fall off of the wall toward the escarpment).

In general terms, the assemblage is very similar in all units, but also all units were placed on roads with a high level of pedestrian traffic. I anticipate that later work on more secluded and narrower roads will show a different distribution of materials (e.g., larger abundance of fine and decorated sherds).

5.1.2.3 Diagnostic materials

One of the main goals of the ceramic analysis was to identify temporal associations between materials and road construction events by identifying diagnostic materials that have already been associated to a cultural and chronological phase, either at Angamuco or the immediate region. To this end, I conducted an attribute analysis of the assemblage following Cohen's work at the site (Cohen, 2016) with a few adjustments that helped me add more details and include more attributes. A visual description of the steps in this analysis can be seen in Figure 5.70. To briefly summarize, I created (with the help of an assistant[20]) a database in Microsoft Excel in which each ceramic fragment represented a row where a total of 35 columns carefully described each one of their physical attributes and information in four general categories:

1) Basic identification information
2) Vessel form
3) Attributes of technology
4) Attributes of decoration

This work was performed at the Archaeology Lab of Universidad de Guadalajara during September to December 2016. Each category was further divided into subcategories and then attributes.

Each attribute option was coded independently (e.g., for granulometry attribute: 00=Cannot be determined; 01=Homogenous; and 02=Heterogenous). As a result, each fragment, uniquely identifiable (including provenience information), was attached to its unique attribute table relatable to all other fragments. With this, I was able to query fragments by specific attributes or cluster a series of attributes to reveal counts, locations, or patterns of distribution.

[20] Gerardo Ochoa Silva, undergraduate student from Universidad de Guadalajara.

For example, I could identify how many fragments with fine paste, one orange slip, and red paint were found in strata II of unit U1A01; and subsequently how many of those were associated to a specific ceramic form (e.g., bowl). Tables 5.9 and 5.10 describe these categories and subcategories, and a more detailed description and a full coding dictionary can be found in Appendix C.

FINISH ATTRIBUTE	
CODE	DESCRIPTION
00	Cannot be determined, due to erosion or breakage.
01	**Smoothing**: smoothed with a soft tool such as cloth, leather, a bunch of grass, or a hand; performed when vessel was wet or re-wet.
02	**Scraped**: striations from scraping tool are present; performed when vessel was still wet or soft.
03	**Burnished**: surface was rubbed repeatedly with a smooth, hard object, such as a pebble, bone, horn, or seeds. Could show narrow parallel or criss-crossing linear facets, careless burnishing results in irregular and streaky luster; performed when vessel was dry.
04	**Polished**: surface was rubbed with a smooth, hard object; luster is uniform; performed on dry surface.
05	**Roughened**: surface was made less smooth through striating, combing, stamping, impressing; may improve grip and heat transfer.
06	**No finish** (simple)

Table 5.9. Example of code options for *finish attribute*, part of the attributes of technology category.

CATEGORY	SUBCATEGORY	ATTRIBUTE	NOTES
Basic identification (Provenience)		Bag FS	
		Internal Code	From pre-sorting
		Area	
		Type of Collection	Survey or Excavation
		Unit	
		Level	
		Feature	
		Analytical Entity	Object (e.g. whole vessel, rim, body, base, etc.)
		Class of the piece	
Vessel form (the upper edge or margin of the rim or mouth of the vessel)	Lip Attributes	Tapering/Thickening	
		Symmetry	Flat, round, round with flattened top
		Flaring	Exterior, interior
		Lip thickness	
	Rim Attributes	Maximum orifice diameter	Measurement of mouth at the uppermost edge of vessel walls (mm)
		Rim thickness at body	Measurement of the vessel wall at the articulation point of the rim and the upper body (mm)
		Rim form	Convex, straight, out-slopping
	Neck	Neck	Restriction of the orifice of the vessel, beginning above the point of maximum diameter of the body
	Body Attributes	Body Form	Incurved, outcurved, flat
		Wall thickness	At thickest point of vessel
		Vessel height	
	Base Attributes	Base form	Annular, flat, convex, rounded
		Base thickness	At closely as possible to center of base (mm)
	Appendages	Appendages	Type of support, handle, or spout
	Vessel Type	Basic Form	Bowl, jar, incense burner, plate, vessel, miniature, etc.
		Morphological type	Bowl convex wall, bowl everted rim, etc.
Technology		Paste	Fine, medium, coarse
		Paste Color	
		Finish	The process that occurs after the pottery vessel has attained its final shape and after any irregularities have been eliminated
		Slip color	
		Slip location	Inside, outside, both
		Slip color description	
		Secondary slip color	
		Granulometry 1	Homogenous, heterogenous
		Granulometry 2	Porous, compact
Decorative Attributes		Subtractive	Incising, combing, fretwork
		Displacement/Joining	Impressing, apliqué, modeling
		Paint class	Simple, 2 colors, 3 colors, etc.
		Paint color	
		Paint color description	
		Paint color 2	
		Paint color 3	
		Motifs	

Table 5.10. General description of attributes in attribute analysis.

About 13 datable diagnostic types and their slight variations have been observed at the site and are consistent with other sites within the LPB (Table 5.11). My ceramic analysis concentrated on identifying these 13 types in the road samples. For this, I created a code-dictionary for each diagnostic ceramic type based on descriptions of the attributes for each of these diagnostic types by Cohen (2016) and Pollard (2001). For example, to identify ceramic fragments that could be classified as White on Red (WR) ware, I searched for all sherds that satisfied all the attributes for that specific ware (see Table 5.12 for example of WR), or an attribute code structure of:

1=(00-07), **2**=(00, 01), **3**=(00, 01, 02), **4**=(00-06, 24), **5**=01, 5=01, **6**=02, **7**=(00, 01, 03, 04), **8**=(00, 01), **9**=red, **10**=(01, 02), **11**=00, **12**=00, **13**=white, **14**=(00-03)

Numbers in bold refer to the attributes, and the numbers in parentheses refer to the codes for each attribute option. If all the required variables for the WR diagnostic type were met in one sherd, then that fragment was marked as WR.

Through this work, I was able to identify how many diagnostic materials were found in each stratum for each unit, and the total number of diagnostic materials for the sample (Table 5.13 & Figure 5.67). Since the diagnostic types are associated to temporal phases (Table 5.11), I was then able to identify the earliest and latest ceramic evidence for each stratum in all units and thus derive a chronology for that layer, structure, or feature.

The complete attribute analysis included documenting each attribute in a systematic process (pictures in Figure 5.71) and taking photographs of outstanding findings (Figure 5.70). Next, I present a summary of these findings per unit in an effort to help situate the temporal sequence of the different construction events associated to the roads.

	TYPE NAME	DESCRIPTION	CHRONOLOGY (EARLIEST APPEARANCE)	UNITS IN PACUA
C	Glazed	Glazed	Colonial	U1I03
P	Polychrome	Polished, primarily light brown slip, red secondary slip, black, white and red paint, fine to medium paste, bottles, jars, bowls, spouted vessels, miniatures.	Late to Middle Postclassic	U1A01, U1A02, U1F01, U1F02, U1I01, U1I02, U1I03
FR	Fine Red	Polished, red slip, fine paste, usually jars, spouted vessels, some bowls.	Late to Middle Postclassic	U1A01, U1A02, U1I01
DR	Dull Red	Polished, red slip, medium paste, jars.	Late to Middle Postclassic	U1A01, U1I01
WR	White on Red	Polished, red slip, white paint with motifs, fine paste, bowls, and bottles	Late to Middle Postclassic	U1A01, U1A02
PB	Pale Brown	Polished, pale brown slip, no paint, fine to medium paste, bowls and jars	Late to Middle Postclassic	U1A01, U1A02, U1I02
FRG	Fine Reddish Gray	Polished, red and reddish gray slip, no paint, medium paste, jars, and miniature vessels.	Late to Early Postclassic	U1A01, U1I01, U1I02, U1I03
DRG	Dark Red on Gray	Polished, grayish slip, dark red secondary slip or paint, un-even firing, no designs, usually bowls.	Late to Early Postclassic	U1A01, U1H01, U1I01
RO	Red on Orange	Polished, Orange slip, reddish secondary slip or paint, coarse to fine paste, jars, bowls, and patojas.	Late to Early Postclassic	U1A01, U1A02, U1F01, U1F02, U1H01, U1I01, U1I02, U1I03
BNP	Biochrome Negative/Positive	Polished, negative or positive, reddish slip, white or red paint, rim bands, fine to medium paste, bowls.	Middle to Early Postclassic	—
POB	Polished Black	Polished, blackish slip, fine paste, usually jars, bowls, and pipes.	Middle Postclassic to Epiclassic	—
IA	Incised & Apliqué	Polished, unslipped or pale brown when there is slip, medium to coarse paste, bowls, jars, incense burners.	Late Postclassic to Classic	U1A01
RPB	Red on Pale Brown	Polished, pale brown, reddish secondary slip or paint, several motifs, usually bowls and jars.	Late Postclassic to Early Classic	U1A01, U1F02, U1H01

Table 5.11. Description of ceramic types ordered by their earliest appearance. Descriptions based on Cohen, 2016.

	CATEGORY	ATTRIBUTES OBSERVED BY POLLARD/COHEN	ATTRIBUTE	CODES
White on Red Biochrome (WR)	Forms	Bowl, Bottle	Analytical entity	00-07
			Class of piece	00, 01
			Vessel type	00, 01, 02
			Vessel type 2	00/06, 24
	Paste	Fine (1-2 mm diameter) Yellowish red to brown	Paste	01
			Granulometry 1	01
			Granulometry 2	02
	Finish/slip	Polished Slip: red	Finish:	00, 01, 03, 04
			Slip location	00, 01
			Slip color	red
			Paint class	01, 02
	Decoration	Paint: white Spiral motifs	Subtractive	00
			Displacement/Jointment	00
			Paint color description	white
			Motifs	00-03

Table 5.12. Example of coding for White on Red type based on descriptions by Cohen 2016, and Pollard 2001.

TYPE NAME		**AREA AD** U1A01	U1A02	**AREA F** U1F01	U1F02	**AREA H** U1H01	**AREA I** U1I01	U1I02	U1I03	**TOTAL**
C	Glazed	0	0	0	0	0	0	0	3	**3**
P	Polychrome	25	5	2	1	0	4	26	2	**65**
FR	Fine Red	3	3	0	0	0	1	0	0	**7**
DR	Dull Red	3	0	0	0	0	1	3	0	**7**
WR	White on Red	1	1	0	0	0	0	0	0	**2**
PB	Pale Brown	13	4	0	0	0	1	0	0	**18**
FRG	Fine Reddish Gray	60	0	0	0	0	2	28	6	**96**
DRG	Dark Red on Gray	1	0	0	0	3	0	1	0	**5**
RO	Red on Orange	24	1	2	1	12	2	17	3	**62**
BNP	Biochrome Negative/Positive	0	0	0	0	0	0	0	0	**0**
POB	Polished Black	0	0	0	0	0	0	0	0	**0**
IA	Incised & Apliqué	1	0	0	0	0	0	0	0	**1**
RPB	Red on Pale Brown	3	0	0	1	1	0	0	0	**5**
										469

Table 5.13. Ceramic fragment counts by decorative types in the road units' sample.

TYPES COUNT

Figure 5.67. Count by types recovered from excavation. For detail of types see above.

Figure 5.68. General images of the archaeology lab at the Universidad de Guadalajara. Left: central patio of the lab. Center: Gerardo in the lab. Right: Kiyo and Gerardo doing attribute analysis.

Figure 5.69. Taking photographs of outstanding fragments using digital microscope.

Figure 5.70. Systematic process for attribute analysis. Top row, left to right: Selecting unit collection, selecting an FS bag, and two photos of confirming provenience and label information. Second row, left to right: two photos selecting pre-sorted sub-bag, re-grouping by general similarities, marking a sherd. Third row, left to right: measuring thickness, exploring for decorative attributes (e.g. slip), identifying color using Munsell chart, identifying max. orifice diameter for a rim. Forth row, left to right: observing small break, identifying attribute in the code dictionary, and two photos of enter attributes/codes in database.

5.1.2.4 Summary of ceramic assemblage by unit

U1A01

Unit U1A01 had a large amount of material (13 bags and 475 ceramic sherds). There seems to be a big variation of sherds (by technology and decorative attributes) including non-diagnostic. The largest concentration of decorated ceramics (with paint, including *bichromes*) was found in the last stratum. A projectile point was also found in this unit although it was not analyzed. A possible fragment of a figurine was found in level 7 (PA.C.FS0081.4), a possible false negative was found in level 3 (PA.C.FS0062.1.1.10), a support and a spoon were found in level 7 (PA.C.FS0081.3.2, PA.C.FS0081.2.1.1), a fishing weight (PA.C.FS0085.3.1.1) and a couple of round reworked pieces (PA.C.FS0085.3.1.2 and 3) were found in level 8 (Figures 5.71 to 5.73).

For diagnostic materials, the biggest concentration was of Fine Reddish Gray (FRG) in stratum V (n=60), with lower, but also significantly large concentrations of Polychrome and Red on Orange (RO) distributed in strata IV, III and II, and few other types observed throughout the unit. From these samples, I suggest that stratum V represents an earlier construction event than strata IV, III, and II, and that the earliest period associated for them was sometime in the Middle Postclassic period, before the formation of the Purépecha Empire (Figure 5.74).

In sum, this unit showed a large variation in terms of decoration and forms in comparison to other units, especially in the last stratum. The construction and use of the ramp/road occurred during the Middle Postclassic period.

Figure 5.71. Objects PA.C.FS0081.4, PA.C.FS0062.1.1.10, and PA.C.FS0085.3.1.2.

Figure 5.72. Spoon: PA.C.FS0081.2.1.1.

Figure 5.73. Fishing weight: PA.C.FS0085.3.1.1.

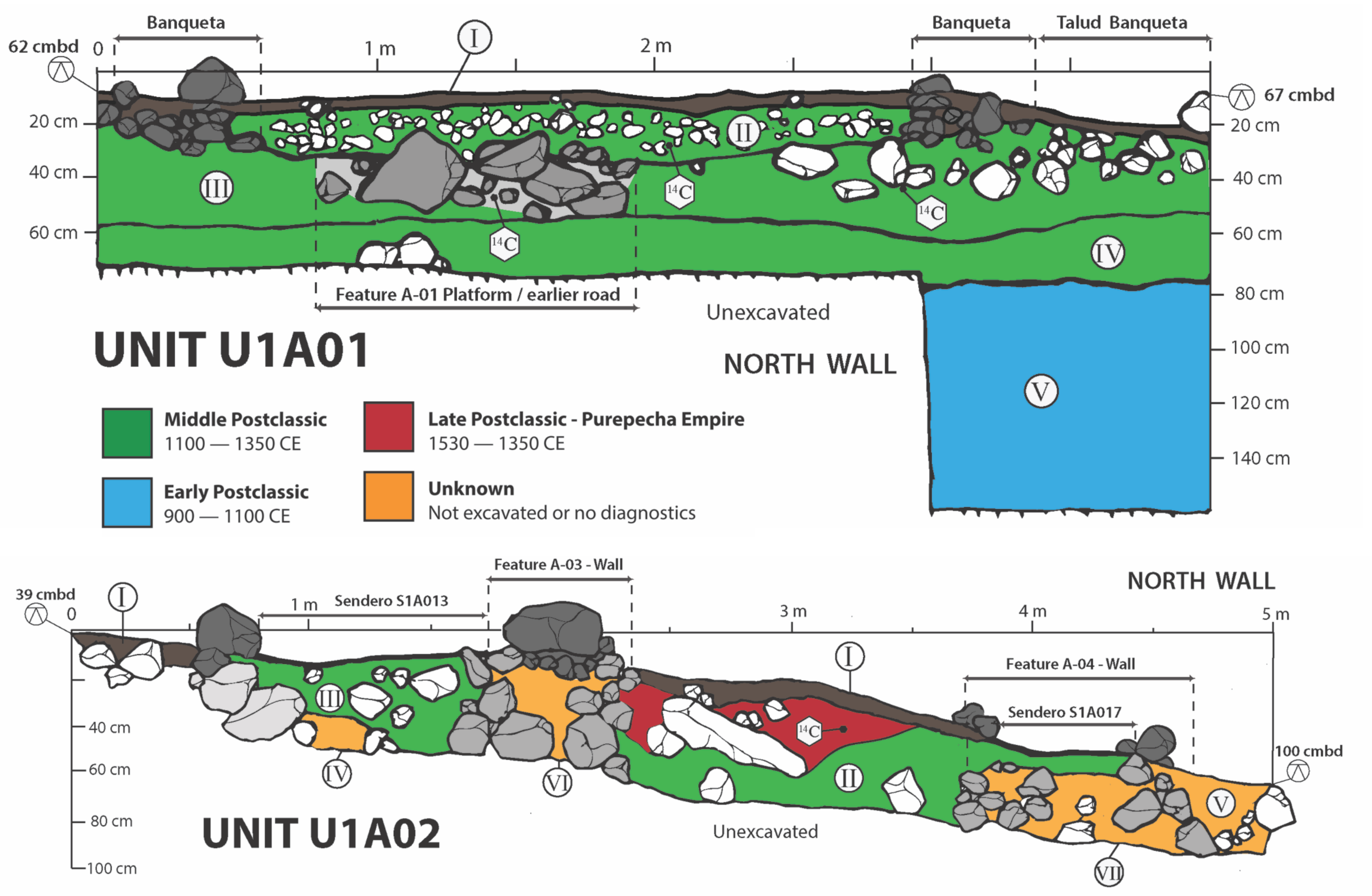

Figure 5.74. Profiles of units in area A where each stratum is symbolized by its earliest possible date according to diagnostic ceramics. Each color in the strata represents a time period.

U1A02

There were 81 ceramic fragments in unit U1A02, the most common decoration styles throughout the unit were red and pale brown slips usually polished or burnished, although some fragments with black and white paint stood out. This unit showed the third largest concentration of rims (after U1I02 and U1A01), some of them very peculiar, like PA.C.FS0105.2.1 which has a thick lip and appears similar to a style border from Ixtépete in Jalisco (Figure 5.75) (example in Mata-Ratkovich, 2011). Few obsidian blades, including re-worked blades, were recovered between stratum III and Feature A-02 (Figure 5.76). Another non-diagnostic common decoration style throughout the unit was a not very compact reddish paste with black granules (also observed in other units). And finally, several pieces showed signs of having been exposed to fire (i.e., smoked).

The most common diagnostic styles in this unit were Polychromes, FR, and PB, although there were very few identifiable examples of them (n=10). These helped establish the chronology of the different construction events in the unit. That is, modification and construction of roads happened as early as the Middle Postclassic period (pre-empire); and sometime later, the blocking/ramp of road S1A017 (probably during the Late Postclassic or Empire period) (Figure 5.74).

Figure 5.75. Ixtépete style rim PA.C.FS0105.2.1.

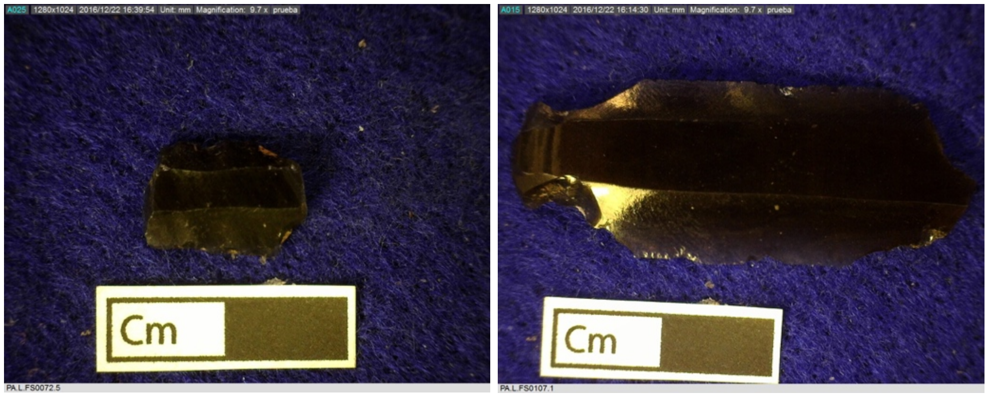

Figure 5.76. Examples of re-worked obsidian blades: PA.L.FS0102.1 and PA.L.FS0107.1

U1F01 and U1F02

Both units in area F showed low density of materials. Only eight diagnostic fragments were recovered from these two units. The most common non-diagnostic ceramic fragments in both units were polished red slip on a single side (most commonly outside). Interestingly, the only color of paint present in the entire sample was red. The paste for the fragments with this red slip, is not very fine, more compact than porous, and usually has black granules. There are also some burnished pieces made of a similar paste (e.g., PA.C.FS2048.1.1.1).

Within these units, sherds with a cream-colored slip and a noticeably superior paste (finer, compact, and homogeneous) to the red slipped pieces were also recovered. The most interesting findings are several fragments (n=5) showing signs of damage (smoked/burned) or *arrastre*, and a couple incised fragments (Figure 5.77). A few examples of re-worked obsidian blades were recovered but not analyzed (Figure 5.78)

Figure 5.77. Left: polished red slip style (PA.C.FS2048.1.1). Center: very eroded polished red slip (PA.C.FS.2040.5.). Right: incised decoration (PA.C.FS.2048.1.1.1.).

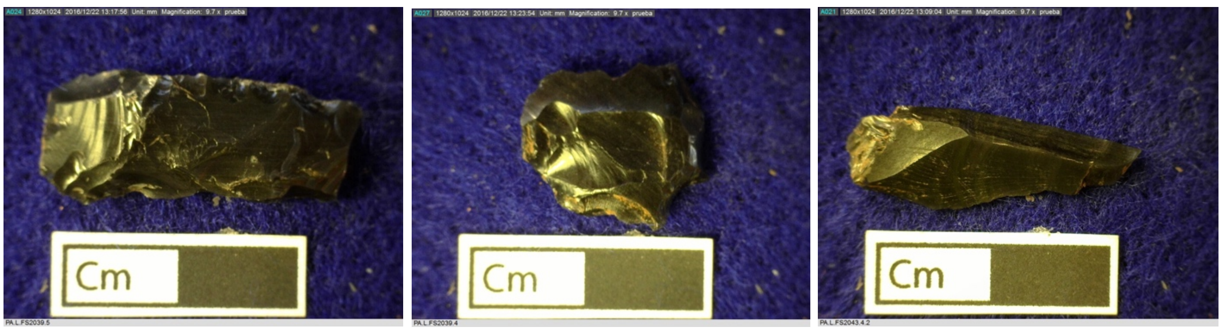

Figure 5.78. Examples of re-worked obsidian blades: PA.L.FS2039.5.0, PA.L.FS2039.4.1, and PA.L.FS2043.4.2.

In general, there was not large variation of ceramic fragments within each unit of area F as compared to areas A and I. However, the few diagnostic fragments that were recovered helped create a chronology for the units. Unit U1F01 might have two modification periods; one occurring during the Early Postclassic and a second during the Middle Postclassic, both before the formation of the Purépecha Empire. This chronology is consistent with unit U1F02 that showed a Middle Postclassic construction event right before the road pavement. Unfortunately, there are no dates associated to the earliest strata, but by comparing what we know from this research, I suggest that the main use and modification occurred at a period right before the Empire formation (Figure 5.79).

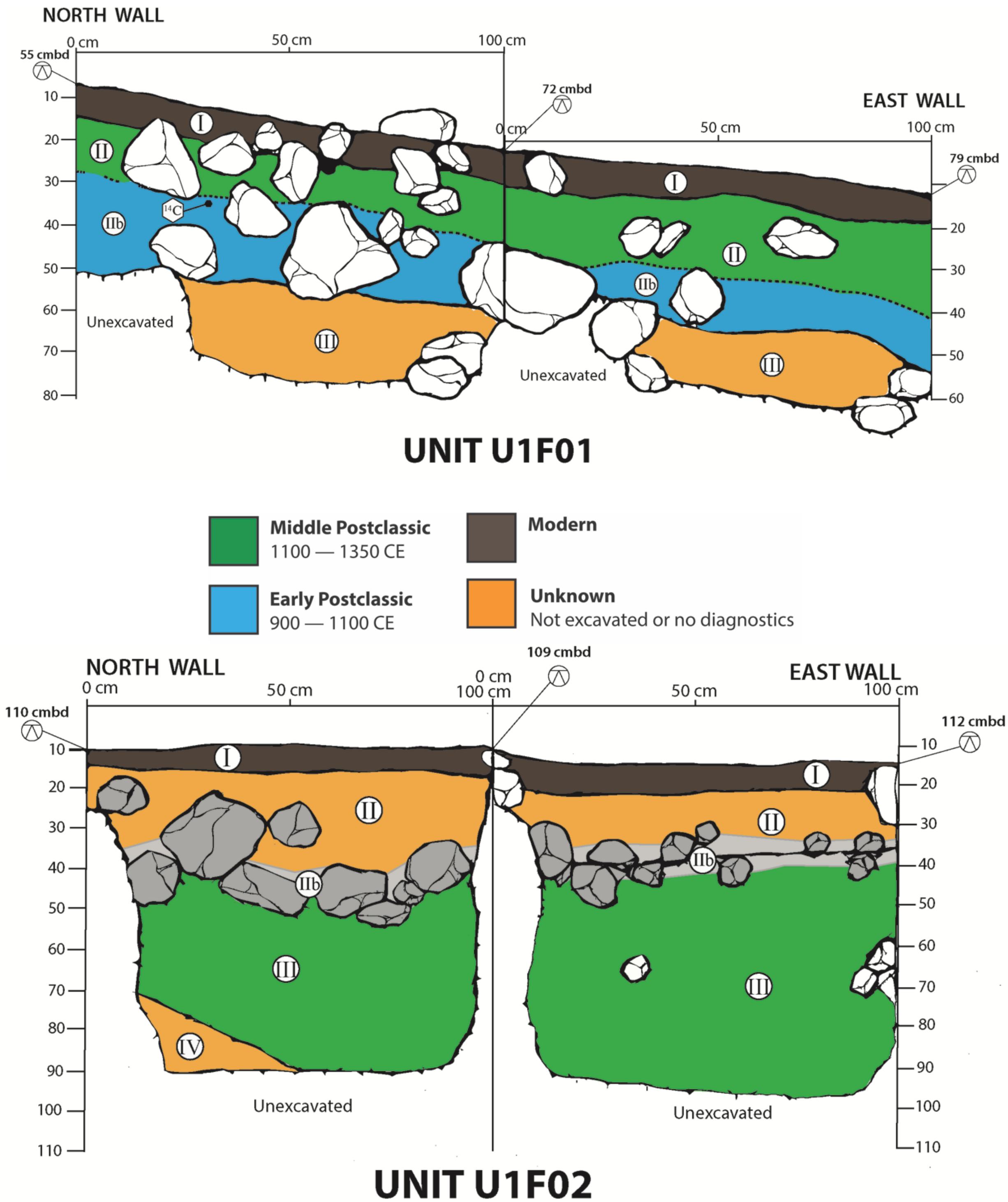

Figure 5.79. Profiles of units in area F where each stratum is symbolized by its earliest possible date according to diagnostic ceramics.

U1H01

Unit U1H01 has a small ceramic sample (n=49) but a higher percentage of diagnostics (n=16 or ~32%). The unit in general shows uniformity in terms of slip colors, where almost all of them are red or yellowish red. There is, however, considerable variation between those that have slip outside, inside, or in both sides. Additionally, there is variation in the finish: most of them appear as being polished but vary as to whether the polished surface is on the inside, outside, or on both sides. There were very few examples without decoration or slip, and few of paint over slip.

Most of the diagnostic sherds were Red on Orange (RO) (Figure 5.80), which can be found from Early to Late Postclassic, however one fragment of Red on Pale Brown (RPB) can be dated as early as Early Classic and helped distinguish the two main strata. I suggest that stratum IV occurred as late as Early Postclassic and then both strata III and II represent time periods somewhere during the Middle Postclassic, all events prior to the formation of the empire. However, the top layer, which was excavated as modern humus, might actually have deposits from as late as the Late Postclassic or post-empire. No materials were found in stratum I, but this unit was very narrow, and unit U1H02 in the opposite ramp showed no materials. More lines of evidence are necessary to confirm and expand the chronology of these two roads (Figure 5.81).

Figure 5.80. Examples of Red on Orange (RO): PA.C.FS2054.1.1, PA.C.FS2055.1.1.2, and PA.C.FS2056.2.1.

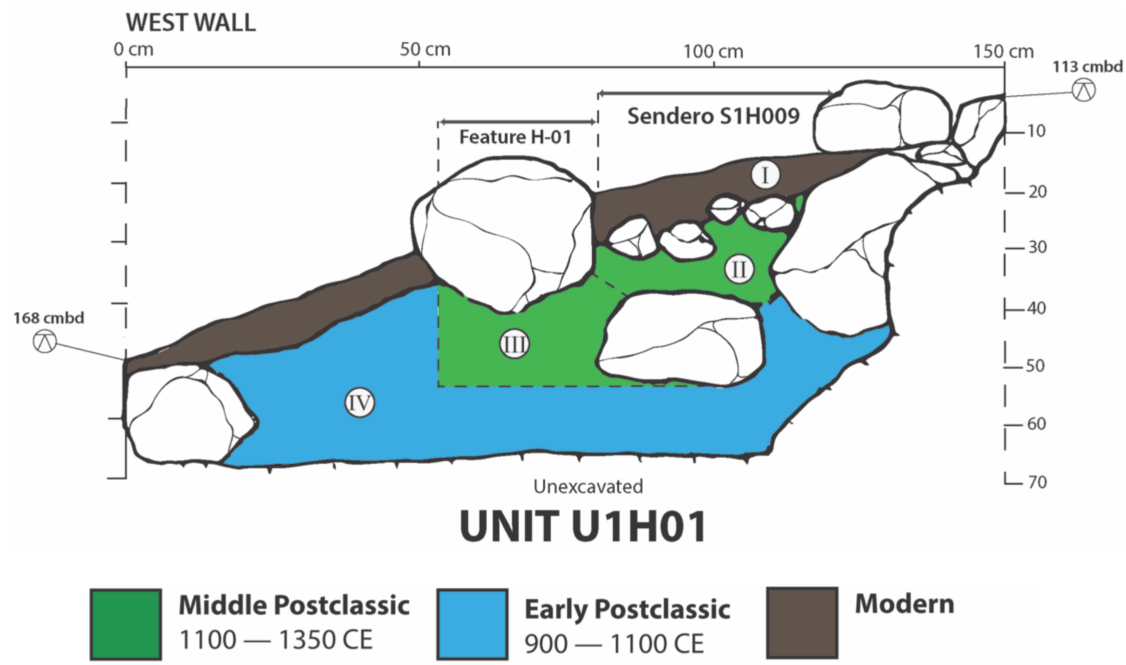

Figure 5.81. Profile of unit U1H01 where each stratum is symbolized by its earliest possible date according to diagnostic ceramics.

U1I01

This unit shows a lot of variation of styles within the different strata and features considering the very small sample (n=27). Feature I-03 within this unit had the largest concentration of materials, especially diagnostic.

Few examples of *arrastre* fragments and a few other fragments of rough finish would suggest that people transported everyday goods through this road. The majority of the sample showed polished red slip fragments (Figure 5.82) similar to unit U1H01. Finally, a small number of obsidian and basalt tools were found within the retention wall.

Figure 5.82. Left: example of rough finish PA.C.FS0094.1.1. Center: red paint over white slip PA.C.FS094.1.1.B.1.1. Right: basalt tool fragment PA.L.FS0094.1.0.1.

Only six diagnostic styles were identified in this unit: Polychrome, Fine Red, Dull Red, Pale Brown, Fine Reddish Gray, and Red on Orange. Polychromes were the diagnostic style with the most fragments (Table 4.13).

Since all these types have a large range of temporal use, it is difficult to derive the temporality of the strata. I suggest that strata IV and V represent earlier time periods than stratum III and the construction of the retention wall (which I dated to the Middle Postclassic, prior to the Purépecha Empire), however, it is difficult to suggest how much earlier. It is possible that the top stratum (II) represents the Late Postclassic period, but I did not find diagnostic materials in this stratum (Figure 5.83).

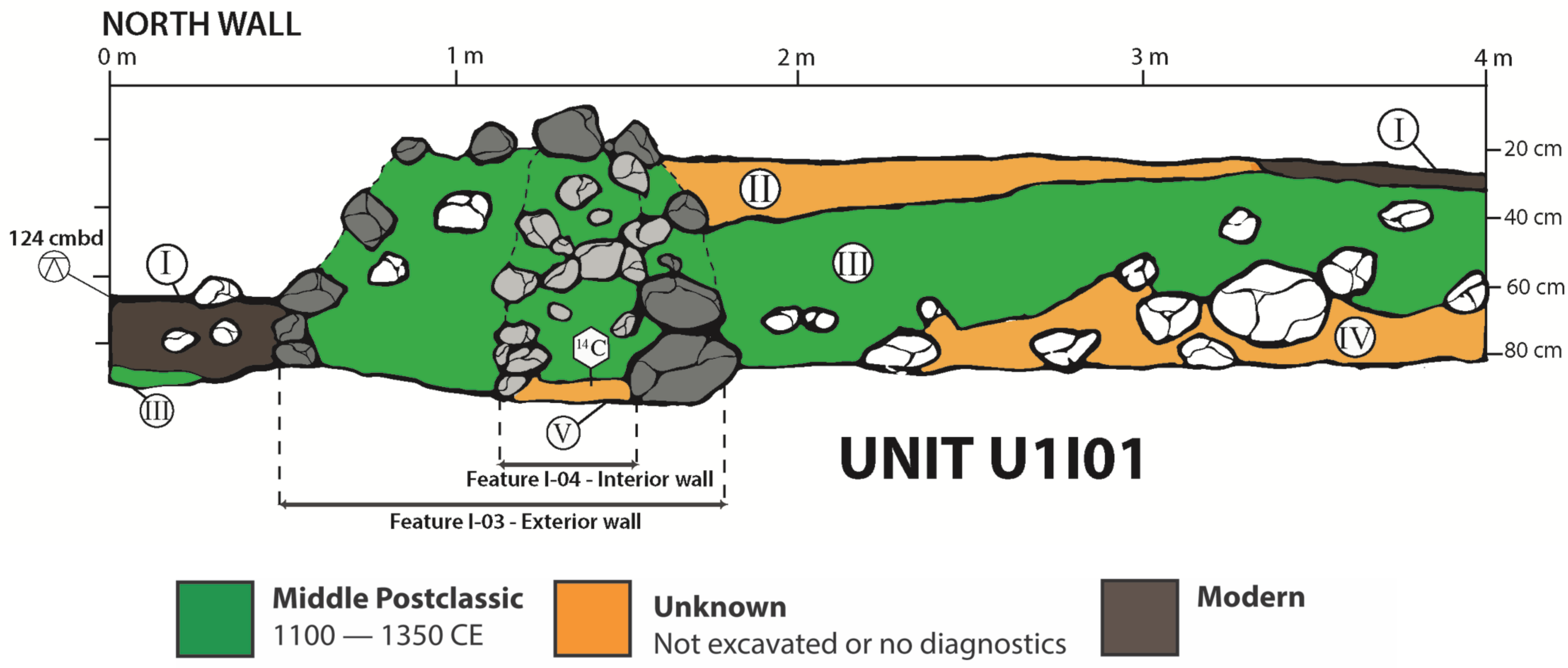

Figure 5.83. Profile of unit U1I01 where each stratum is symbolized by its earliest possible date according to diagnostic ceramics.

U1I02

Unit U1I02 had the largest density of materials (n=484) due to the different construction events observed within the unit (see chapter 4), and the largest number of diagnostic fragments (n=72). Interestingly, the variation of diagnostic sherds was low with only three different types observed: polychrome, fine reddish gray, and red on orange, all of them with concentrations of >20 fragments.

The majority of non-diagnostic fragments had a red slip, usually polished on the outside, but with a light polish (smoothed) on the inside. A lower number of ceramic fragments showed an orange or light brown slip, although the finishing of the light brown slip fragments is usually of better quality than those of orange slip. The light brown slip with a very thin and compact paste was found inside the room and not within road contexts. This unit also had a very large concentration of ceramic fragments with red paint (usually geometric motifs and rim bands) (Figure 5.85). A few other ceramic fragments with white paint, a jar fragment with incised decoration, and a few other smoked sherds were also recovered. *Arrastre* fragments were rare. Seven basalt and obsidian scrapers/knives were also found within this unit (Figure 5.84).

Figure 5.84. Examples of basalt and obsidian knifes: PA.L.FS0061.4.1, PA.L.FS0061.5.1, and PA.L.FS0097.1.1

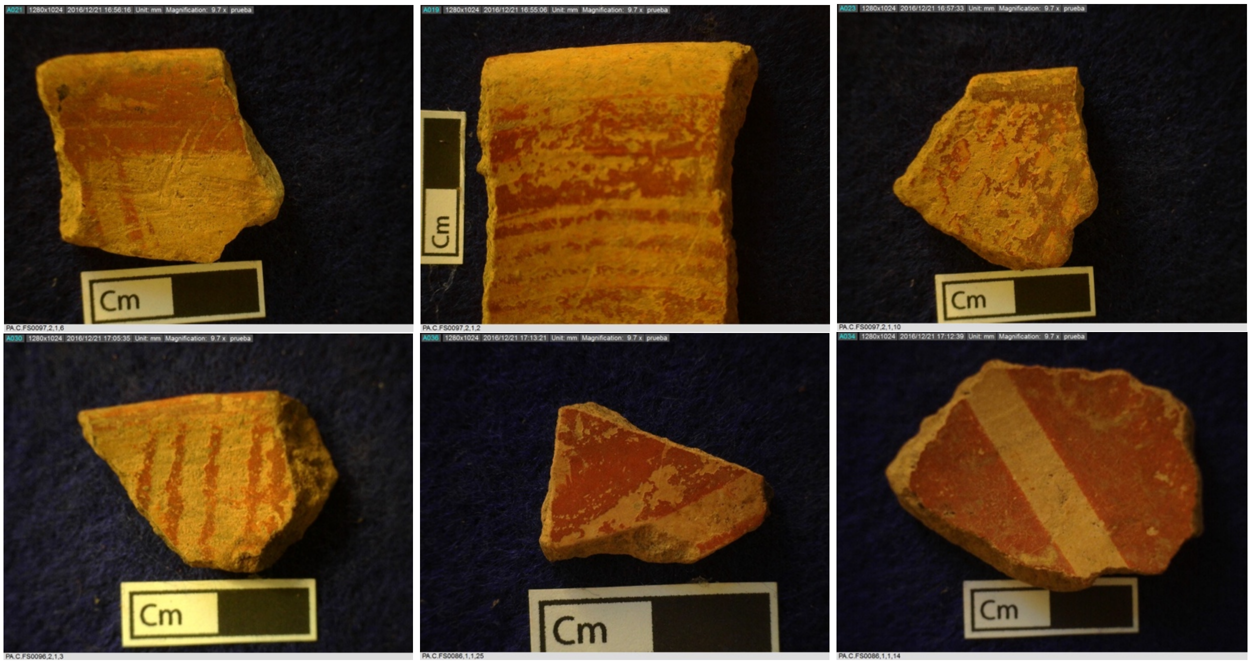

Figure 5.85. Examples of red paint. Top: PACFS0097.2.1.6, PACFS0097.2.1.2, PA.C.FS0097.2.1.10. Bottom: PA.C.FS0096.2.1.3, PA.C.FS0086.1.1.25, PA.C.FS0086.1.1.14.

Unfortunately, no diagnostic materials were found below the room that would have given an accurate reference for the earliest use of this space. A distinction can be made between the construction of the platform (stratum II), probably built as early as Early Postclassic, and the room (stratum IIb), built during the Middle Postclassic (Figure 5.86). The room was probably covered to create a road (S1I020) during the Middle Postclassic, although it is hard to suggest how much later after the use of the room.[21] If this is true, this chronology lines up with unit U1I01 directly east and connected to this unit through road S1I020.

[21] A C14 sample was tested from this room to gain a better understanding of all these events, though regrettably the sample was not useful. See next section for C14 results.

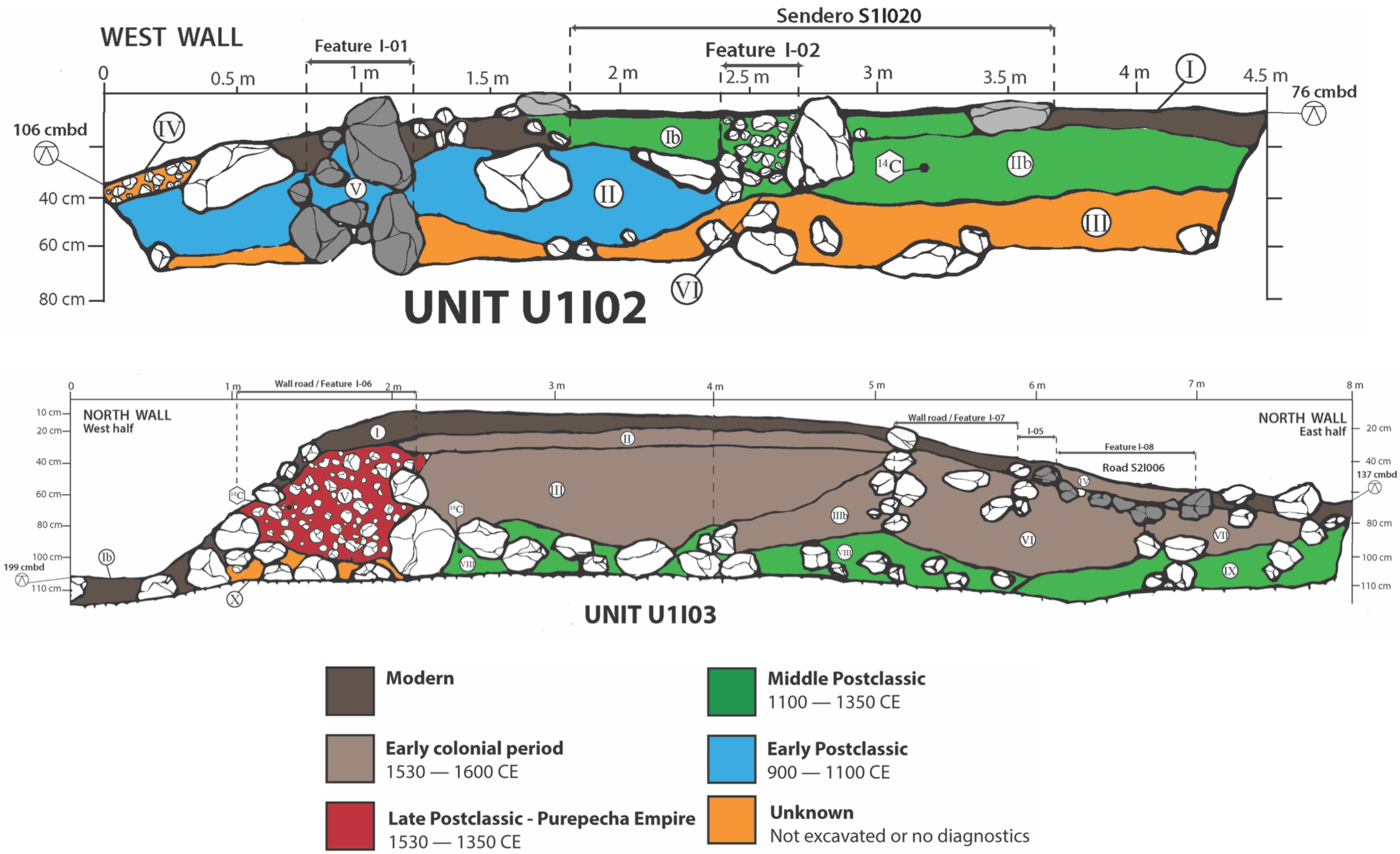

Figure 5.86. Profile of units U1I02 and U1I03 where each stratum is symbolized by its earliest possible date according to diagnostic ceramics.

U1I03

A total of 66 fragments were recovered in unit U1I03, despite having a total excavated volume of 8.4 m^3. One possible interpretation of this is that most of the excavated strata correspond to a single construction event in the Early Colonial period where different construction techniques might have influenced a more careful use of filling materials for the raised causeway.

Even with this small sample, there seems to be a uniformity of thin ceramics with a red slip and polished exterior, most of them without any decoration. Something similar was actually observed by Anna Cohen in elite rooms in areas A and D (Cohen, 2016). In these same, however, I also found *arrastre* fragments. Several (n=9) basalt knifes were recovered from different strata which I suggest might be discarded tools used during the aforementioned massive architectural construction event (Figure 5.87).

Figure 5.87. Examples of basalt knifes: PA.L.FS0118.5.2, PA.L.FS0118.5.3, and PA.L.FS0118.5.1

The diagnostic materials (n=14) found are distributed in polychromes, FRG, and RO types. I suggest that the earliest platform (strata VIII and IX) was built as early as the Middle Postclassic, and the west retention wall was probably built during the Late Postclassic (stratum V), however, the base for that wall was not possible to date.

The other three diagnostic fragments are all glazed and from the Colonial period. It is not clear if the glaze in these fragments was used as a technology improvement like a slip (used to prevent porosity for holding liquids) or if it was part of a decorative style. The two variations of glazed fragments found in this unit have either a black or a red glaze on both sides; both have a thin, very fine, and compact paste (Figure 5.88). This paste looks very similar to other Prehispanic ceramics. Similar glazed fragments were found during excavations of area D in 2014 (Cohen, 2016; Fisher et al., 2016). I suggest that all other construction events that included reconfiguring the road S2I006 and modifying the causeway (strata I-IV, VI and VII) (Figure 5.87) all occurred at the very end of the Late Postclassic period during the transition stage right after the conquest of the Purépecha Empire and the establishment of the colony.

Figure 5.88. Glazed ceramics associated to the colonial period. PA.C.FS0115.1.1, PA.C.FS01115.1.2, PA.C.FS0116.1.1

Arrastre sherds

Ceramic fragments suffer physical alterations during taphonomic processes causing sherds to lose attributes, change color, break, etc. (Schiffer, 1987), however, other mechanical processes during the use of these objects in the past ("the systemic context") affect the integrity of the ceramic fragments (size and shape) and the composition of the assemblage as a whole (Sanhueza Riquelme, 1998). I observed several fragments in my sample that seem to have rounded edges, with cuts so dull that they almost looked like they had been sanded or have achieved a circular shape. I documented these fragments as *arrastre* (drag), following some observations at La Peña, Jalisco (Liot et al., 2006), and even within the Angamuco collection (Cohen 2016, Fisher et. al. 2016). In total, I found 68 of such fragments distributed in half of the excavated units. All of them were found in strata near the walking surfaces, directly below road surfaces (see examples on Figures 5.89).

Others have noted how these alterations may be related to human trampling by walking over them and constantly kicking them around modifying the shape and roundness of their edges (Nielsen, 1991). Although some studies have explored the relationship between the area size of fragments, human trampling and amount of breakage (Sanhueza Riquelme, 1998), it is difficult to assess if this was the case from this sample. The roundness of the ceramic assemblage could be an important line of investigation for understanding traffic at the site.

Figure 5.89. Examples of *arrastre* sherds. PA.C.FS0094.1.1.1.B.1.1. and PA.C.FS2045.1.2.

To sum up, attribute analysis helped identify diagnostic materials that were used to derive the chronology of the different construction events within the roads. There are five significant general conclusions that can be drawn from my research:

1) Roads are unique architectural features with a low density of cultural materials. Almost all of the materials were recovered at *banquetas*, walls, or within the fill during construction and modification of the roads, and not in the very thin layers of actual walking surfaces.

2) The earliest evidence of road construction is the Early Postclassic period (900–1100 CE), but most modification and construction occurred somewhere around the Middle Postclassic period (1100–1350 CE). Both periods take place before the formation of the Purépecha Empire.

3) There is a similar variation of ceramic fragments among roads and this variation is lower than that seen in rooms.

4) Roads continued being used, re-used, and modified even after the conquest of the Empire.

5) Daily pedestrian traffic and topography (slope) of roads may have contributed to the damage of ceramic fragments, creating a distinctive type of rounded and smoothed edges.

My ceramic collection represents materials collected only within boundaries of roads and at crossroads, and excavated from architectural features associated to the construction or modification of roads. More ceramic analysis especially aimed at exploring patterns of technology and composition of non-diagnostic types is still needed at Angamuco, especially for the Middle Postclassic, an important period of landscape modification.

5.1.3 Radiocarbon determinations

A goal of this dissertation was to generate absolute dates for the roads. Roads are associated to periods of urbanization and settlement and understanding the dates of road construction would enable us to connect these with changes in the social, political, and cultural developments in the area, especially during the establishment of the Purépecha Empire.

Given that the site of Angamuco is located in a volcanic range with high magnetic disturbance optical-stimulated and thermoluminescence methods (OSL and TL) would not be suitable for these type of dating techniques (Wallinga and Cunningham, 2015). On the other hand, traditional radiocarbon dating has proven to be somewhat problematic in the site. The LORE-LPB project received mixed results from the analyses of radiocarbon samples from the excavations during 2013 and 2014. These samples showed that the best results came from testing human remains rather than charcoal fragments (see table 3.5 of Cohen 2016). During the 2013 LORE-LPB excavations, six samples were taken from essentially four distinct deposits: five from charcoal fragments and one from human remains (bone collagen determination) that were part of an *ofrenda*. Only the bone collagen and two of the charcoal samples provided dates that agree with other ceramic base determinations (i.e., prehispanic periods). Because of this, samples from human remains were prioritized in 2014 and more rigorous sampling techniques adopted.

Recently, however, studies in the area have been successful using archaeomagnetism to date architectural features and paleomagnetism to date sediments at El Prieto and El Palacio, both sites with similar topography to Angamuco (Mahgoub et al., 2018; Terán Guerrero, 2017). Unfortunately, these results were not available at the time I began fieldwork and thus were not considered for this research. I did not expect to encounter human remains associated with the roads, so I decided to test charcoal fragments for radiocarbon determinations despite the high possibilities of failure. To increase the chances for accurate results, I improved and standardized the sampling protocol and developed a system to rank all samples (see chapter four). A big challenge was to define the target event to which the radiocarbon samples could be associated. I ended up selecting charcoal fragments that were located within clear architectural structures and be easily associated to road construction (e.g., *banquetas* or walls).

A total of 70 charcoal samples were collected during the excavation, 17 were considered likely successful[22] determination, and nine were submitted for Accelerator Mass Spectrometry (AMS) at the University of Arizona AMS Laboratory. Instead of selecting samples from similar contexts, I selected the best candidate samples from each unit (Table 5.14).

#	ID SAMPLE	AREA	NODE / SEGMENT	WEIGHT (gr)	UNIT	CONTEXT
1	PA.O.FS0104.2	I	N1I002 / S1I013	3.4	U1I01	Sample taken from the floor (*apisonado*) adjacent to the wall. Directly associated to feature I-04.
2	PA.O.FS0061.1	I	S1I020	3.2	U1I02	Associated to earlier structure below the road. Sample collected directly under medium (~20cm) sized. rock part of the foundation of the structure.
3	PA.O.FS0081.7	A	N1A051 / S1A059	6.6	U1A01	Under a rock in north unit wall. Associated to east banqueta.
4	PA.O.FS0069.1	A	N1A011 / S1A013	5.8	U1A02	Near center of unit, directly beneath feature A-01.
5	PA.O.FS0092.3	A	S1A017	6.7	U1A02	Between rocks that form feature A-02.
6	PA.O.FS0115.1	I	N1A011 / S1A013	3.3	U1I03	Located near west retaining wall, near area where colonial sherds were located.
7	PA.O.FS0111.1	I	S1A017	7.8	U1I03	In stratum that has been described as fill beneath pavement of road. An earlier construction event for the causeway.
8	PA.O.FS2040.1	F	N2I006 / S2I005	4.5	U1F01	At the base of possible road construction.
9	PA.O.FS0059.3	A	N2I006 / S2I005	4.8	U1A01	Within pavement (possibly an earlier ramp).

Table 5.14. List of selected samples and their contexts for Radiocarbon (AMS) determination.

[22] I referred to "successful" to samples that provided prehispanic dates in-line with other age determinations from other radiocarbon analysis in the area of the site by LORE-LPB.

LORE-LPB radiocarbon determinations

The LORE-LPB project produced a total of 17 dates for the site (see Table 5.15). Those radiocarbon dates were collected from different contexts including architectural features, *ofrendas*, burials, and other deposits from areas A, B, C, E, and F (see map in Figure 4.8). These dates, informed by other ceramic and geoarchaeological data (Fisher and Leisz, 2013), suggest that the site was occupied at different times through a span of around 1,700 years between the Preclassic and Late Postclassic periods (~250–1530 CE). However, radiocarbon dates suggest that occupations were not continuous in all these areas (Figure 5.1).

In sum, area A seemed to be occupied continuously for over ~1,300 years (250–1530 CE). Area B was occupied at least during two periods: one between ~250–500 CE and another from 1250–1530 CE. In contrast, area C produced ten radiocarbon samples from human bones, and suggests a constant occupation from the Middle to Late Postclassic. Area D did not produce radiocarbon samples, but the area is adjacent to area C, and the deposits of ceramic, obsidian, and architecture suggest a similar habitation that extended into the Colonial period. Areas E, F, and G are located in the Upper zone of Angamuco and produced dates prior to the establishment of the Empire. Area E dates to ~1000 CE. Area F produced a very early date of ~500 BCE and we are still unsure if it truly represents a human occupation. Regardless, ceramic and architecture for area F and area G suggest a similar occupation as to area E (for more detail of AMS samples see Table 5.15).

AMS LAB ID#	AREA	UNIT	CONTEXT	MATERIAL	^{14}C YR BP	95.4% CONFIDENCE INTERVAL (CE)	CULTURAL PERIOD	
***AA105504	F	F6S3E0	Commoner plaza	charcoal	2,529	795-547 BCE	Preclassic	Prehispanic
*AA102895	B	BN12E8	Multi-purpose house, interior, capa 4	charcoal	1,739	145-402	Early Classic	Prehispanic
*AA102893	A	AN18E52-53	Elite plaza; bone ofrenda	bone-long bone	1,653	257-537	Early Classic	Prehispanic
*AA105512	C	CN12E4-6	*Yácata* plaza/cemetery, Burial 7	bone-right arm	789	1188-1280	Early Postclassic	Prehispanic
*AA105510	C	CN12E14	*Yácata* plaza/cemetery, Burial 1.1	bone-left arm	680	1268-1390	Middle Postclassic	Prehispanic
*AA105509	C	CN10E4	*Yácata* plaza/cemetery, Burial 6.1	bone-left radius	644	1281-1397	Middle Postclassic	Prehispanic
*AA105515	C	CN10E20-22	*Yácata* plaza/cemetery, Burial 16	bone-femur	580	1301-1417	Late Postclassic	Prehispanic
*AA105507	C	CN12E16	*Yácata* plaza/cemetery, Burial 2	bone-left fibula	574	1301-1423	Late Postclassic	Prehispanic
*AA105508	C	CN10E20	*Yácata* plaza/cemetery, Burial 17	bone-long bone	557	1307-1431	Late Postclassic	Prehispanic
*AA105506	C	CN14E14	*Yácata* plaza/cemetery, Burial 25	bone-metatarsal	555	1309-1432	Late Postclassic	Prehispanic
*AA105511	C	CN12W4	*Yácata* plaza/cemetery, Burial 4	bone	478	1405-1457	Late Postclassic	Prehispanic
*AA105514	C	CN12W4	*Yácata* plaza/cemetery, Burial 14	bone-long bone	459	1414-1464	Late Postclassic	Prehispanic
*AA105513	C	CN12E16	*Yácata* plaza/cemetery, Burial 9	bone	435	1416-1617	Late Postclassic	Prehispanic
*AA102894	A	AN2E28	Elite room	charcoal	399	1430-1635	Late Postclassic	Prehispanic
**AA102891	B	BN16E10	Public building	charcoal	235	1526-1935	Colonial/Modern	Non-Prehispanic
**AA102892	B	No unit listed here	Public building	charcoal	150	1667-1919	Colonial/Modern	Non-Prehispanic
**AA102896	B	BN18E10	Public building	charcoal	124	1675-1942	Colonial/Modern	Non-Prehispanic

Table 5.15. Radiocarbon (AMS) determinations for LORE-LPB listed in ascending chronological order from Angamuco. Modified from table 5.1 from Cohen, 2016. Analysis occurred at the University of Arizona AMS Laboratory; calibration used OxCal version 4.2, Intl 13 Calibration Curve (Reimer et al., 2013). * Successful determination ** Unsuccessful determination *** Questionable

PACUA radiocarbon determinations

Of the samples collected only one sample returned a Prehispanic date, two returned Early Colonial dates, and three Late Colonial dates, while the rest did not provide consistent results[23]. The complete list of calibrated AMS results (OxCal) from this project is presented in Table 5.16.

The most significant is sample AA108962 from unit U1I01 (Figure 5.90). This charcoal sample was taken from the base of a retention wall (see profile in Figure 5.83). Since this sample dates to the Early Postclassic period (991–1147 CE), I propose that a road was first created at that time, but also that architectural features surrounding and related to this road were indeed created and used at this time. Subsequent modifications of the landscape occurred in the following century, and by the Middle Postclassic, a massive transformation of the landscape that included creating the sunken plaza associated to this road/wall and the road on top of the early room in unit U1I02 took place. Thus, the sediment dated in this sample represents the remains of an earlier *banqueta*-wall that was covered by some of these later modifications.

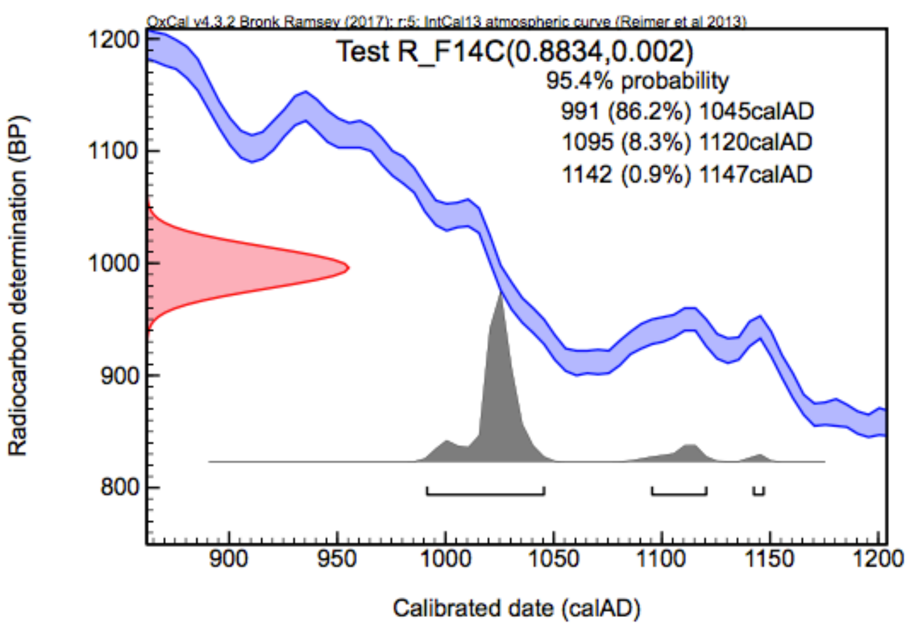

Figure 5.90: Calibrated radiocarbon determination results for sample AA108962.

[23] Either late dates or contaminated by members of the excavation. See table 5.16

AMS LAB ID #	AREA	UNIT	STRATUM	CONTEXT	^{14}C YR BP	Δ13C%	95.4% CONFIDENCE INTERVAL (CE)	CULTURAL PERIOD	
*AA108962	I	U1I01	V	*Wall on road*	996 ± 19	-24.7	991-1147	Early Postclassic	Prehispanic
***AA108965	A	U1A01	VI	*Early road*	365 ± 18	-24.3	1453-1630	Late Postclassic / Colonial	Prehispanic
***AA108964	A	U1A01	III	*Banqueta road*	300 ± 18	-24.3	1518-1649	Late Postclassic / Colonial	Prehispanic
***AA108967	I	U1I03	VI	*near retaining wall of large calzada*	116 ± 18	-23.8	1682-1930	Historic	Non-Prehispanic
***AA108966	A	U1A02	VII	*Wall on segment*	148 ± 18	-24.2	1668-1945	Historic	Non-Prehispanic
***AA108968	I	U1I03	III	*fill beneath paved road*	132 ± 18	-24.5	1679-1940	Historic	Non-Prehispanic
**AA108969	F	U1F01	II	*base of possible road construction*	179 ± 18	-25	1665-present	Modern	Non-Prehispanic
**AA108970	A	U1A01	II	*pavement–early ramp*	183 ± 18	-24.5	1665-present	Modern	Non-Prehispanic
**AA108963	I	U1I02	II	*early structure under road*	163 ± 18	-24.6	1666-present	Modern	Non-Prehispanic

Table 5.16: Radiocarbon (AMS) determinations for PACUA listed in ascending chronological order from Angamuco. All samples were charcoal fragments. Analysis occurred at the University of Arizona AMS Laboratory; calibration used OxCal version 4.2, Intl 13 Calibration Curve (Reimer et al., 2013). * Successful determination ** Unsuccessful determination *** Questionable

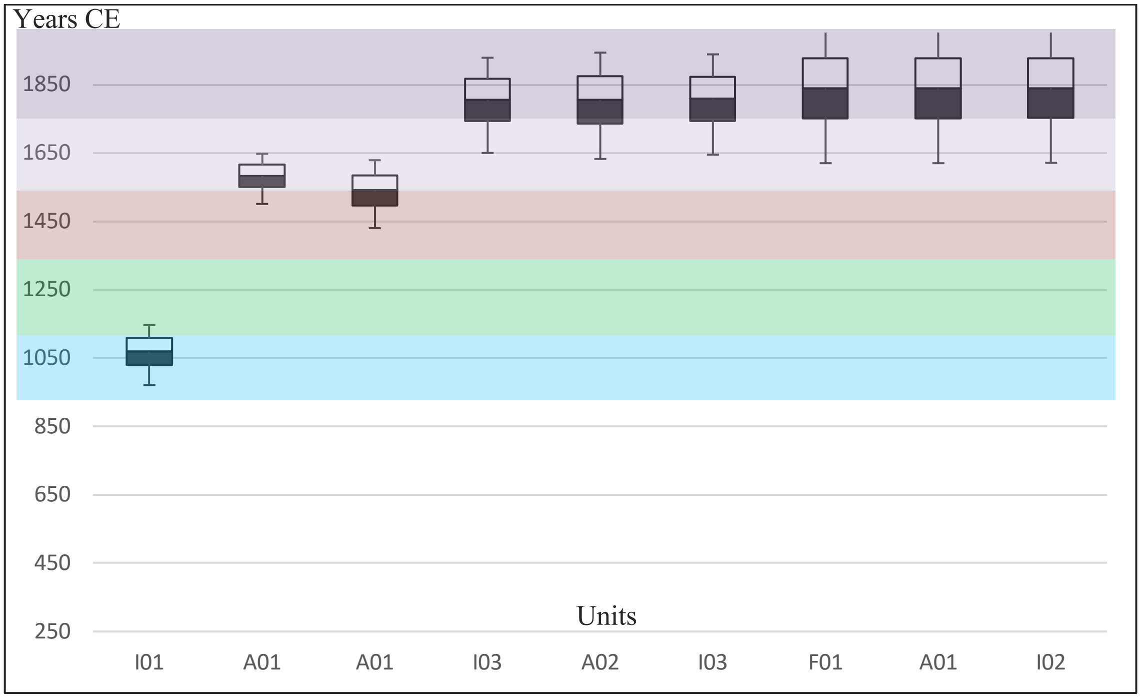

Figure 5.91: Box-plot for radiocarbon (AMS) calibrated determinations for PACUA showing their error ranges. Colors bands represent the different periods: dark purple = Late Colonial/Historic; light purple = Early Colonial; red = Late Postclassic; green = Middle Postclassic; blue = Early Postclassic.

Together with previous results for the site from LORE-LPB project (Table 5.17), the chronology of Angamuco supports the idea that most areas close to lower Angamuco (near or below the escarpment on the south hemisphere of the site) were continuously inhabited at least since approximately 250 CE. But three important observations can be drawn from my dissertation AMS dates:

1) The one prehispanic date from unit U1I01 (991–1147 CE) that dates to the Early Postclassic reinforces the ceramic and stratigraphic conclusions that large landscape modification (a subsequent retention wall built on top of this context) occurred after the Early Postclassic period, most likely during the Middle Postclassic period, right before the foundation of the Purépecha Empire.

2) There was an active engagement with the landscape throughout the Early Colonial period. One interpretation is, if the date for the "early road" in unit U1A01 is correct (1453–1630 CE), then the above (later) ramp feature would have been modified or built during the last decades of the Late Postclassic, right before the Spanish conquest, or immediately after. This might be supported by the second AMS date in that unit from stratum III (1518–1649 CE), in that the fill used to cover the "early road" was ~50 years older. However, that is not what was observed through ceramic analysis. A second interpretation is that those same charcoal samples from the 15th and 16th centuries (U1A01) might actually have been introduced from upper strata into the archaeological features through bioturbation but were generated during those periods.

Historically, radiocarbon dating through charcoal samples has been problematic for Angamuco (Fisher et al., 2016; 2019b), but similar contamination, and low confident levels have been observed in comparable malpaís landforms in the region (e.g., Mahgoub et al., 2018). It is possible that wildfires can affect charcoal displacement (e.g., modern charcoal downwards into archaeological contexts) especially for shallow deposits like those at Angamuco (e.g., Johnson, 2004), although no geoarchaeological analysis for wildfires has been conducted for this site. Another alternative would be human induced and controlled fires like those for charcoal production during early 20th century.

During the summer of 2011 while performing fieldwork for the LORE-LPB, I conducted a pilot ethnographic research study[24] in the local community of Fontezuelas, home of most *ejidatarios* and owners of the land where Angamuco is located. Three different older men recounted a similar version of a period of 20–30 years of intense production of charcoal at the site sometime close to the Mexican revolution war (1910–1930s). This industry was performed by many families without a formal structure or organization. Part of this process included

[24] This research has not yet been published.

creating stone ovens (~1.5 m diameter) directly on the ground and using local wood as fuel to produce charcoal. This activity did not continue for more than a couple of decades, but according to the interviewees[25], several carts (tons) of charcoal were produced daily. If these testimonies are true, it would explain the ubiquitous presence of charcoal fragments dated to historic time in the units[26].

In any case, dates during the transition period between the late Postclassic and early Colonial period like samples (AA108964 and AA108965) suggest that the abandonment of Angamuco was not sudden and immediately after the Spanish conquest, but within the first three quarters of the 16th century.

3) Similarly, the pervasive presence of historic AMS dates (including those considered modern determinations) suggests human activity and use of this landscape in recent times (the last three centuries), or at least for a period around the 19th century.

Several lines of evidence point out that Angamuco was likely abandoned at the end of the Prehispanic period (Cohen, 2016; Fisher et al., 2016, 2019b). It is generally accepted that the Spanish conquest of the Purépecha Empire (and diseases) initiated around 1530 CE and rapidly decimated and contributed to the abandonment of many second-tier cities like Angamuco (Arnauld and Faugére-Kalfon, 1998; Beekman, 2009; Pollard, 1993; Warren, 1985). Historic documents and Ethnohistoric sources do not describe a settlement with the characteristics and location of Angamuco during the 16th, 17th and 18th centuries (Espejel, 1992; Fisher et al., 2010; Urquhart, 2015), and the survey and excavation seasons by LORE-LPB have not produced archaeological evidence of significant occupation after ~1530 CE (for example: no historic constructions, no massive extraction of architecture materials like rocks for nearby constructions,

[25] Don Francisco Juárez, Don Manuel Juárez, and Don Gustavo from Fontezuelas, Michoacán (May-June 2011).
[26] More work is necessary on this topic to clarify post-colonial use of land, and/or possible charcoal displacement.

no flattening of land or massive deforestation for European-style agriculture, and no substantial colonial ceramic materials found on surface).

The earliest historic and ethnographic accounts for use of the land at Angamuco, at least partially, were until early 1800s that Hacienda Los Corrales was founded in the western side of the site, in the outskirts of the malpaís (Boyer, 2003; Cohen and Solinis-Casparius, 2017; Lagunillas, 2007). This was a moderately active Hacienda with a population of around 700 people (Lagunillas 2007; INEGI, 2007) that collapsed around 1860s and transformed into a small town of less than 300 people until today. Similarly, the community of Fontezuelas was founded in 1931 and acquired the land where Angamuco is located as communal *Ejido* land during the Mexican revolution period (1920-1940). Fontezuelas' residents might be the only significant users of Angamuco land since the 20th century, although for low impact activities[27], like cattle grazing, harvest of wild plant species, hunting, and opportunistic logging (Lagunillas, 2007; Juarez, F. personal communication, June 30, 2011[28]).

In sum, there is no archaeological, historic, or ethnographic evidence of human settlement in the site of Angamuco after the 16th century. However, these radiocarbon determinations might suggest that in fact, some degree of landscape interaction occurred between 1800 and mid 1950s. The intensity of landscape transformation does not appear to have impacted the prehispanic architecture layout, or general archaeological contexts, but at least, it is possible that wildfires or human induced fires might have affected subterranean charcoal deposits. Lastly, it is possible that the sampling protocol was not followed correctly by excavators or was insufficiently strict, and thus, several samples were contaminated during extraction (e.g., AA108969, AA108970 and AA108963).

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[27] Excluding the charcoal production during 1930s.
[28] Part of informal interview with Don Fernando Juarez (93 years old), I conducted during 2011 LORE-LPB field season.

AREA	OCCUPATION	CULTURAL PERIOD	DATES	SUPPORTING DATA
LORE-LPB				
A	Continuous	Early Classic to Late Postclassic	~250 to ~1530 CE	Architecture, ceramic, metal, AMS
B	Intermittent Phase 1	Preclassic to Classic (Pre-empire)	~145 to ~500 CE	Ceramic, AMS
B	Intermittent Phase 2	Early Postclassic to Late Postclassic	~1250 to ~1530 CE	Architecture, ceramic
C	Continuous	Middle to Late Postclassic	~1150 to ~1530 CE	Architecture, ceramic, obsidian, metal, AMS
D	Continuous	Middle to Colonial	~1150 to ~1600 CE	Architecture, ceramic, obsidian
E	Continuous	Epiclassic to Early Postclassic (Pre-Empire)	~650 to ~1250 CE	Architecture, ceramic, metal, AMS
F	Continuous	Epiclassic to Early Postclassic (Pre-Empire)	~650 to ~1250 CE	Architecture, ceramic
G	Continuous	Epiclassic to Early Postclassic (Pre-Empire)	~650 to ~1250 CE	Architecture, ceramic
PACUA				
A	Continuous	Early to Late Postclassic	~900 to ~1530 CE	Ceramic, stratigraphy, AMS
F	Continuous	Early to Late Postclassic	~900 to ~1530 CE	Ceramic, stratigraphy
H	Continuous	Early to Late Postclassic	~900 to ~1530 CE	Ceramic, stratigraphy
I	Continuous	Early to Late Postclassic	~900 to ~1530 CE	Ceramic, stratigraphy

Table 5.17 Chronology by area and supporting data. The LORE-LPB section is modified from Cohen, 2016 data.

In general terms, charcoal continues to be a challenging material to produce absolute dating in Angamuco. The high cost of this analysis and proclivity for contamination during sampling ultimately limited the number of samples tested in this research. Only three samples produced positive results within the range of Prehispanic times. These three samples add valuable information to the LORE-LPB hypothesis that massive transformation of the landscape —and therefore inhabitation— occurred during the Early to Late Postclassic. These results additionally support the idea that the site was occupied until at least 1600 CE, extending the Postclassic a few decades, when Colonial/European ceramic technologies were incorporated and when the built environment was altered.

CHAPTER SIX: Computer Analyses methods

Characterizing the road network

Computational approaches, GIS, and modeling are some of the innovative methodologies that aid in the study of how people move within cities in both contemporary settings and ancient urban settlements (Brughmans, 2013; Groenhuijzen & Verhagen, 2016; Jenkins, 2001; Kaiser, 2011; Wernke, 2012).

In general, certain structural characteristics of the road network are directly related to social and economic systems of a city. For example, a more integrated network (i.e., a network where most roads are connected to each other) improves assimilation among all residents. For my dissertation, I used *Urban Network Analysis* (UNA) (Sevtsuk, 2018a) to study different qualities of Angamuco's road network. Each of these are covered in separate sections where an explanation of the measures and tests used, as well as summary of the most relevant results is provided. I start with a small discussion on some general considerations surrounding UNA, and about the data as they are used for this research.

The work presented in this chapter was performed at the DigAR laboratory at UW, between winter of 2017 and fall of 2018.

6.1. Urban Network Analysis

The use of networks as a form of data representation has been rapidly adopted in the last few decades by a number of scientific disciplines to study a wide range of systems that range from biological, technological neural, to socio-relational, economic, etc. (Knappett, 2013). To some extent, the attractiveness of using network approaches is because of how well and how powerfully they work with mathematical tools and methods (Crucitti et al., 2006; Wasserman & Faust, 1994).

Spatial networks in particular have been investigated and used to understand humans and their physical world in disciplines like sociology, geography, and archaeology. Certain spatial phenomena, such as path networks, lend themselves easily to be represented by spatial networks (Zhong et al., 2014). Moreover, urban spatial networks like that of urban roads, have unique properties that help understand social phenomena motivated by patterns of mobility (Joh et al., 2009). These characteristics may be of different types: geometric (how this network is configured), and functional (how this network works) and are very useful in learning how people move. For example, the shape and function of an urban road network influences people‘s choices on how and where to move, favoring certain patterns of mobility, and thus affecting with whom and how individuals interact with others (Sevtsuk, 2018a).

Representing street networks with graphs for investigating flow, incidence, routing, geometry, network structure, design, and transportation originated in the 1960s with the development of graph theory (Haggett & Chorley, 1967; Herbert & Murphy, 1970). The representation of road network in the form of a mathematical graph has provided researchers the ability to understand various characteristics of entire path networks by reference to various concepts such as *centrality*. Centrality aims to explore the most *important* nodes in a network (Borgatti, 2005; Sabidussi, 1966). How important is a node however, may be understood in many different ways such as topological or geometric, hence, several mathematical indices have been developed to measure different aspects of a network's centrality, (e. g., closeness, cohesiveness, reach, etc.) known as *centrality indices*.

With the rise of computational capabilities and GIS since the late 1980s, urban networks are now made out of large datasets with more sophisticated models of connectivity and distribution. This advance allows us to explore scale and mobility in much more sophisticated ways (e.g., geometric graphs, Waxman, spatial growth, optimal models, etc.) (Barthélemy, 2011). But is perhaps the development of analytical and methodological approaches like Space Syntax (Hillier and Hanson, 1986) that together with Network Analysis through GIS has propelled the study of urban networks in the recent decades (e.g. Taliaferro et al. 2010; Richards-Rissetto and Landau 2013; Polla and Verhagen 2014). These developments have resulted in digital tools of easy application for scientists and urbanism professionals with less command of mathematical models and graph theory (e.g., Isaksen 2008; Schintler et al. 2007; Boeing 2017; Gil et al. 2015; Sevtsuk 2013).

In this dissertation, I have adopted some of them, particularly parts of the Network Analyst toolkit in ArcGIS, Space Syntax toolkit for QGIS, DepthmapX, and most importantly, the Urban Network Analysis (UNA) toolkit for Rhino 3D and ArcGIS developed by the City Form Lab at Harvard University (Table 6.1).

SOFTWARE	AUTHOR/YEAR	TYPE	REQUIREMENTS / PLATFORM	METHODS AND TOOLS USED IN THIS RESEARCH
Network Analyst extension	ESRI	Licensed	ArcGIS 10+ / Windows	Topology
UNA, Urban Network Analysis Toolkit	City Form Lab: Andreas Sevtsuk et al. (2012)	Opensource	For ArcGIS 10+ & Rhino 6 / Windows	Betweenness, *Reach*, Closeness, *Gravity*, Straightness, Cluster Analysis
DepthmapX Ver. 0.35	Alasdair Turner and Tasos Varoudis (2011)	Opensource	Standalone software / Windows or Mac	Integration, Accessibility
Space Syntax Toolkit	Jorge Gil (2015)	Opensource	QGIS 2.18 / Windows or Mac	Topology, Integration, Accessibility
AxWoman 6.0	Bin Jiang (2012)	Opensource	ArcGIS 10+ extension / Windows	
ComplexNetGIS	Simone Caschili (2010)	Opensource	ArcGIS 10+ extension / Windows	Degree and cluster analysis

Table 6.1. Common tools and software available for Spatial Network Analysis.

I used a combination of selected tools to explore four main qualities of Angamuco's urban road network:

1) Integration: How well integrated or cohesive is Angamuco's Network;

2) Accessibility: How easy to reach are different locations and parts of the site through the network;

3) Traffic-Flow: What roads where most likely used by pedestrians;

4) Evidence of planning of roads;

A description of the exact methods, approaches, and parameters for each of these are discussed below together with the results of each analysis. First, I point out the limitations of the network and the considerations for applying UNA on Angamuco.

6.1.1 Assumptions and considerations of the road network

Angamuco's road network has to be studied with caution. Even after the successful identification of roads both in the field and digitally, there are several assumptions I needed to establish in order to continue this research. Each of them is a complicated archaeological problem that would require many more resources (time and personnel) and extensive work. I decided to make the following assumptions about the Angamuco network.

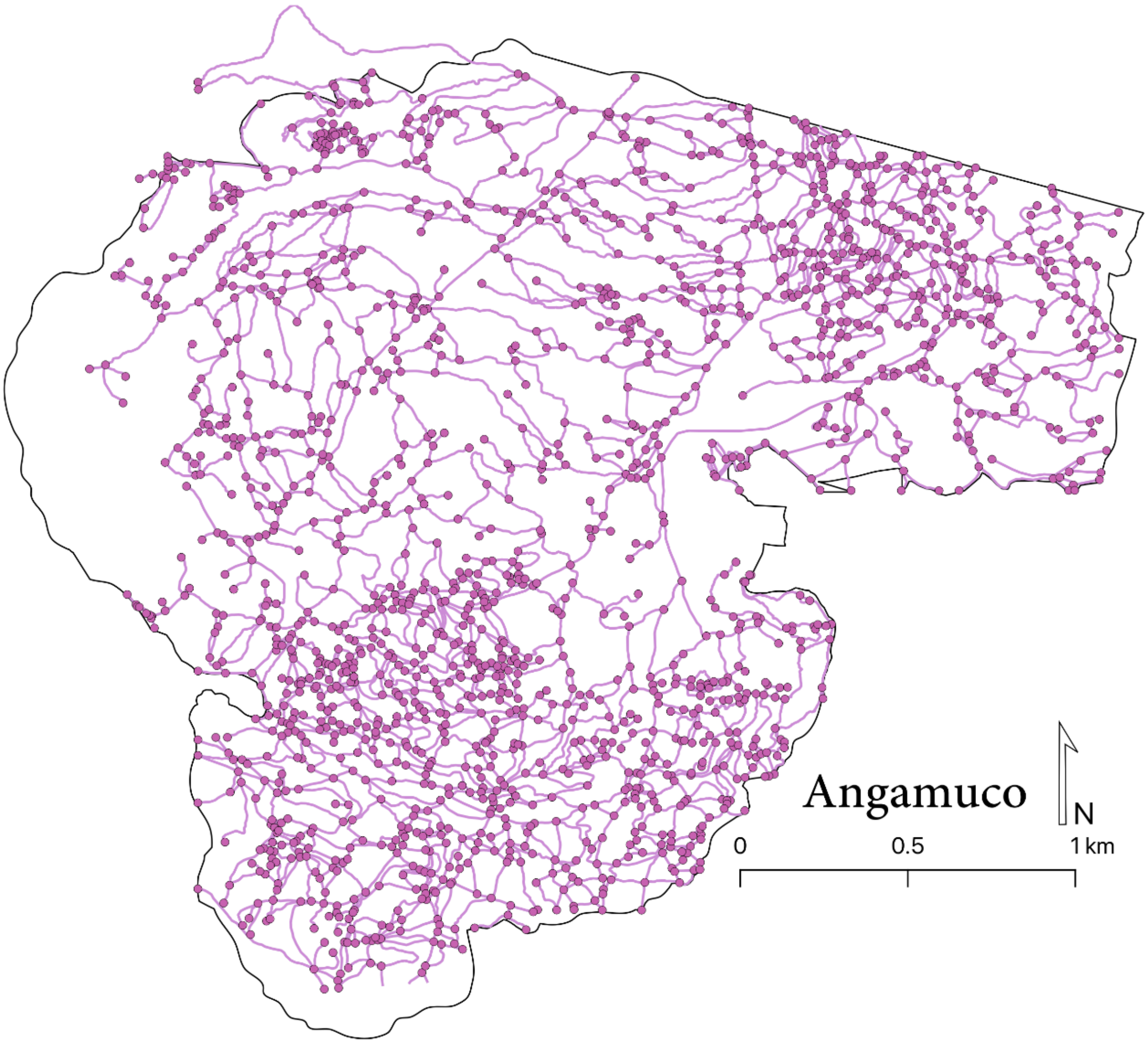


Figure 6.1. A general image of the complete road network. Purple dots represent nodes and lines represent road segments.

Assumption I: All roads were used by humans.

There are two other features in the landscape that resemble roads but are not created and used by humans:

a) Natural pluvial drainage or water catcher corridors. A big challenge of this research project was to differentiate roads from natural topographic or water drainage features. Some of these features may have been used by inhabitants as roads. I argue that people took advantage of the topography to build their city. Thus, some natural features that already have advantageous shapes, like pluvial drainage that might facilitate movement, were indeed used or modified to function as roads. However, these features are difficult to differentiate from simple roads. Based on my fieldwork observations, I used the following criteria to distinguish drainage-related linear features:

1) Extremely narrow, about 30 cm wide;

2) Do not show evidence of architecture;

3) Concave, or are round in their internal edges;

4) Always found on a slope;

5) Continuous. They do not have abrupt changes in direction or have intersections (they are long sinuous single segments).

During the digital extraction of roads, only points 4, and 5 can be identified and were adapted to create the topological, visual, and spatial criteria for road interpretation (Table 4.8). Naturally, some larger drainage features co-existed with the network. They are very similar to small roads or might have been used seasonally/opportunistically as roads (during no-rain season). For this reason, during the digital extraction of roads, only the drainage-like features located in the escarpment or other abrupt elevation features were discriminated as natural pluvial corridors.

b) Cattle trails: Cattle has been roaming free in the site at least since 1920s. Without predators or human guidance, cows and bulls are left on the site for weeks at a time, to feed by themselves on wild weed and grass. As they move around, they create their own routes and trails that are distinct from human Prehispanic human roads. In the field, these can be easily distinguished from human-made trails. Based on my fieldwork experience, I used the following criteria to identify animal-made linear features:

1) Continuous. They do not have abrupt changes in direction or have intersections (they are long sinuous single segments).
2) Extremely narrow, about 30 cm wide with no changes in width per segment.
3) Not guided by architecture. They go through structures as opposed to around features (a clear evidence of been created after prehispanic architecture had collapsed and covered by sediment/vegetation).

For cattle trails, only points 1 and 3 can be identified during the digital extraction, and were used for the criteria in Table 4.8

Assumption II: The network is contemporaneous

A very big challenge for this analysis was dealing with the palimpsest nature of roads as a result of their use, re-use, modification, and abandonment. Enough evidence has been provided in the years of work in this site and immediate landscape since 2005 to suggest that there is likely a long occupation and use of the landscape for over 1500 years (Fisher 2005, 2012, 2013; Fisher et al. 2011, 2017, 2019a; Cohen 2016; Urquhart 2015). It is also suggested that not all areas of the site were inhabited at the same time for this entire time span. Despite this realization, I argue here that the entire network was used at least at one particular period[1] (Middle Postclassic).

In light of these two assumptions, several other parameters were also established for the network analysis and discussed below: 1) the cost of moving through Angamuco; 2) the use of network distance; 3) the existence of a hierarchy of locations (nodes and architecture); and 4) the choice of particular origins and destinations.

[1] See chapter seven

6.1.1.1 Pedestrian walking time

Many spatial analyses (e.g., gravity, reach, patronage) require an important parameter that is also significant to understand how people moved within the city: pedestrian walking time and/or cost of moving (Handy & Niemeier, 1997).

I relied on work done by Fino & Lockhart (2014), and Fitzpatrick et. al. (2006) that have calculated walking speeds and cost in several modern settings comparable to Angamuco and came up with a list of likely speed and walking distances for the site.

I used Fino & Lockhart's (2014) reported speed for "old" pedestrian to compensate for the very rugged terrain of the site. Thus, the average pedestrian speed using the road network at Angamuco is of 1.18 m/s (Table 6.2).

DISTANCE IN METERS	TIME WALKING	AVERAGE SPEED
100	2.5 min	
250	5 min	
500	8 min	1.18 m/s
1000	14 min	
2000	28.5 min	

Table 6.2. Table of pedestrian time-distance for Angamuco based on Fino & Lockhart, 2014.

6.1.1.2 (Network) distance

For measures like *accessibility*, *integration*, or *reach*, it is important to set up different parameters like the extension of travel, or search radius. There are two ways to create this distance. The most traditional and commonly used in spatial analysis is the Euclidean distance, also known as as-the-crow-flies, which essentially refers to the shortest distance between two points (Borgatti, 2005). This is useful for some analysis but necessarily ignores the actual layout of the network, the architecture, or topography. So, it is not the best approach to understand movement in Angamuco.

Conversely, a second approach is to measure distance along the network. That means that pedestrians can only use road segments and necessarily pass by nodes to get to places, and in turn, the distance radius gets distorted, but it is much more coherent with the actual experience of walking (Figure 6.2).

During this work I only used network distance. Thus, all distance parameters refer to meters walked along the roads.

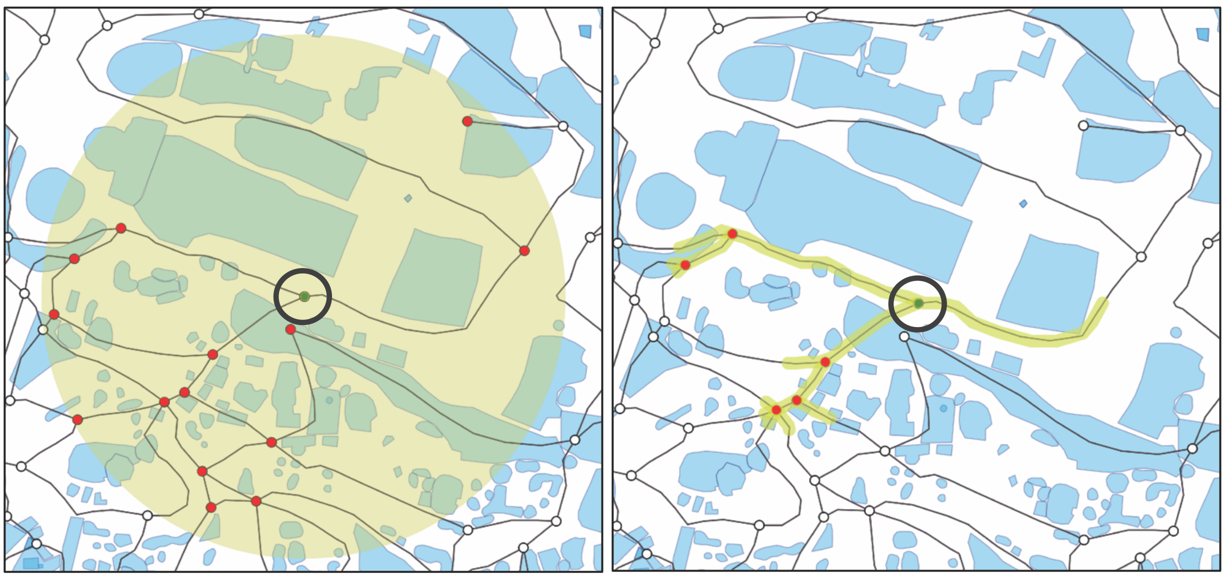


Figure 6.2. Two examples of approaching distance from the same origin (black circle). Left: example of as-the-crow-flies' distance of 100m radius that reaches a total of 15 nodes. Right: example of network distance of 100m that reaches 6 nodes.

6.1.1.3 Ranking of locations

The other parameters that are usually incorporated in UNA are weighted locations that influence how routes are created, the number of pedestrians in a route, or the effect of a node over their neighboring locations. Some analyses (e.g., *reach*, *gravity*) require that locations are not weighted so that their spatial and topological characteristics help identify how much influence they actually have in the network. When appropriate, other attributes of the locations (e.g., ritual vs habitational, number of residents per buildings, etc.) can in fact be seen as directly affecting how people used the network and what locations allowed more chances for interaction.

Here I describe how I ranked two types of locations: architecture and nodes. Ultimately, ranking was associated to each feature (node or architecture) in the geodatabase so that it could be integrated in GIS and network analyses. Ranked architecture is based on data from LORE-LPB. However, this set of architectural features only represents an area of ~37 % of the site. During pedestrian survey of 2009 to 2011, the LORE-LPB digitally created over 4,300 features corresponding to the LORE-LPB architecture typology (Cohen 2016; Fisher et al. 2012; Fisher et al. 2011). I used a modified dataset of the architecture (see Table 4.12) and ultimately, based the ranking on how "public" or "private" buildings were according to their suggested function and use (see Table 6.3).

RANKING OF PUBLIC BUILDINGS

RANK	TYPE OF BUILDING	RATIONALE
1	Entrance to site	Used by everyone regardless of social/religion/ethnicity
2	Plaza	Possibly associated to Religious and Social affiliation, but with more access points and larger areas
3	Sunken Plaza	Similar to Plazas but with more restricted access
4	Pyramid	Similar to Sunken Plazas but with more restricted access
5	Terrace	Probably shared by some but not to all public

RANKING OF PRIVATE BUILDINGS

RANK	TYPE OF BUILDING	RATIONALE
1	Cuartos	The most intimate type of building. Nuclear or immediate family only. Privately owned and built
2	Montículos	Shared in community for either semi-private buildings but only for people within the same *complejo*, ethnicity, or other affiliation
3	Patios	Probably associated to adjacent Cuarto, thus familiar, however some patios might have been shared by several households (cuartos).

Table 6.3. Ranking of public and private architectural features in Angamuco.

Ranking of the nodes was done by making reference to two different datasets: one that refers to all digitally extracted nodes in the site (DIGAR dataset) and other that corresponds to a subsample of nodes collected during fieldwork (PACUA dataset). Ranking in this case corresponds to the level of interaction expected to have occurred at each of these spaces based on how many segments they connect, and their size (see Table 6.4).

RANKING OF NODES (BOTH DATASETS) ACCORDING TO THEIR CONNECTIVITY

RANK	TYPE OF NODE	RATIONALE
1	5 or more Segment	More than 5 segments are connected through this node
2	4-Segment	4 segments are connected through this node
3	3-Segment	3 segments are connected through this node
4	2-Segment	2 segments are connected through this node. Usually is an abrupt change of direction. Also, a sharp turn
5	1-Segment	Dead-end. Usually also a patio or plaza.

RANKING OF NODES (PACUA DATASET) ACCORDING TO THEIR SIZE

RANK	CLASS	RATIONALE
1	Large	More than 3 square meters
2	Medium	Between 1 and 3 square meters
3	Small	Less than 1 square meter

Table 6.4. Ranking of nodes in Angamuco.

6.1.1.4 Origins and destinations

Along with architectural features, three other point locations were used frequently as origins and/or destinations in these analyses: *Entrances* to the site, *centroids* of site division areas, and *nodes*.

Entrances to the site

Following the chronology proposed for the site (see chapters three and five), there are two distinctive topographic and cultural zones in Angamuco (Lower and Upper Angamuco). Details on the relationship and settlement between these two zones is presented in detail in chapter seven. However, it is important to highlight that the two zones are clearly divided by a natural escarpment of ~45 m at its highest point and that surrounds a great extension of the site. I identified points of formal access and road segments crossing between these two zones. I called these locations *Site Entrances*, as they represent funnel points of traffic where lower and upper road networks meet.

A total of 14 of these entrances were identified, labeled, and used for UNA. These entrances are not weighted, their number does not correspond to any ranking system, and are all registered as point features (x, y, z coordinates) (Figure 6.3).

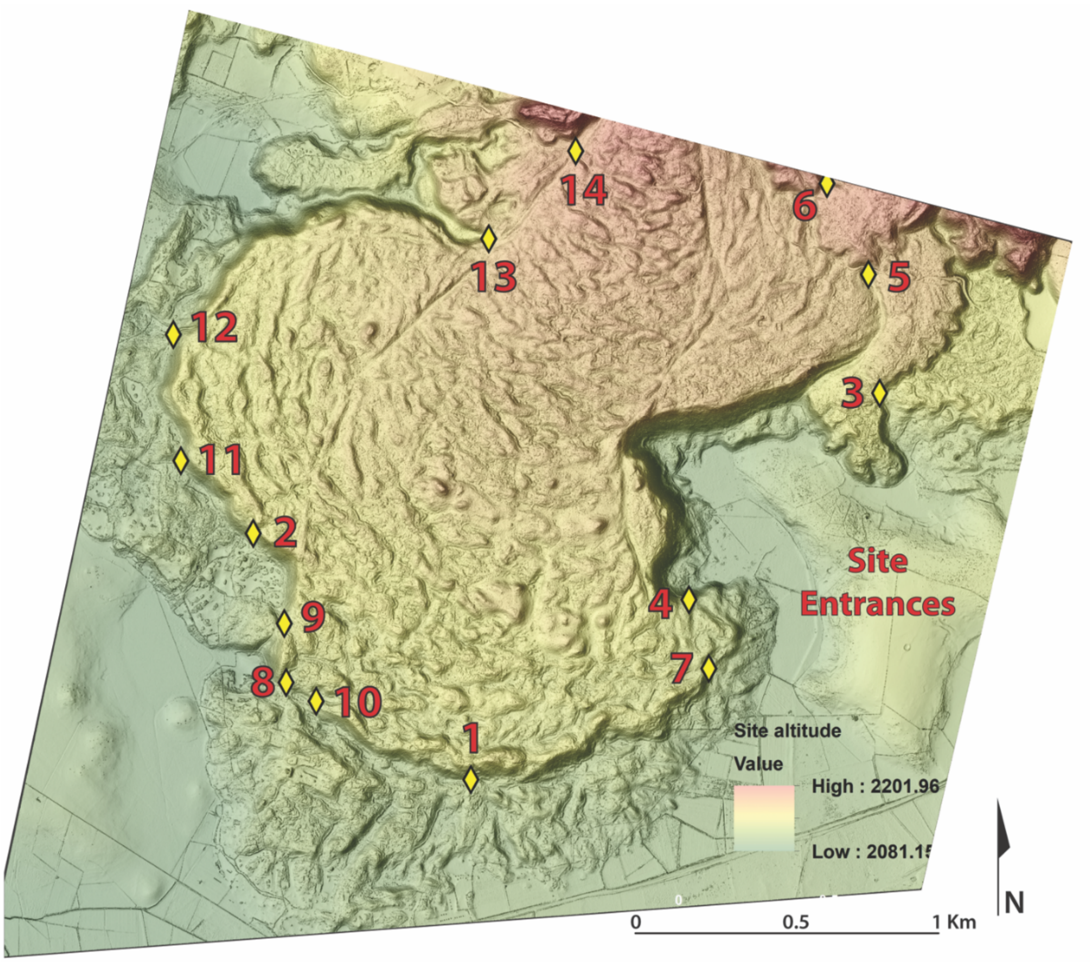


Figure 6.3. Location of site entrances (yellow diamonds).

Centroids of site division areas

It has been suggested that Angamuco was organized by groups of housing features that shared some resources (like water catchment tanks, plazas for markets or religious activities, etc.) in a space delimited by topography or roads (Bush, 2012; Fisher et al., 2017; Urquhart, 2015). These groups might have existed in several scales of social organization going from the smallest (mean ~4,500 m^2) named *complejos*, to neighborhoods (mean ~70,000 m^2), and to districts (mean ~ 35,000 m^2).

In chapter seven I offer a detailed discussion of the social organization of Angamuco and suggest a different approach to these site division units. However, first, in order to explore several characteristics of the network I used a modified version of these polygons (areas) originally created by Christopher Fisher and the LORE-LPB project. Most of the analyses require points as opposed to areas. So, I created centroids for each area unit (Table 6.5 and Figure 6.4). These centroids were then directly connected to the network by means of a perpendicular line to the closest road in the network

	COMPLEJOS	NEIGHBORHOODS	DISTRICTS
Total	685	69	15
Example name	0, 1, 2, 3	23, 24, 25	A, B, C
Smallest (m^2)	441	3,741	26,116
Largest (km^2)	0.03	0.32	5.27

Table 6.5. List of site division units.

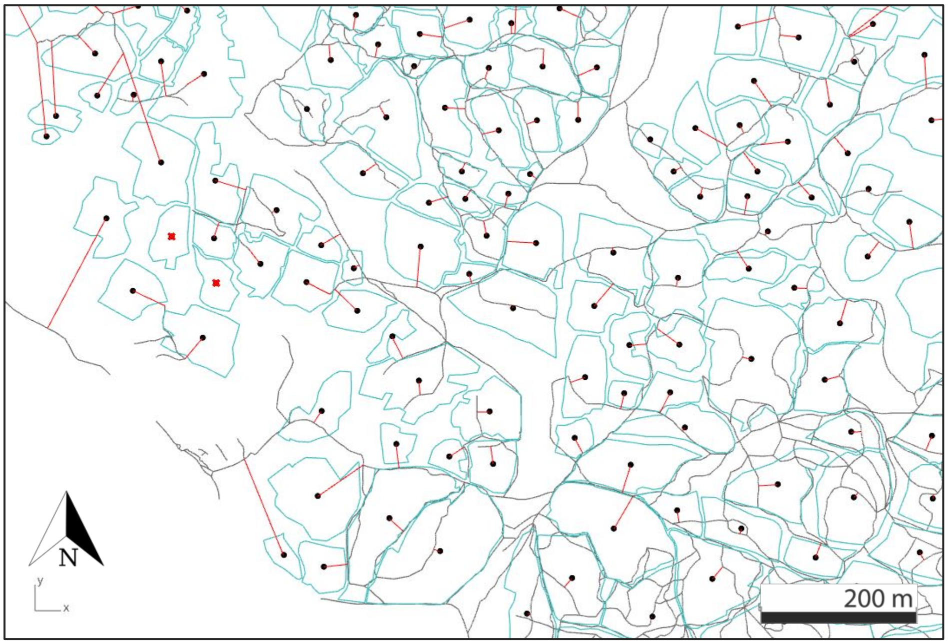
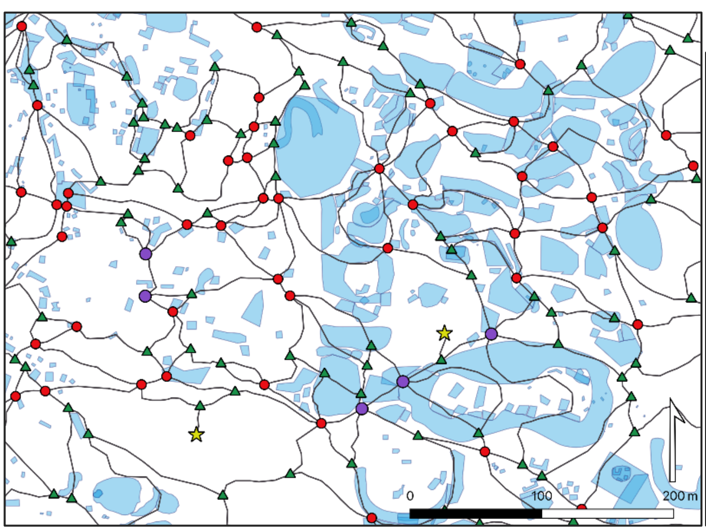


Figure 6.4. Example of *complejos'* polyline (blue) and their centroids (black circles). Red lines are the most direct connection to a road in the network (black lines)

Nodes

Finally, the road intersections were also used as origin and destination points for several analyses. Each of the nodes has unique attributes (some collected through field survey), unique identifiers, and are all represented as point features (Figure 6.5).



	ID_Code	INITIALS	COMPUTER	DATE	QUAD	TILE	CLASS
1	N4X001	ATE	4	2017-10-11	J17	99	1
2	N4X002	ATE	4	2018-01-14	J17	99	3
3	N5X007	JEJ	5	2017-10-27	J18	113	2
4	N5X006	JEJ	5	2017-10-27	J18	113	2
5	N4X003	ATE	4	2018-01-14	J18	100	1
6	N4X006	ATE	4	2018-01-14	J18	100	1
7	N8X009	ARR	8	2017-10-27	I18	61	3
8	N5X009	JEJ	5	2017-10-27	J18	113	1
9	N8X010	ARR	8	2017-10-27	I18	61	3
10	N8X011	ARR	8	2017-10-27	I18	61	3
11	N8X014	ARR	8	2017-10-27	I18	61	3
12	N5X098	JEJ	5	2017-11-19	K18	126	1
13	N5X091	JEJ	5	2017-11-19	K18	126	1

Figure 6.5. Example of node point feature symbolized according to their class (number of connecting segments), and attribute table. Blue polygons are architectural features.

Keeping these two important assumptions of the network, and the general considerations (parameters) are fundamental for the UNA. Next, I describe several analyses, their goals and main observations.

6.1.2. Integration of Angamuco's road network

Before any detailed investigation, general observations from field and lidar survey hinted a cohesive road network, but it was still unclear if all areas of the site could be considered part of the same unique and global network. Two inquiries were set for exploring the level of *integration* of Angamuco's network. On the one hand, on a global scale of the network, I wanted to find out if sections of the network showed different morphological shapes/patterns, or if the entire network had a more uniform shape as a whole. On the other hand, I aimed at exploring if social units (complejos, neighborhoods, or districts) as they have been suggested by LORE-LPB could be distinguishable by looking at how are their road networks are configured internally. I used *integrity* analysis for the former inquiry; and *closeness* and *cluster* analyses for the latter.

6.1.2.1 Exploring Integration

Integration refers to the number of steps (or change in direction) that it takes to get from one location to any other in the network (Tencer, 2012): The lower the total count of these steps, the more integrated the network. The number of steps (turns, decisions, changes of direction, etc.) can be correlated to levels of movement —at the very least, how fluid is the movement of pedestrians— and thus create a model of movement (Turner, 2005).

A more integrated network would mean that less time is spent on deciding how to get to places, or at the route-changing locations (in this case nodes). In other words, a well-integrated network is also an efficient network, and may suggest some level of planning and design. The global level of integration of the network was calculated using DepthmapX by computing the extent to which any segment is connected to every other segment in the network[2] (Figure 6.6). At this global, segments/nodes have an average level of integration of 0.854496 which means that ~85% of the segments are integrated to the network and only fewer than 15% are segregated or not connected (Figure 6.7).

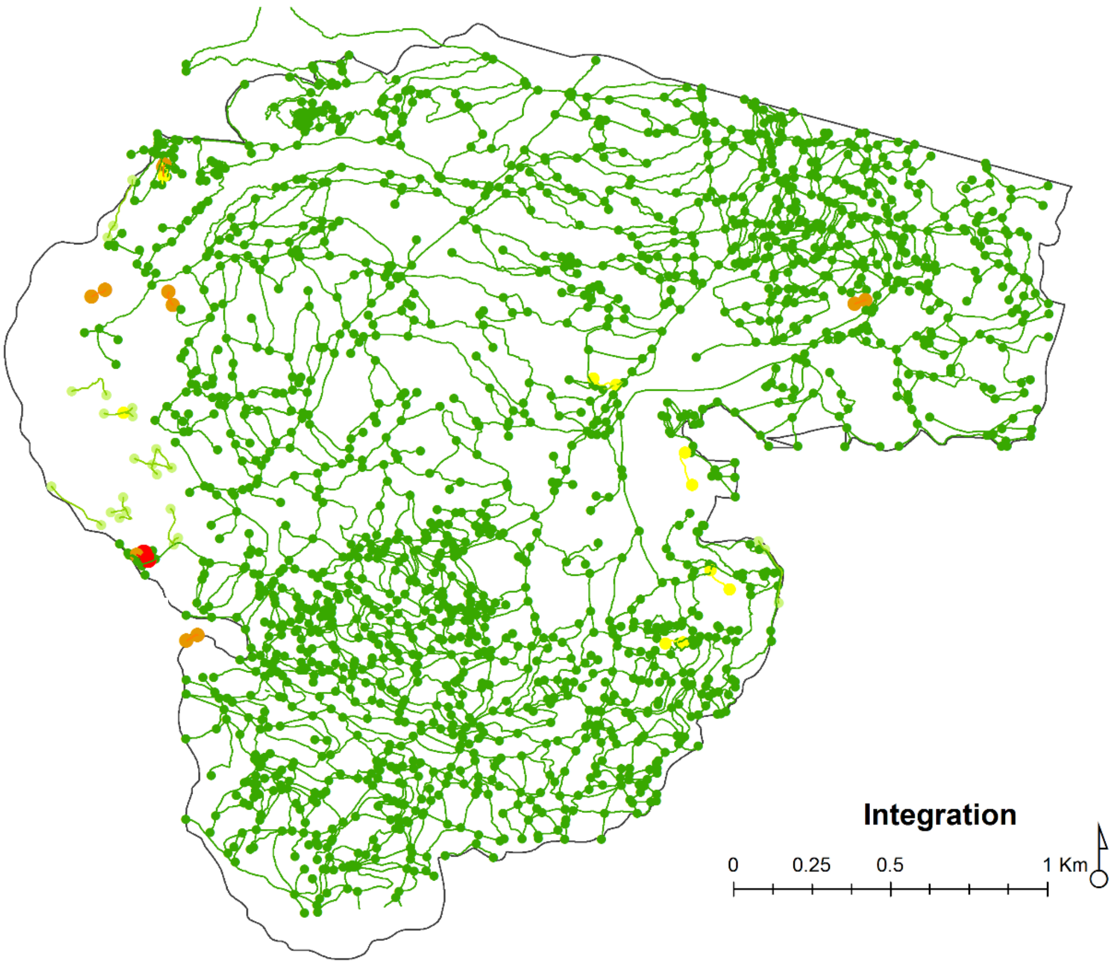


Figure 6.6. Integration analysis of Angamuco's network. Dark green segments/nodes are fully integrated to the network.

[2] There are several ways to calculate integration, for example, by doing a closeness analysis using turn as impedance, or the sum of average distances between adjacent nodes in the betweenness analysis. I used the Integration analysis on an axial map of the network through DepthmapX to calculate the average value.

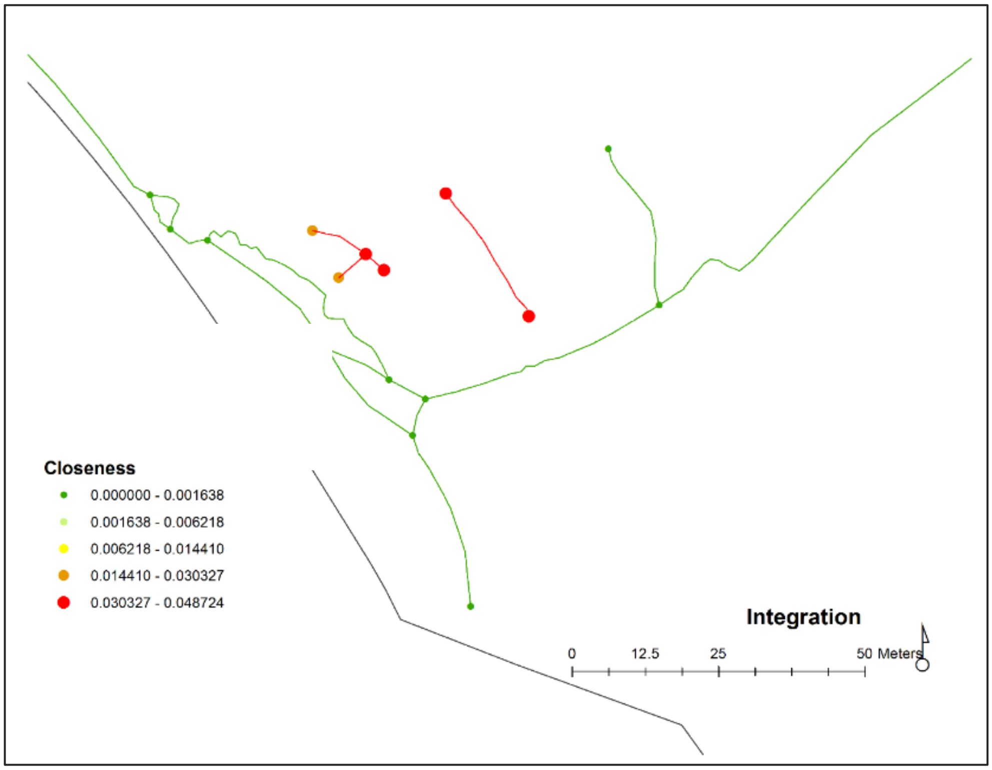


Figure 6.7. Detail of integration analysis. Red and orange segments are not integrated to the network.

This means that the network at Angamuco as a whole is well-integrated and that virtually any location (node) is connected to the network. There are few sections of the network that seem segregated, all located near modern urbanization that explains how segments and nodes are now missing or hard to identify in the DEM. In general terms, a well-integrated network like this could be interpreted as a uniform network. The following analyses helped explore this further.

6.1.2.2 Closeness analysis

Closeness is a centrality index that calculates how close a location is to all other locations (e.g., nodes, buildings, *complejos*, etc.) within a given distance threshold. Generally used to measure buildings' proximity in spatial network analysis, it has been defined as the inverse of the average shortest-path distance from one location to any other in the network (Crucitti et al., 2006; Sabidussi, 1966). It can be interpreted as how intimate locations are to each other. For example, exploring how integrated are *complejos*. The lower the closeness level of a *complejo* (i.e., its centroid), the shorter the average distance from that *complejo* to any other surrounding *complejo*. Thus, this *complejo* will be better positioned to facilitate close interaction between inhabitants of neighboring *complejos*.

In Figure 6.8 below, closeness has been calculated for all *complejos* at a network radius of 500 m (or about 10 min walking distance using roads on the network). Clearly, *complejos* located at the edges of the site that are not surrounded by other *complejos*, are less integrated to the network. In general terms, it seems like *complejos* located in the center of the site are more integrated to the network (in dark green), i.e., residents of such *complejos* would be able to get to neighboring *complejos* easily and with more chances of encountering neighbors than residents of *complejos* in the peripheries of the site (yellow, orange, and red in Figure 6.8).

What seems to be a better factor for integration of *complejos* is not necessarily their location within the site but a combination of factors: a) the proximity of their centroid to a well-integrated road segment, and; b) how dissimilar is this proximity distance is to the average distances of neighboring *complejos* to well-integrated road segments.

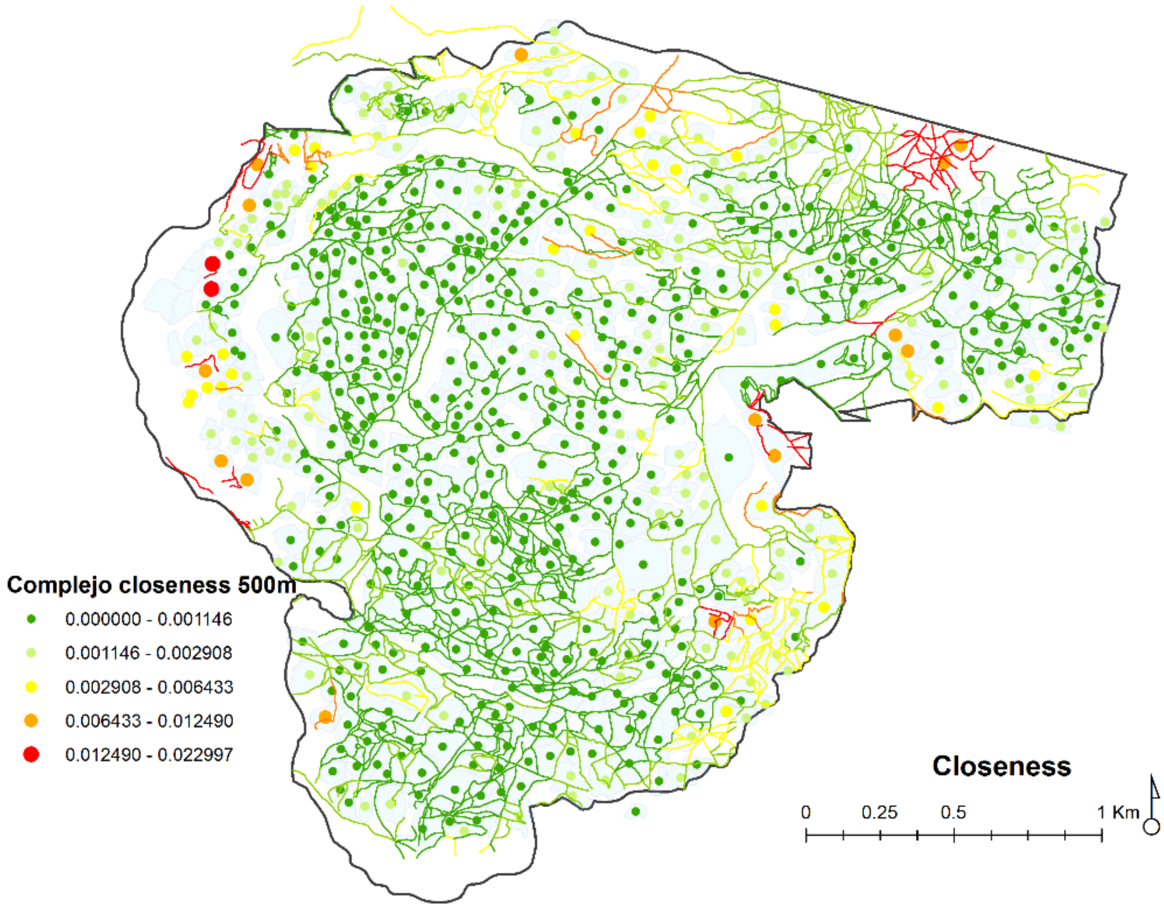


Figure 6.8. Closeness of complejos at a 500 m radius. Complejos in green have a lower level of closeness and are more integrated to the network.

These two factors are more evident if the radius is decreased, for example, to 250 m (or ~5 min walk) (Figure 6.9). In this case, instead of seeing integration at a global scale, it is possible to see that groups of *complejos* share different levels of closeness, something that could suggest spatial relationship of these groupings, similar to the neighborhoods suggested by Fisher (2011) and Urquhart (2015). In other words, closeness of *complejos* is useful to suggest a simple patterning of spatial association.

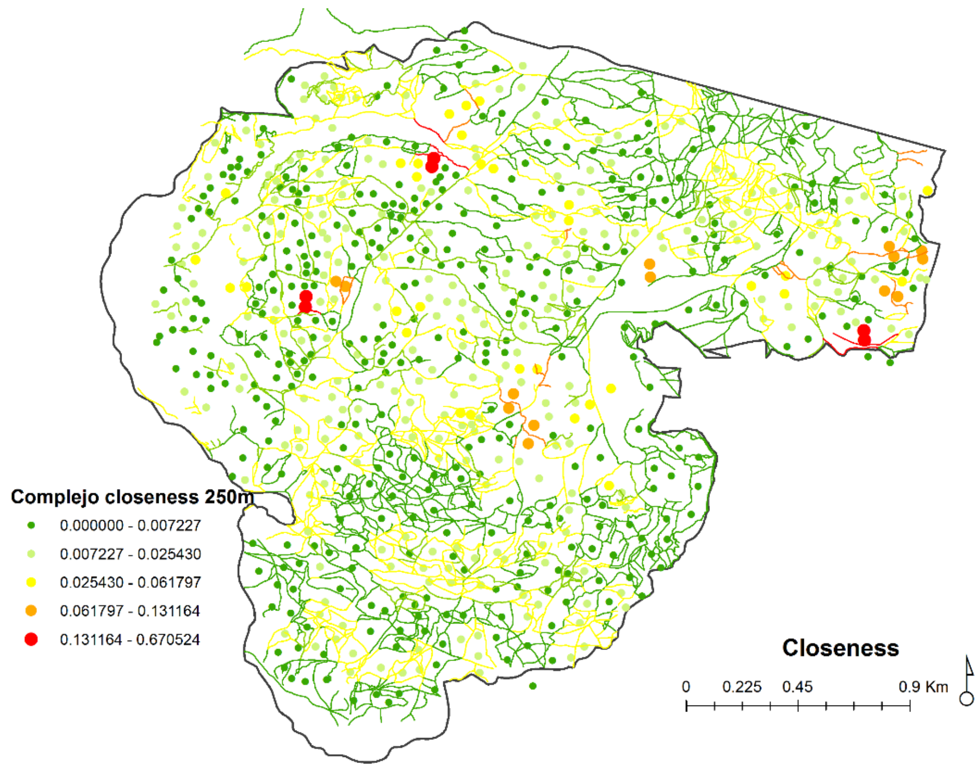


Figure 6.9. Closeness of *complejos* at a 250 m radius.

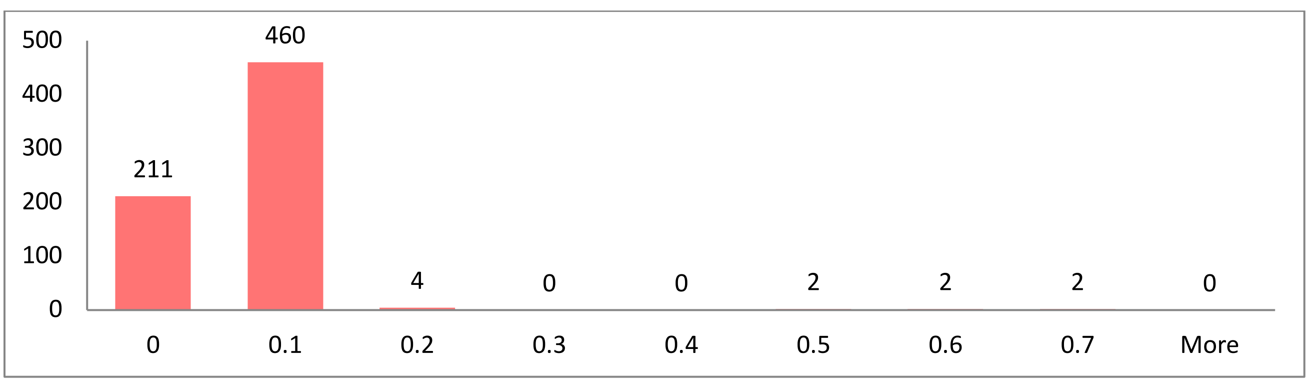


Figure 6.10. Distribution of closeness values (x axis) of *complejos* at a 250 m radius.

Similarly, neighborhoods (Figures 6.11 and 6.13 at a 1,500 m radius) and districts (Figure 6.12 at a 2,500 m radius)[3] show a varied level of integration, which again might suggest that while these groupings of spatial features are well integrated at a global scale in the network, moving through them differs from one district/neighborhood to another.

[3] Both of these distances are more relevant for traveling within and to other neighborhoods and districts.

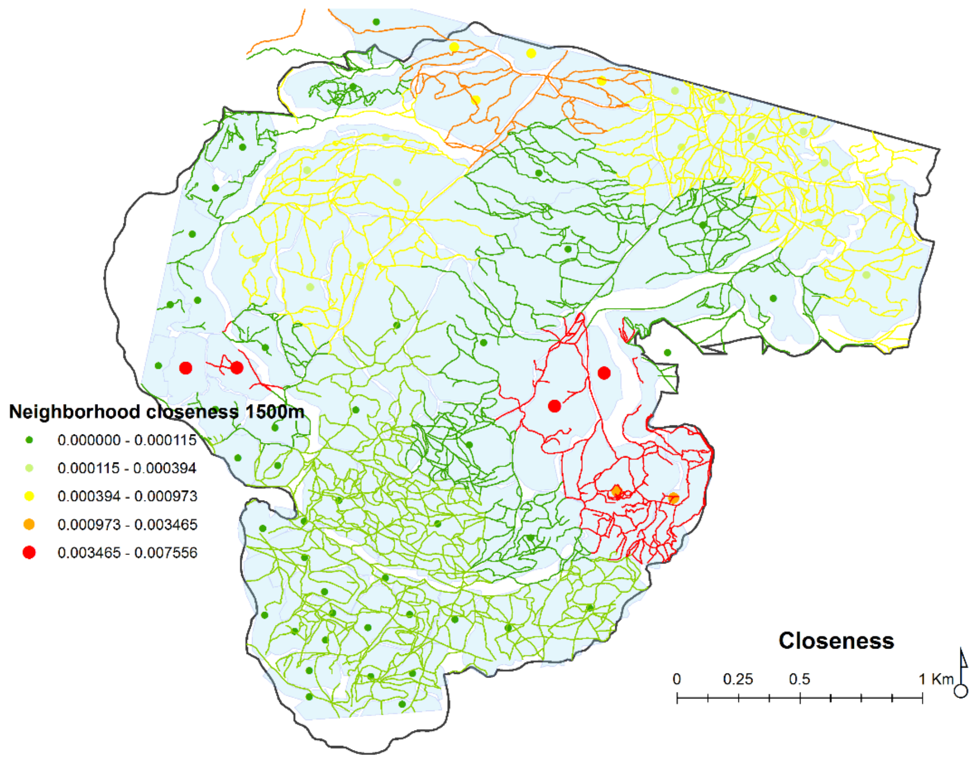


Figure 6.11. Closeness of neighborhoods at a 1500 m radius. Neighborhood boundaries in blue.

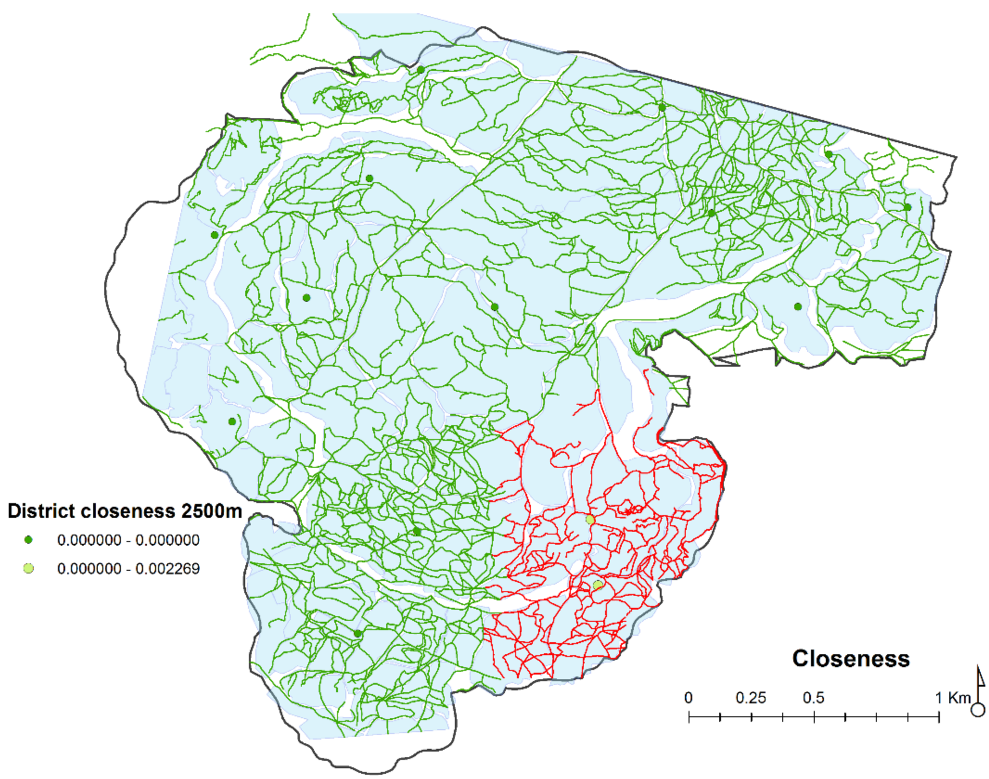


Figure 6.12. Closeness of districts at a 2500 m radius. District boundaries in blue.

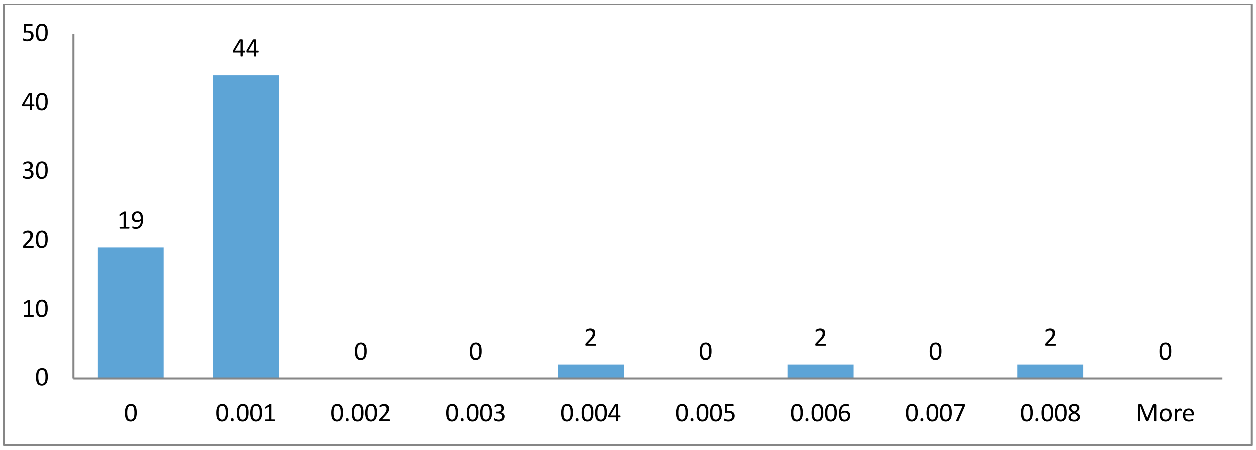


Figure 6.13. Distribution of closeness values (x axis) of neighborhoods at a 1500 m radius.

In sum, *complejos* are generally well-integrated with about 95% of them having a closeness value of 0.0005 or lower (for radius of 500 m and higher). That is, that for only fewer than 30 *complejos* it takes longer to walk to their centroid from a road in the network, than to any other adjacent *complejo*.

While this simple index does not confirm that *complejos* are located according to socio-cultural associations, it does suggest that the entire network is well integrated and its configuration might explain settlement patterns, especially at larger scales of integration. Moreover, cluster analysis helps explore this patterning in a more detailed way.

6.1.2.2 Cluster Analysis

As I mentioned at the beginning of this chapter, cluster analysis was designed to validate the spatial structure of social units. Results indeed provided evidence, although not that clear at the smallest scale (*complejo*). Additionally, cluster analysis also contributed to identify two patterns of road network within the site.

Spatial clusters or aggregations of buildings, nodes, and segments illustrate physical groupings of features that can suggest patterns of urban layouts (e. g., orthogonal, radial, etc.). For example, it is well studied that housing patterns (e.g., distribution of buildings, rooms, and even the shape of houses) corresponds to periods of urbanization (Smith, 2010) and social cohesion (Carballo, 2010; Smith, 2003). Either informal or planned housing arrangement can reflect cultural affiliation or trends of adaptation to the landscape (Harrison, 2016; Manzanilla, 2001). One characteristic of spatial patterning is the distance between architectural features, and therefore, the roads that connect them. Here I explore whether the road network reveals any spatial clusters which could be interpreted as promoting social/cultural cohesion, or, reveal the spatial distribution of urban communities.

To identify clusters in the network it is important to first define certain criteria:

1) A minimum number of locations that constitute a cluster; and

2) The maximum allowable network distance from each location (member of the cluster) to at least one other location in the same cluster (Sevtsuk, 2018b).

Unfortunately, it is challenging to use architecture (e.g., housing structures) for Angamuco since not all the architectural features have been mapped for the entire surface of the site. Additionally, internal roads (*pasillos*) within *complejos* are very small (< 0.50 m width)[4] and not identified through the digital road extraction. Instead, I used the nodes of the network as locations. I estimated the minimum number of nodes in a *complejo* to be three, and the maximum distance within a cluster to be 12.4 m. These values were estimated based on a sample of *complejos* for which the architecture had been field-verified and the number of segments and nodes were tallied (see Table 6.6 below). [5]

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[4] See road typology in chapter seven, section 7.1.
[5] For a detailed discussion on *complejo* composition see chapter seven, section 7.3.1.

For example, complejo 0 for Angamuco in Figures 6.14 and 6.15 show a total of 10 buildings and an average distance of 5.22 m between buildings. Thus, this particular *complejo* has a density ratio of 19.35 (houses) per every hectare. Another example, *complejo* 81 shows a total of 37 buildings with an average distance of 13.78m between them, and a housing density of 14.12/Ha.

More important is the number of nodes and segments identified in each of these *complejos*. While the total count of nodes/segments differs between them, the density of nodes per area remains similar (7.74 for *complejo* 0, and 8.77 for *complejo* 81).

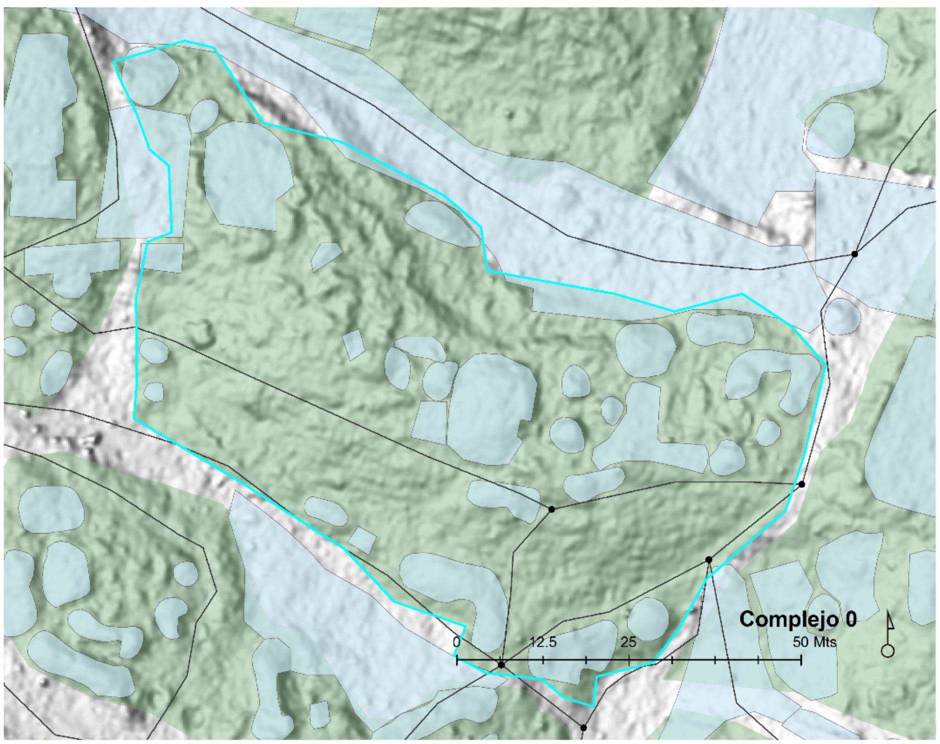


Figure 6.14. Detail of *complejo* 0. The distribution of buildings is not consistent; however, the distancing and density of architectural features and nodes remains similar.

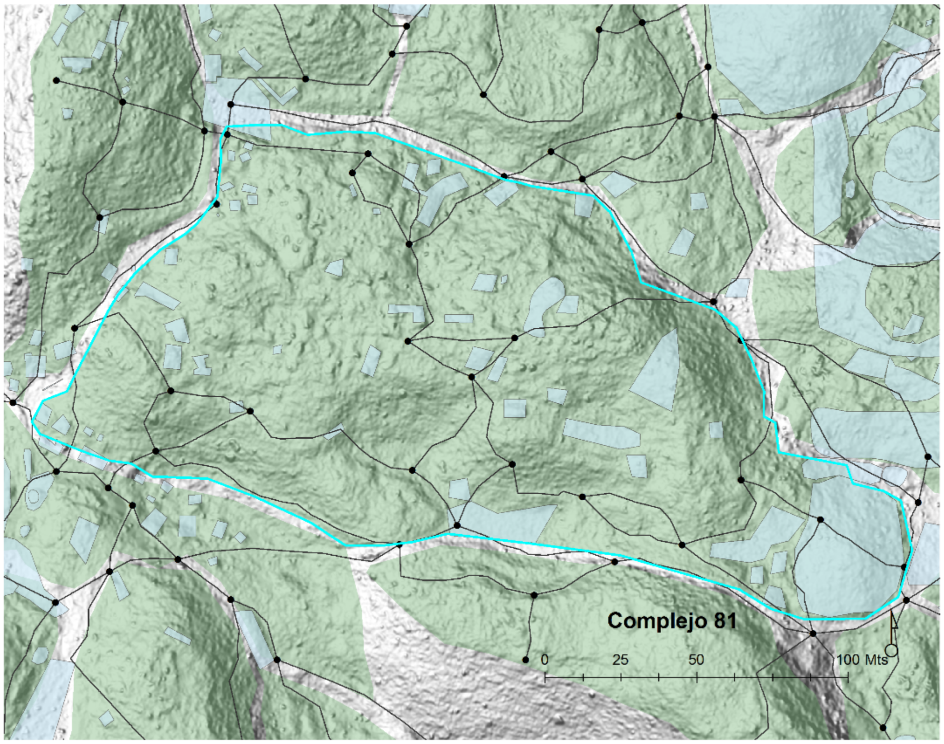


Figure 6.15 Detail of *complejo* 81 (B). The distribution of buildings is not consistent; however, the distancing and density of architectural features and nodes remains similar.

COMPLEJO ID	TOTAL AREA (Ha)	TOTAL NUMBER OF HOUSING FEATURES	DENSITY OF HOUSING	AVERAGE DISTANCE BETWEEN FEATURES (m)	SEGMENTS	NODES	DENSITY OF NODES
64	0.4665	22	53.59	3.21	50	25	8.5750
254	0.4681	25	47.00	4.48	53	32	6.4092
100	0.8565	9	10.51	8.48	7	7	8.1723
81	2.6202	37	14.12	13.78	30	23	8.7779
188	0.5368	14	26.08	6.67	3	3	5.5887
7	0.6770	16	23.63	5.37	14	6	8.8629
171	0.5249	13	24.77	10.14	3	4	7.6211
147	0.3705	13	35.09	7.4	6	3	8.0978
89	0.5359	9	16.79	8.75	7	5	9.3295
1	0.5354	17	31.75	6.67	7	4	7.4711
0	0.5169	10	19.35	5.22	8	4	7.7386
87	0.8852	23	25.98	9.44	13	7	7.9075
AVERAGES	**0.75**	**17.33**	**27.29**	**7.47**	**8.83**	**6.08**	**7.88**

Table 6.6. List of housing buildings per *complejo* and average distance between each other. First two roads represent *complejos* surveyed and mapped in the field for this project. The nodes and segments have been calculated from digital road extraction, not the field mapping of 2016. Last row shows the average for all values. Density is calculated as the number of features per hectare.

In general, a *complejo* in Angamuco can be defined as a spatial aggregation that contains at least 17 houses, where the average distance between buildings is 7.47 m, with a minimum distance of 1.8 m and a maximum distance of 25 m within the same cluster.[6]

This information was used to run cluster analysis for the network using UNA on Rhino 3D software. The results were mixed. On the one hand, cluster analysis did not confirm the general configuration of *complejos* (or, that it is possible to make a correlation between the number of architectural features and the number of nodes for medium to large roads at *complejo* scale). In Figure 6.16, the clusters of nodes do not line up with *complejos* configurations. Instead, they show groups of nodes at the intersections between *complejos*.

[6] Something similar has been observed in the field, however, these calculations have not been done by any member of LORE-LPB project to this date.

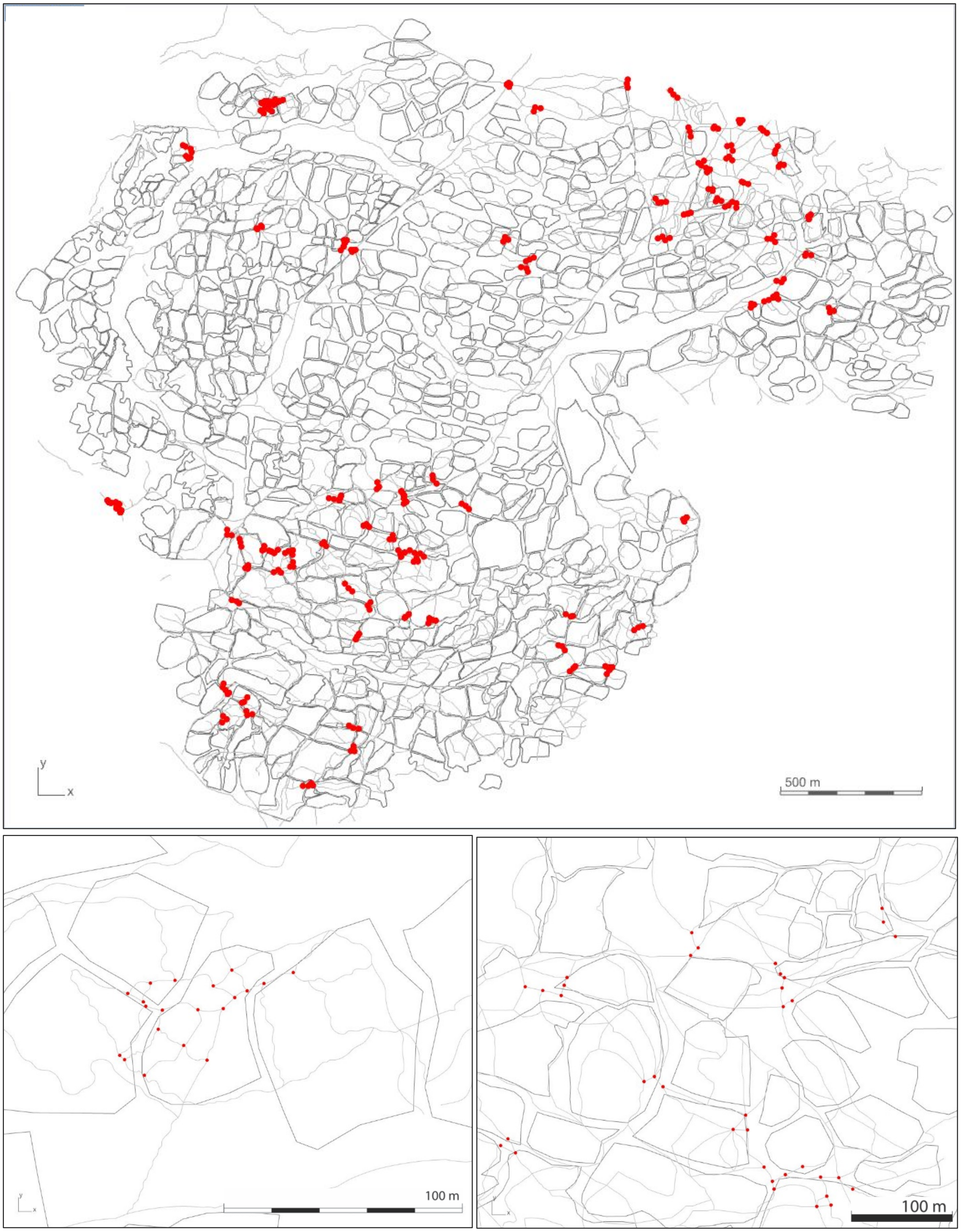


Figure 6.16. Whole site (top) and details of node clusters at *complejos* scale (bottom). Polygons represent *complejo* boundaries and red dots are nodes. Y axis represents North.

I suggest that the reason for this discrepancy is the lack of information at the *complejo* scale. More research focused on mapping the circulation inside a *complejo*, and the morphology of *pasillos* will help clarify this. During digital extraction of the network I only identified roads wider than 1 m. So, only few *pasillos* are actually represented in the digital road network of Angamuco, and thus, not all nodes inside *complejos* were identified.

I repeated the cluster analysis focusing on neighborhood polygons. The results suggest that cluster analysis is much more helpful to understand integration of the network and the site at this scale. For this, I calculated the average, minimum and maximum number of architectural features, nodes, and segments for a sample of five neighborhoods where all this data was available (Table 6.7).

With a minimum of 25 nodes per neighborhood and a maximum distance of 90 m between each node, the cluster analysis now reflects the configuration of neighborhoods (Figure 6.17). These clusters do not align with the neighborhood boundaries exactly (Figure 6.18) but suggest a level of integration in two important areas of the site: a south-central region (SoC), and a north-eastern region (NoE).

NEIGHBOR-HOOD ID	TOTAL AREA (Ha)	TOTAL NUMBER OF HOUSING FEATURES	DENSITY OF HOUSING	SEGMENTS	NODES	AVERAGE DISTANCE BETWEEN FEATURES (m)
22	39617.69	79	19.9406	26	18	84
54	72418.92	112	15.4656	31	19	112
52	118035.61	201	24.9925	48	29	81
7	34400.40	98	28.4880	38	25	96
12	79690.65	138	20.5796	116	35	79
AVERAGES	**68832.65**	**125.60**	**21.89**	**51.80**	**25.20**	**90.40**

Table 6.7. List of housing buildings, nodes and segments per neighborhood, and average distance between each other. Last row shows the average for all values. Density is calculated as the number of features per hectare.

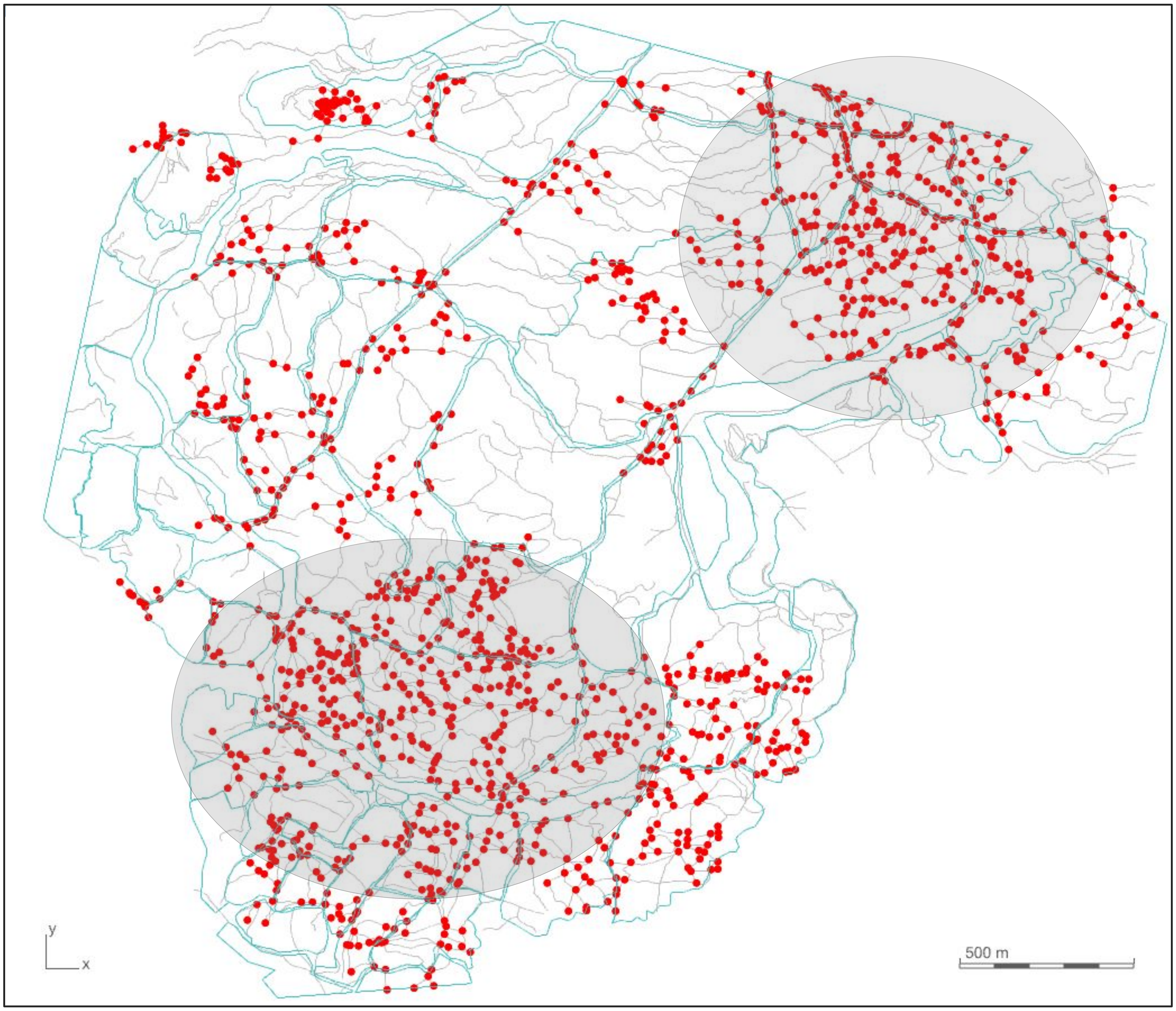


Figure 6.17. Cluster analysis at neighborhood scale. Polygons in blue represent neighborhood boundaries and red dots are nodes. Y axis represents North

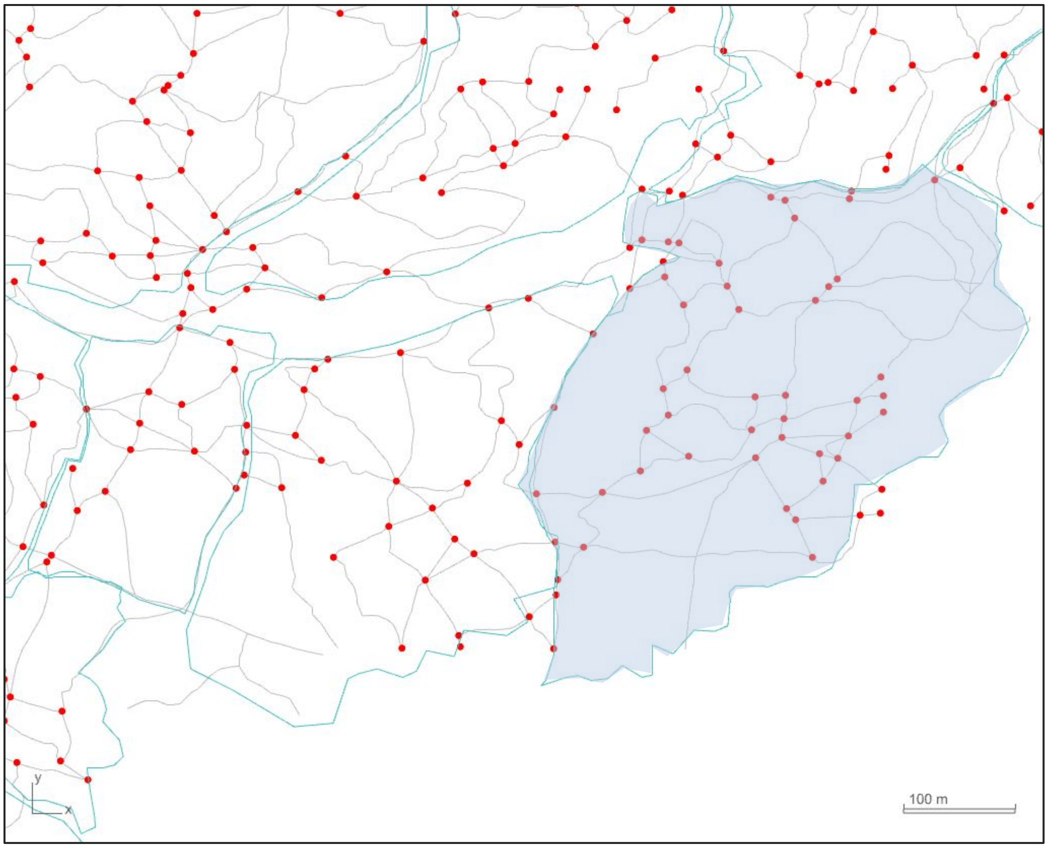


Figure 6.18. Detail of cluster analysis at neighborhood scale. Polygons in blue represent neighborhood boundaries and red dots are nodes. An example of neighborhood is shaded in light blue. Y axis represents North.

Brief summary of Integration analyses

Although a more in-depth research is needed when exploring the subdivision of Angamuco into different units, the work done here can be used to draw some general conclusions. For example:

1) The road network of Angamuco is very well integrated. Only few segments/nodes are segregated from the network.
2) Integration levels do not correspond to *complejo* site divisions previously created by LORE-LPB. This does not mean that integration is not a good measure for spatial

configuration but does reveal that the parameters used by LORE-LPB to define complejos might not reflect actual spatial units.

3) By contrast, *integration* indexes reveal a patterning of the network for two large areas (NoE and SoC) where network connectivity appears to be much more integrated than in other parts of the network. In other words, cluster analysis reveals that the network, although serving to communicate all areas of the site, is not uniform.
4) Finally, a well-integrated network means that people have many route options reducing the chances for encountering others. It also suggests that the network is complex which is a characteristic of more organic (less-planned) network.

6.1.3. Accessibility of Angamuco's road network

The LORE-LPB project suggested that the site of Angamuco did not function under a centralized system. For example, instead of a mayor political and religious center, there seem to be various smaller ceremonial centers. Instead of one general area for farming fields, every family had their own garden, etc. (Fisher, 2011; Urquhart 2015; Bush 2012; Fisher, et al. 2011). Moreover, there are several water reservoirs, access points to the lake basin, wells, and water tanks within the city that were shared by many inhabitants. This likely had an effect on how residents were interacting and socializing.

Studies in modern cities have identify *accessibility* as a good measure to understand social interaction and even economic development (e.g. Abubakar and Aina 2006). Exploring how people reached locations, the ease of navigation within the network, and identifying the shortest routes or closer resources, are very relevant for understanding interaction at large in Angamuco. *Accessibility* can be thought of as the connectivity of the network in terms of how fast and easy it is to reach to one or several destinations from a particular origin, but is also as a measure to identify potential opportunities of interaction (Shen, 2017). Its simplest expression is the measure of the network distance (i.e., distance separating two points along the network), however, it can also be calculated as the average distance between sets of points, the weighed area distance, network distance to the closest destination, or the number of road segments or nodes used to travel to any destination (Jiang et al., 1999).

In the Space Syntax literature, *accessibility* is a more complex measure. Cost of traveling and distance do not account for the many factors that influence a pedestrian in choosing a route (Charalambous & Mavridou, 2012; Hillier, 1996). Instead, factors like how exposed the streets or buildings are (convex landscapes), the lighting, the sense of safety, other important locations in the route, etc. are used to calculate different dimensions of accessibility. Unfortunately, this way of calculating accessibility is challenging when we consider an archaeological site. Very rarely we can reconstruct urban landscapes as they were experienced by pedestrians in the past, factors like how dangerous was to travel through an area might need to be assumed, or the identification of all possible destinations is generally unclear. Consequently, I am adopting a more general approach to study accessibility using indices, *Reach* and *Gravity*, that are based on measurable distances along the network.

6.1.3.1 *Reach* analysis

Reach index accounts for how many locations can be reached using the shortest path from a particular origin given a defined radius. The extent of the radius can be calculated using network distances. For example: the number of locations (e.g., nodes) can be reached from their house if a pedestrian walked for 15 min or 1 km using only the roads.

I calculated this index using the UNA toolbox for ArcGIS and Rhino 3D. The parameters for this measurement are: a) *Origin*: that can be one or many points; b) *Destination*: that can also be one or many points; and c) *Distance radius* in meters (network). The *Reach* results are displayed in total counts (e.g., the number of nodes that can be reached).

Entrances are perhaps the best locations to explore accessibility. Compared to pyramids, ballcourts, or other significant features in the site, all entrances have been identified at Angamuco.

I calculated *Reach* in relationship to site entrances, to find out which of all the entrances of the site can reach more nodes. Using a 1 km (~15 minute walk) as network radius, Entrance 1 is the entrance with the largest reach index (a total of 1,361 nodes). The location alone of this entrance —south-center of the site, crossed by a major causeway—, would suggest that this entrance is very important. Moreover, this index confirms that Entrance 1 was of great importance when it came to accessibility to the rest of the site (Figure 6.19).

Once again, the SoC and NoE areas seem to be better connected, similar to what was observed during integration analysis. This does not mean that the group of Entrances 1, 8, 9 & 10 (SoC) or 3, 5 & 6 (NoE) are the easiest to access from any part of the site (or, overall), but that those two areas have nodes and segments that are better connected within their own immediate area (see detail of network in Figure 6.20). *Reach* analysis for entrances calculated using other radii (250 m, 500 m, and 1 km) showed similar results. That is, the entrances with highest Reach (number of nodes), are the same regardless the distance (1, 8, 9 & 10). The distribution however is slightly different, at 500 m distance, most entrances can reach between 150 and 475 nodes with Entrances 11, 12, 13 and 14 reaching less than 150 nodes. Interestingly, Entrance 5 (Northeastern most entrance) has the highest *Reach* (475) at 500 m, and 250 m, but is only the 5th with highest reach at 1 km distance (see Figure 6.22).

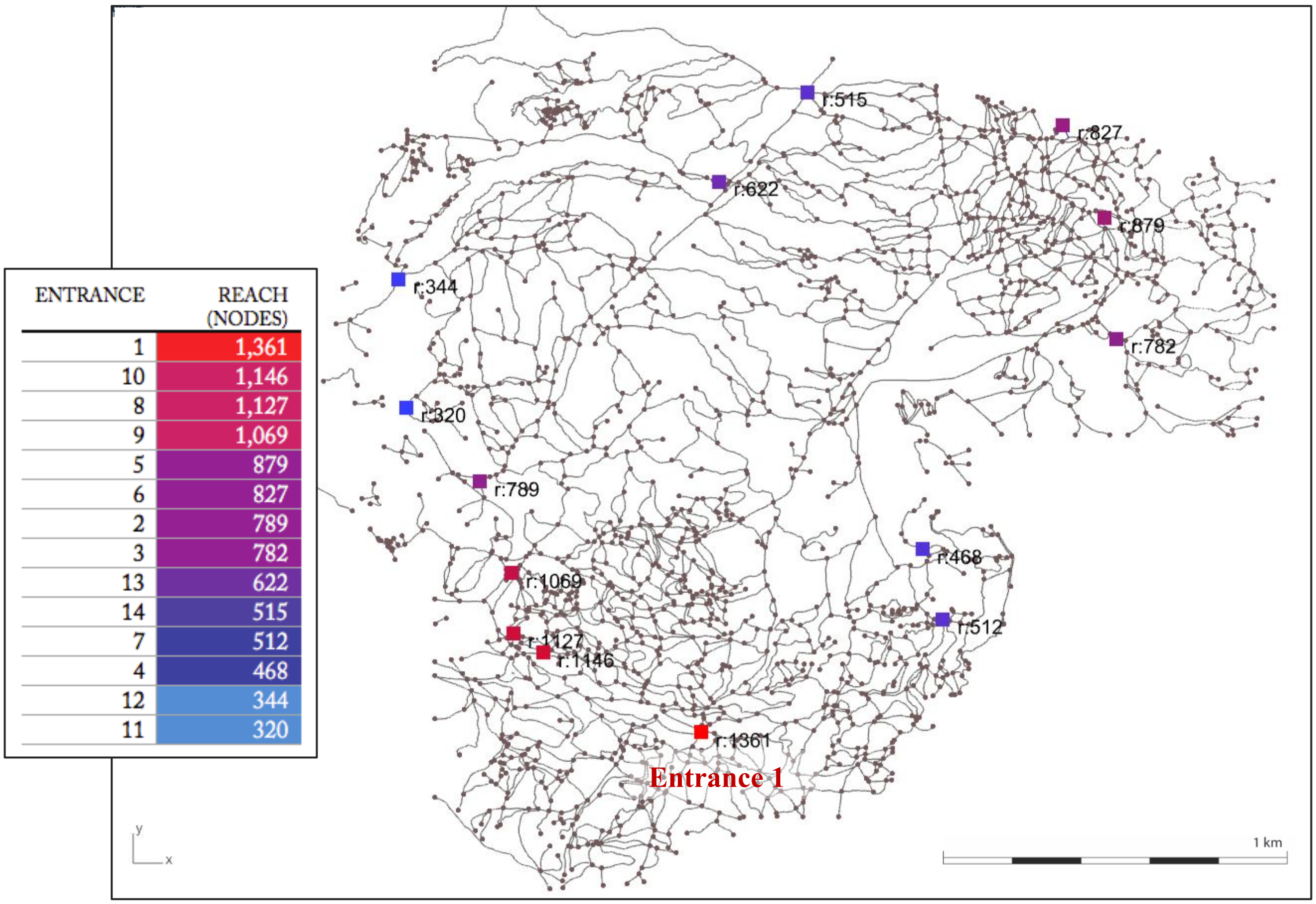


Figure 6.19. *Reach* analysis from site entrances to all nodes in network (total count) using a 1 km radius. Color squares are entrances and small dark brown dots are nodes. Y axis represents North.

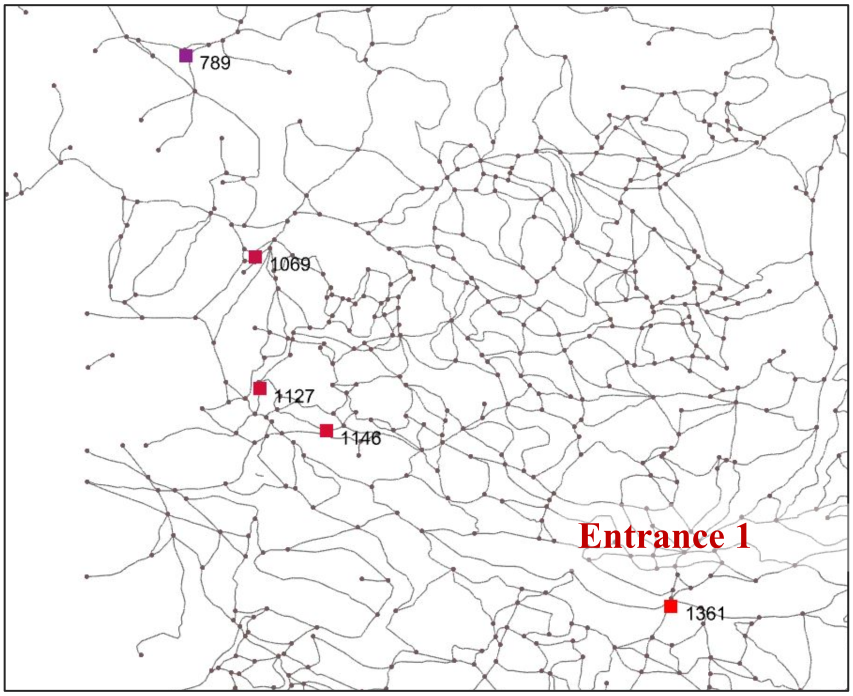


Figure 6.20. *Reach* Analysis from site entrances to all nodes in network (total count) using a 1 km radius. Detail of SW area of site. Color squares are entrances and small dark brown dots are nodes.

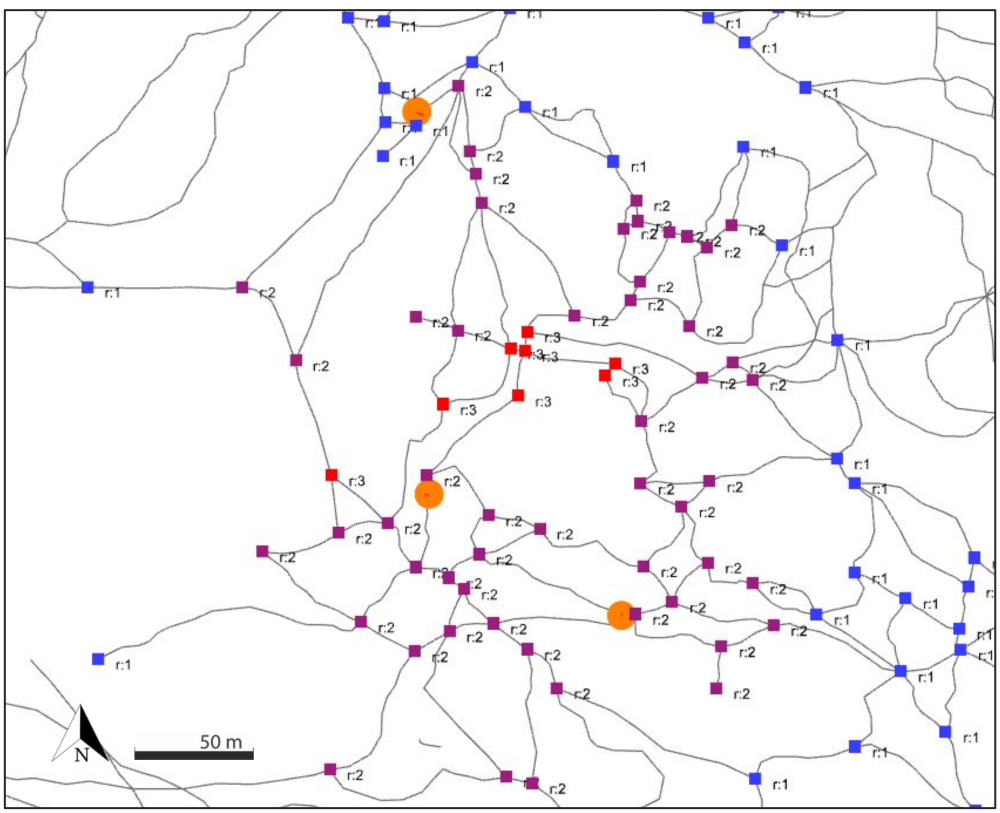


Figure 6.21. Detail of *Reach* Analysis from nodes to site Entrances at a 250 m network radius. r = reach and the number represent the total count of entrances that can be reached from that particular node.

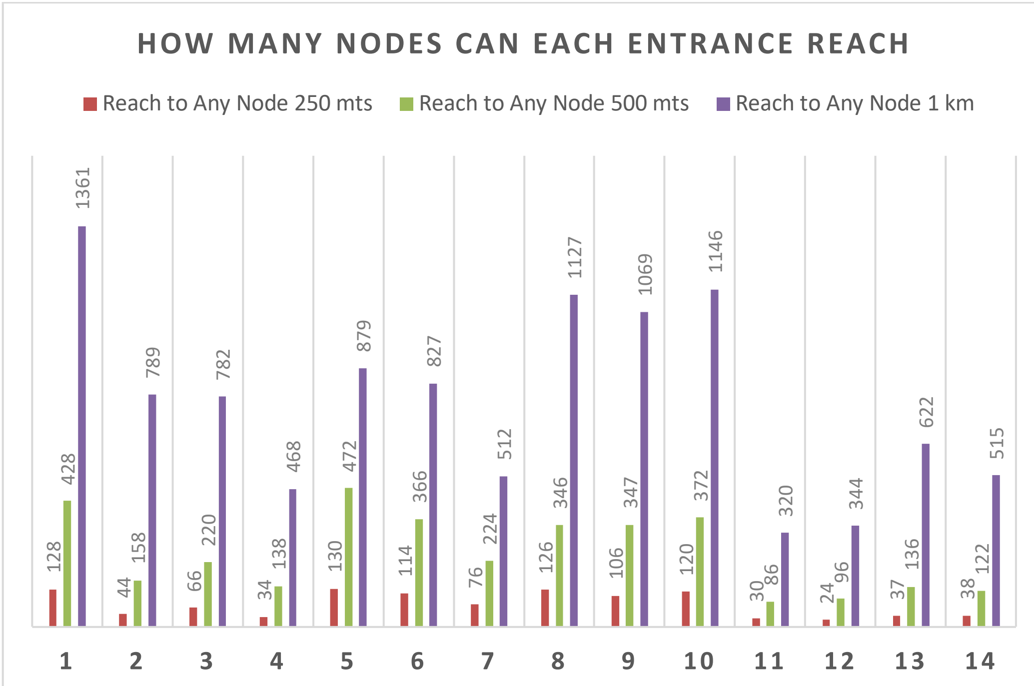


Figure 6.22. Total count of nodes reached from site entrances at different network radius. X axis represents all entrances.

In Figure 6.23, I show how many (if any) Entrances can be reached from any node in the site at different network distances. For example, if a pedestrian were to start a trip from any node in the network and only willing to walk for 1 km (~15 min) how many and which Entrances would they reach? Entrances in Figure 6.23 are symbolized as orange circles. Nodes that reach at least one entrance are symbolized as colored squares (see detailed in figure 6.21 as an example). If settlement was established based on location or accessibility to important features like site entrances, it would be worth exploring for temporality markers at *complejos* near such locations.

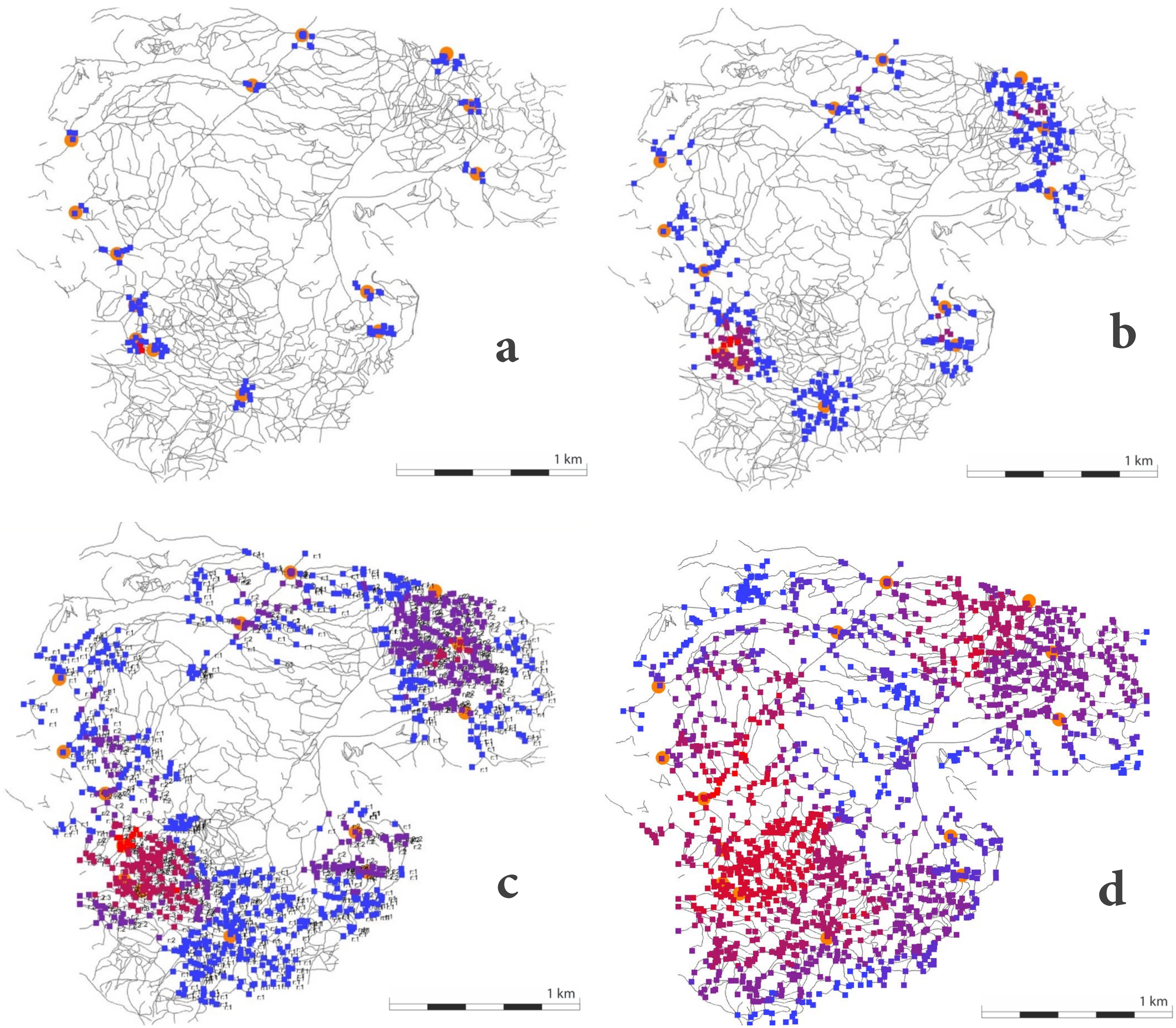


Figure 6.23. Reach analysis of nodes to Entrances at 100m (a), 250m (b), 500m (c), and 1,000m (d) radius. From blue (less) to red (more).

The results revealed that most nodes are well connected to the network and that it would take about 15 minutes (1 km) for a pedestrian to get to any entrance regardless their original or starting location.

The distance between the two most distant entrances is about 3 km (~30 minute walk). *Reach* analysis for that radius shows that if a pedestrian would be willing to walk that far to exit the site, then virtually any location can reach at least one entrance, particularly the nodes located in the center of the site (red in Figure 6.24).

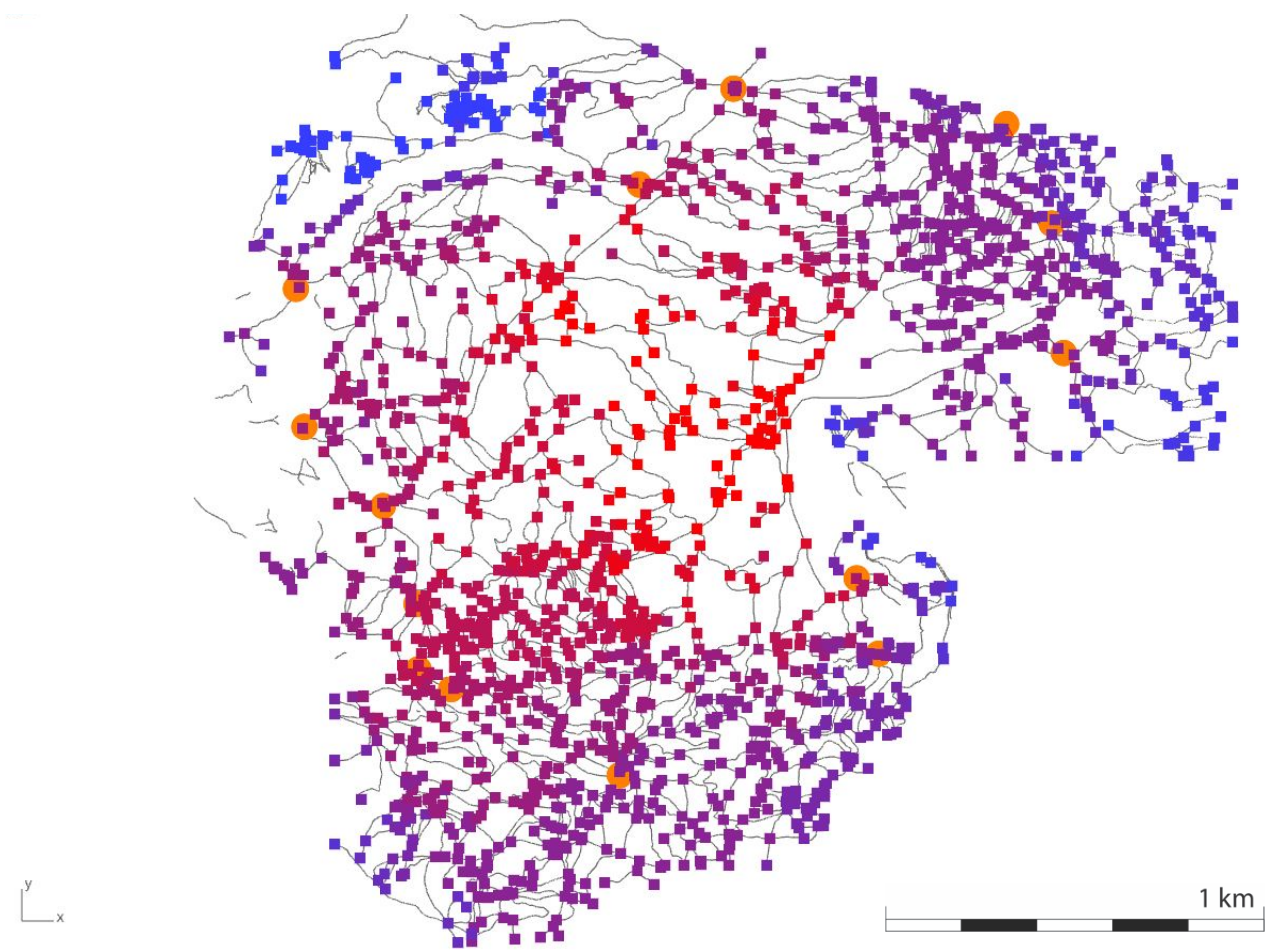


Figure 6.24. *Reach* Analysis from nodes (squares) to site Entrances (orange dots) at a 3 km network radius.

These results suggest that the network is well-integrated and well-connected. So, even if a person leaves near an entrance, they have the possibility to get out of the site through any other entrance with relatively little effort and time. Again, I am using nodes as a proxy for place of residence. Next, I present reach analysis on other two proposed site division areas that should be related to housing and daily activities for Angamuco residents: *complejos* and neighborhoods.

Reach among nodes

The same pattern of network connectivity is observed if the same analysis is done directly on nodes, rather than entrances, as origins and destinations. The question is how many other nodes can each node reach, given a network radius. The results for small radii or short walking distances reveal a similar pattern for two areas of the site with distinctively well-connected networks —NoE and SoC— as observed in Figure 6.17 (Figure 6.25 a & b). In this case, a group of nodes and segments around the SoC area of the site reveals a pattern of an intricate and highly accessible network that appears to start in Upper Angamuco (above the escarpment) and extends towards Lower Angamuco by Entrance 1. A second group of nodes-segments is also clear in the NoE section of the site, again above the escarpment. As a way of comparison, I show reachability changes towards the center when extending the maximum distance/time of travel, a natural mobility phenomenon (Figure 6.25 c & d).

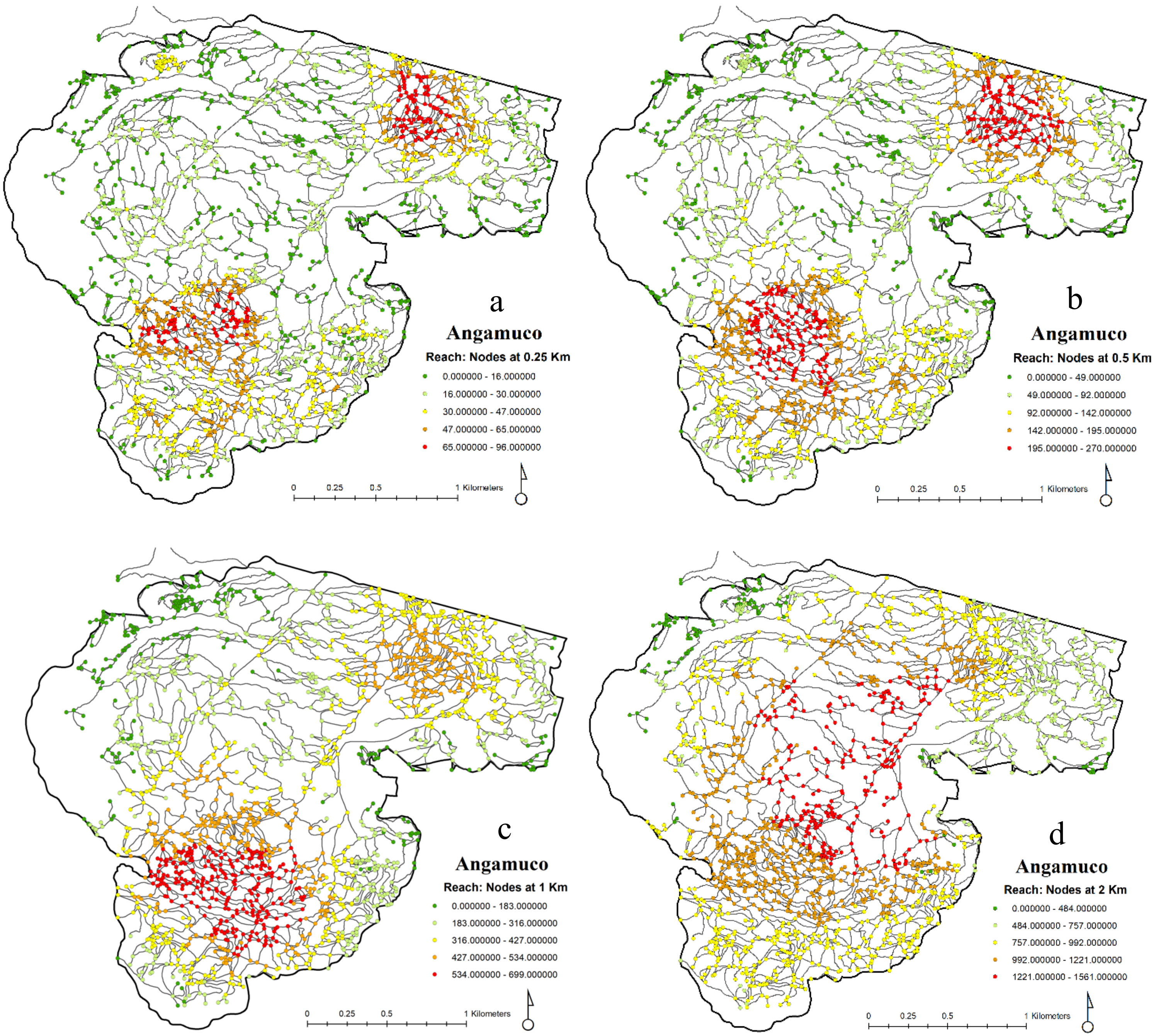


Figure 6.25. Reach analysis of nodes to nodes at 250 m (a), 500 m (b), 1 km (c), and 2 km (d) radii. Green (less) to red (more).

Reach among complejos

At a 3 km network radius —the maximum distance between remote entrances— 666 out of 685 (97.2%) *complejos* can be reached starting from the center or any other *complejo*. There are five that cannot reach any other *complejos* using the roads (Figure 6.26), four of which are located in the periphery of the city but close to entrances. Three are located in Lower Angamuco, and two in the Upper zone. Interestingly, one of them is located in the center of the site (*Complejo* 445 in District I) which does not fit the general pattern of reach observed with the rest of the *complejos*. There are two interpretations for this: 1) settlement of that complejo occurred in a different time period (probably later), 2) intentionally segregated from the network (see section 7.2 for further discussion). It should also be noted that six complejos can only reach one neighboring *complejo* probably because the road network has been disturbed from modern urbanization and agriculture.

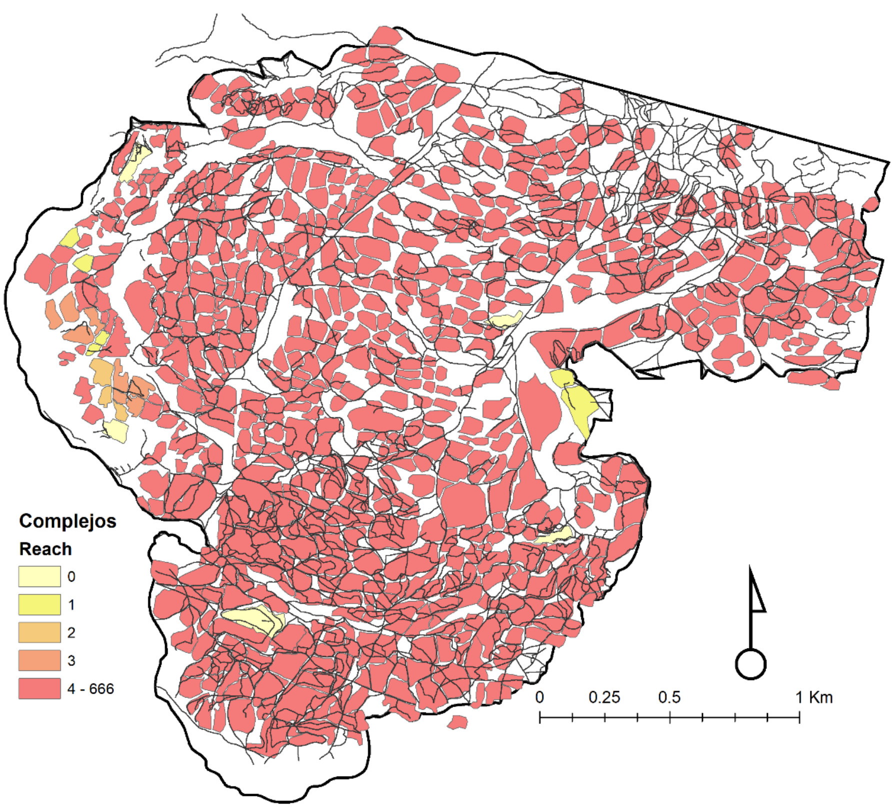


Figure 6.26. *Reach* Analysis from *complejos* to *complejos* with at a 3 km network radius. Red *complejos* can reach each other, virtually the entire city.

As I mentioned before, the number of other *complejos* that can be reached has to do with how accessible the network is, and not necessarily the individual spatial characteristics of the *complejos*. If a *complejo* has a level of reach below 666 that means that part of the network around this *complejo* is not accessible. In other words, if the distance between the centroid of a *complejo* and a road segment is greater than the entire length of such *complejo*, then that complejo is not connected to the network. This measurement needed to be estimated since the actual location of the *complejo* entrances to roads in the network has not been mapped yet.[7]

Thus, *complejos*' reach is dependent on whether there is a road near it, and if the roads near that *complejo* are integrated to the network (see example in figure 6.27).

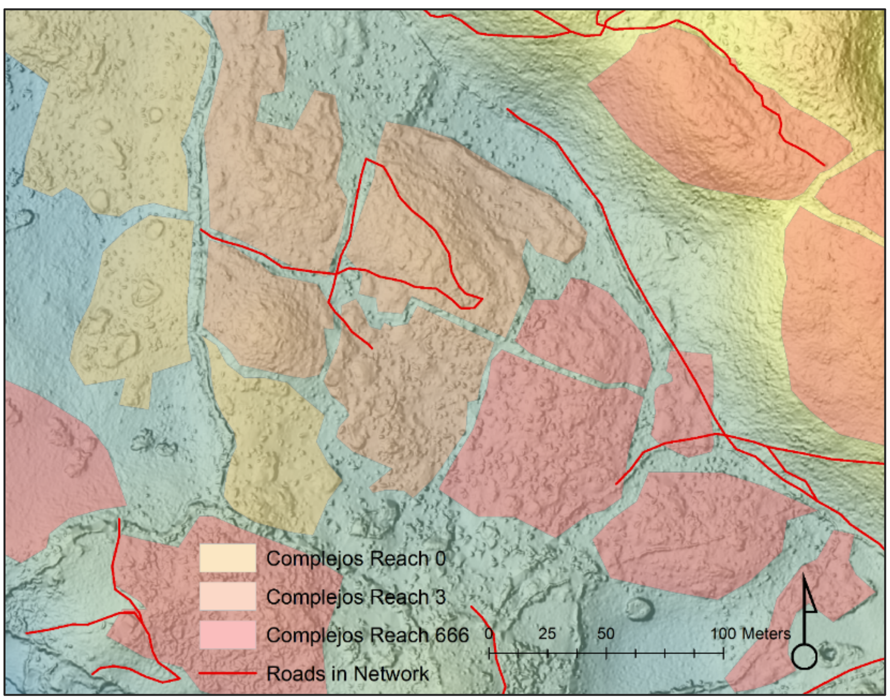


Figure 6.27. Example of *complejos'* reach. Here, yellow complejos cannot reach any other *complejo* using the road network. Orange *complejos* can only reach each other. The center of all red *complejos* is closer enough to any road that is connected to the network. Color in the background is representing topography (green = lower elevation).

[7] See discussion on *complejos* in section 7.3 of chapter seven

Notably, the majority of *complejos* with low reach value are located in the western edge of the site. As previously mentioned, this area is very disturbed from modern urbanization. Intense agricultural activities in the last century have modified the landscape greatly and many features including roads are not identifiable.

In sum, *complejos* with a value of reach below 4 are relatively isolated from the network. Their residents probably used very small pathways or pasillos in order to get to a nearby road, but those smaller road segments have not been mapped for this dissertation. Another interpretation is that these *complejos* were newer or in the process of forming. As such, they had not been settled by the time of abandonment of the site.

Reach among Neighborhoods and Districts

The calculation of *Reach* for neighborhoods (i.e., their centroids) shows that these are also very accessible to each other. The only neighborhoods that were not connected to the network are, most likely, the result of modern disturbance (neighborhoods with a value zero in the west side of the site) (Figure 6.28). The fact that all neighborhoods of Angamuco (total of 64) can connect to each other, means that all their residents could reach any other neighborhood using public roads, and that shared resources and features (e.g., pyramids, markets, plazas, wells, etc.) were also accessible among neighborhoods.

Districts (i.e., their centroids) were found to be very similar to neighborhoods in that they are all (14) very accessible to each other. This is expected as the network (specially the main roads) crosses or passes by all districts regardless their shape and extension (Figure 6.28).

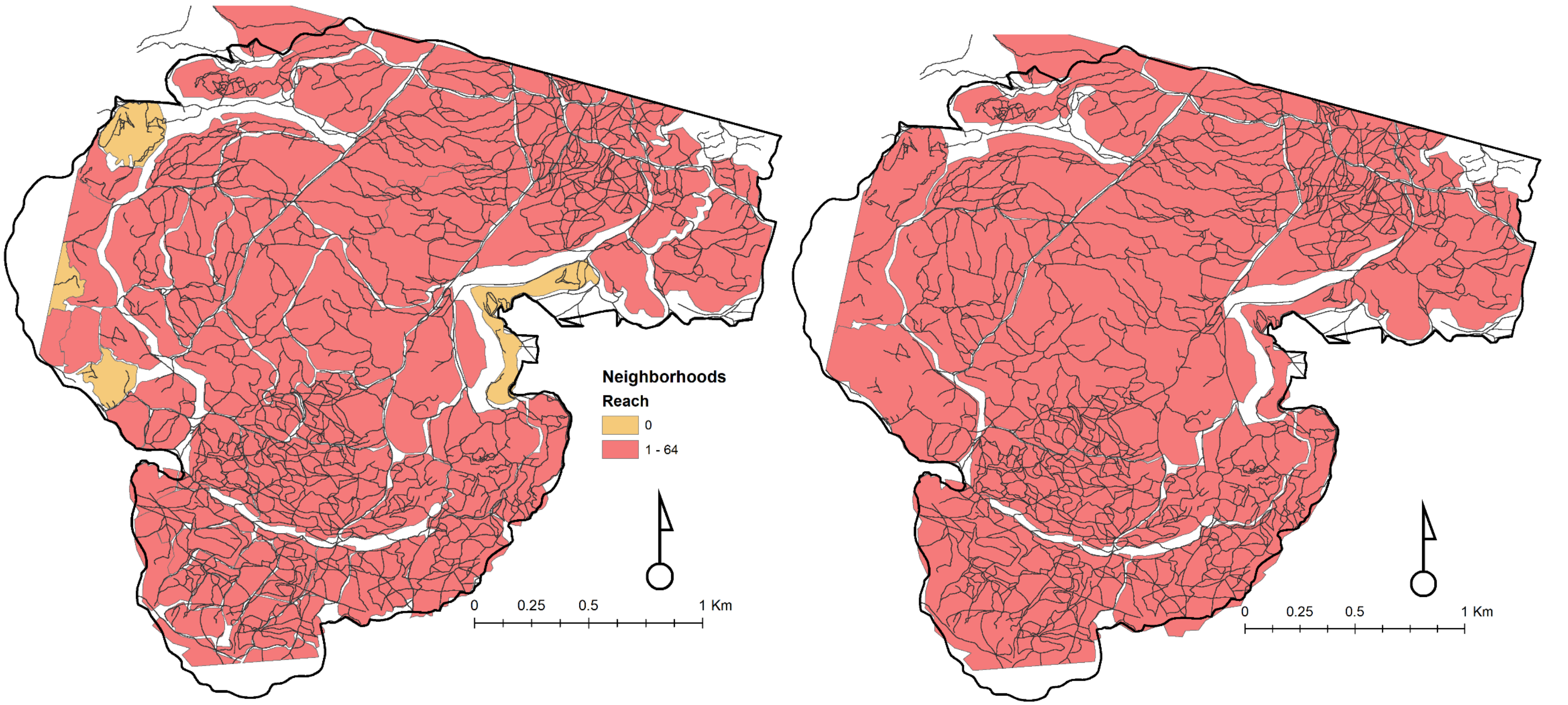


Figure 6.28. *Reach* analysis of neighborhoods (left), and districts (right) red *complejos* and districts can reach each other, virtually the whole site.

Reach to special features

Pyramids in Angamuco have been described as mounds with more than three tiers. Only a total of 25 have been identified in the field. I used the14 entrances as origin points, the 25 pyramids as the destinations, and several radii to inspect accessibility to these monuments. The results obtained with different radii are presented in figures 6.29 and 6.30. With small radii (150 m, 500 m, and 1,000 m) pyramids appear as being less accessible from the entrances as I have expected. However, when the radius was increased to 3 km, instead of observing that all entrances gaining greater reach to most pyramids, the NoE sector of the site become less accessible. It appears that the three entrances by NoE can only reach six of the pyramids in that area but no other pyramids. In other words, the residents of the NoE do not need to access other pyramids than those within reach of their own area.

This is the first time that instead of seeing a completely accessible network where all areas and resources eventually become available and reachable to any other part of the network, I could observe some sort of segregation. This observation suggests that different configurations within the network might actually be related, or resulted, from a different settlement pattern, and that this NoE region enjoyed a stronger sense of community (at least in terms of the religious use of their own exclusive pyramids).

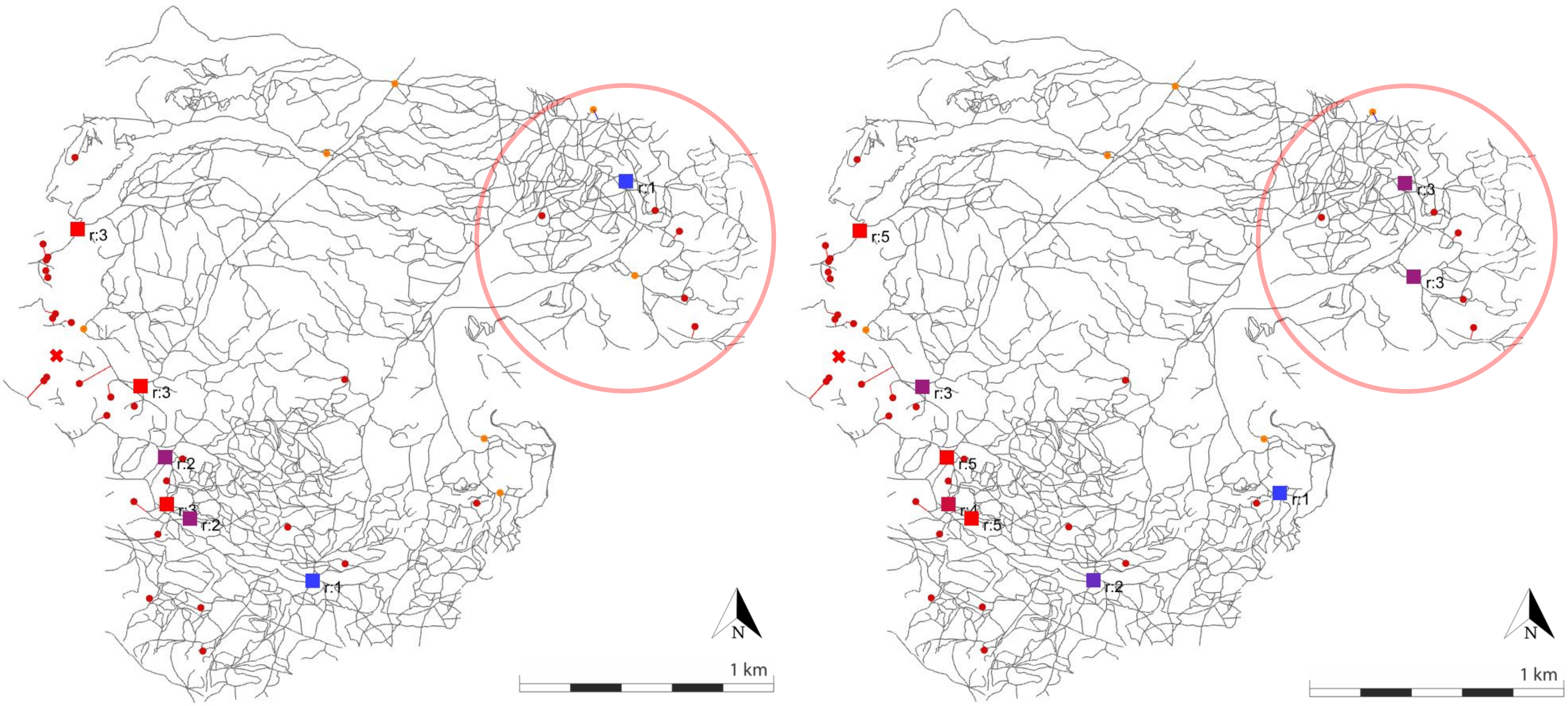


Figure 6.29. *Reach* analysis from Entrances to Pyramids. Left reach analysis done at 250 m radius, and right at 500 m. Red dots represent pyramids and yellow dots (or colored squares) represent entrances. Number next to entrances is the total count of reached pyramids. In the red circle, the pyramids only accessible from entrances in the NoE region

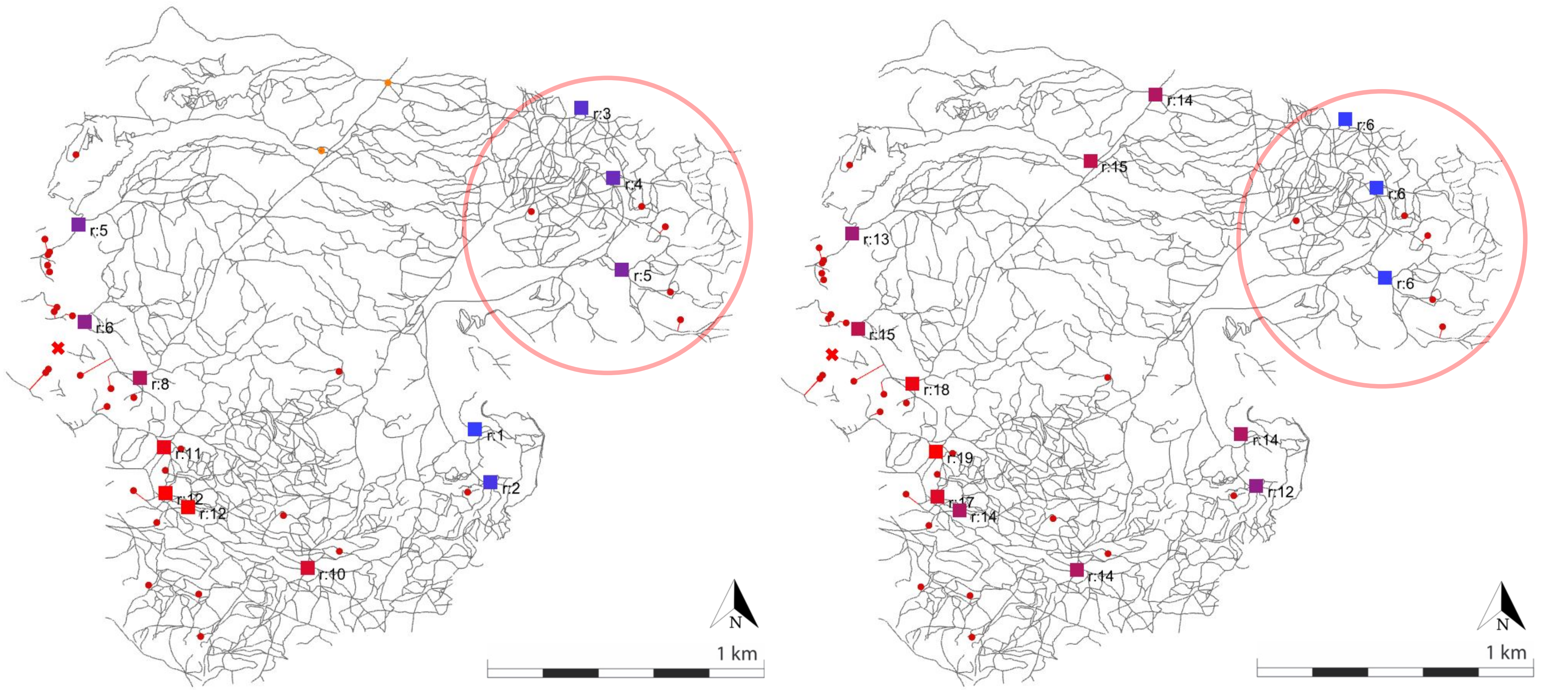


Figure 6.30. *Reach* analysis from Entrances to Pyramids. Left reach analysis done at 1,000 m radius, and right at 3,000 m. Red dots represent pyramids and yellow dots (or colored squares) represent entrances. Number next to entrances is the total count of reached pyramids. In the red circle, the pyramids only accessible from entrances in the NoE region

Brief summary of *Reach* analysis

Reach analysis helped confirm that Angamuco's road network is well-integrated and accessible. Moreover, I observed two main patterns of network accessibility:

1) At smaller radii: very short travel distances or time to travel, usually below 1 km, reveal two areas of the site have better accessibility than the rest. One at the south-center of the site — near the grand Yácata— (SoC) and another in the north-eastern area of the site (NoE).

2) At larger radii: medium distance/time of travel, usually between 2 and 4 km, the center of the site appears to be more accessible or easier to reach from any other part of the network. This is expected for a normally well-connected network.

3) About 97% of *complejos* can reach any other *complejo* in the network. A few *complejos* or small groups of *complejos* are isolated from the road network. They most likely had some way to connect to the network through *pasillos* or roads narrower than 50 cm. In other words, the vast majority of residents in the city, or residents in 648 out of 666 *complejos* could potentially reach any other *complejo* using the roads of Angamuco.

6.1.3.2 *Gravity* analysis

Gravity is another centrality index that captures another form of accessibility. In this case, it measures the attraction that destinations have within the network. *Gravity* has been used in urbanism studies to explain how a city develops as different parts of it become more attractive to settle (e.g., changing the "center of gravity" from the historic city center to a more popular new developed area in the periphery) (Hillier & Stonor, 2010). Archaeologists have employed a similar rationale when conducting some spatial analysis (e. g., central place theory) and interpreting density and intensification of material scatters. *Gravity* explores the influence, or "attractiveness" a location has over other nearby locations. Certainly, what makes an area of the city "attractive" is something that needs to be defined by archaeologists, for example: size (Rivers et al., 2013). Urbanists have approached this measurement to identify attractiveness as areas of benefit to work, social interaction, sight-seeing, etc. (Siewwuttanagul et al., 2016).

The *Gravity* index in this study uses the number of destinations, their attractiveness, and the travel cost of approaching these destinations to generate a single value (gravity value). The gravity of a location (origin) in a network for a given radius is inversely proportional to the shortest path distance between that same origin and each of the other locations that are reachable from the origin (Sevtsuk & Mekonnen, 2012).

For this analysis I used UNA toolbox for ArcGIS and Rhino 3D. The analysis requires a set of origins, destinations, radius and an *impedance* or *beta* value which can be interpreted as the cost of moving.[8] Impedance values can be calculated for an average pedestrian and varies from city to city based on the landscape, climate, and even culture (Handy & Niemeier, 1997). Some authors refer to this value as the value for walkability generally calculated to be between 0.002 and 0.004 for distances in meters (Ibid). For Angamuco, I have used a standard 0.00217 value similar to that of cities with moderate urban plans or a combination of intricate and major streets (Sevtsuk, 2018a; Sevtsuk & Mekonnen, 2012).

I used gravity index for Angamuco to explore how the city is connected, and to identify what locations have more influence in the network.

[8] It is actually a factor that controls the effect of distance decay on each shortest path between origin and destinations (see Handy & Niemeier, 1997).

Gravity of nodes

In Figure 6.31, the gravity of nodes (graduated by size) is presented at various radii: 500 m, 2,000 m, and no-limit. It is fairly clear again that nodes with higher gravity value (symbolized as bigger dots) are located in the same two areas observed before (SoC and NoE). What is particularly interesting is that within these areas nodes with high gravity values are located along important roads across the center of the site. This is the first time in my analysis that connected segments (the roads themselves) could be considered as important locations that influence the settlement of the site. At smaller radii (Figures 6.31 and 6.32) the NoE and SoC areas standout once again. However, at these radii there is not one gravity center in each area, but a few small clusters of nodes with high gravity that eventually bind together as one big cluster in the SoC area (Figures 6.32 and 6.33). Moreover, the NoE area also shows that these clusters are not centered around a *complejo* structure but instead around one section of a road. Since *Gravity* measures a version of *Reach,* but in this case considering the cost or impedance factor, it makes sense that nodes that are part of a road are better connected than nodes *near* but not *on* the road.

A final analysis on *Gravity* was done from all nodes to entrances at different radii (100 m, 250 m, 2,000 m and 6,000 m). The results (Figures 6.32 A and B) show a cluster of nodes with higher *gravity* values located in the southern part of the site but heavily leaning towards the western edge where the entrances are located. The results are similar for all radii. I suspect that the proximity of more than one entrance influences the *gravity* of the nodes.

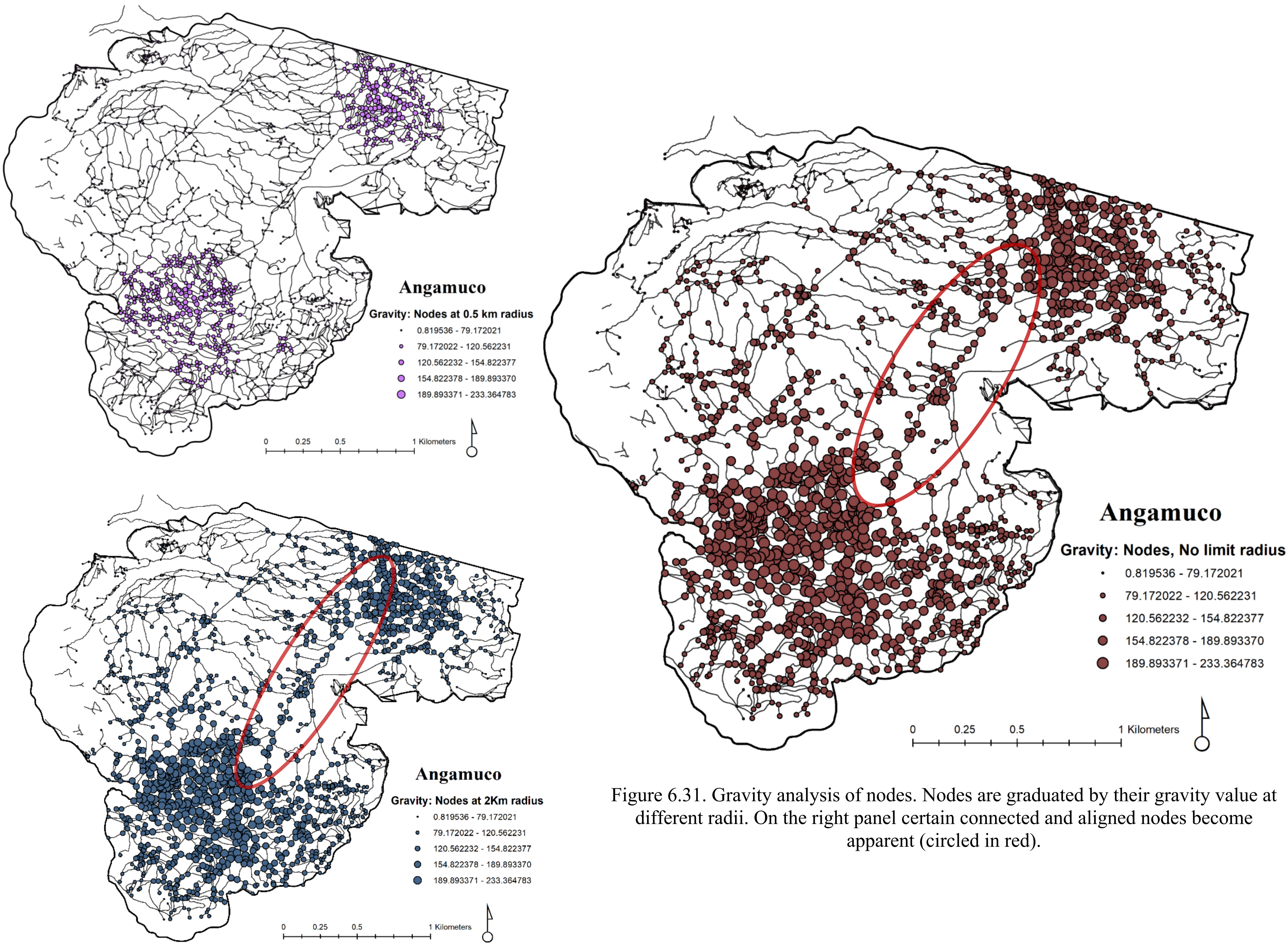


Figure 6.31. Gravity analysis of nodes. Nodes are graduated by their gravity value at different radii. On the right panel certain connected and aligned nodes become apparent (circled in red).

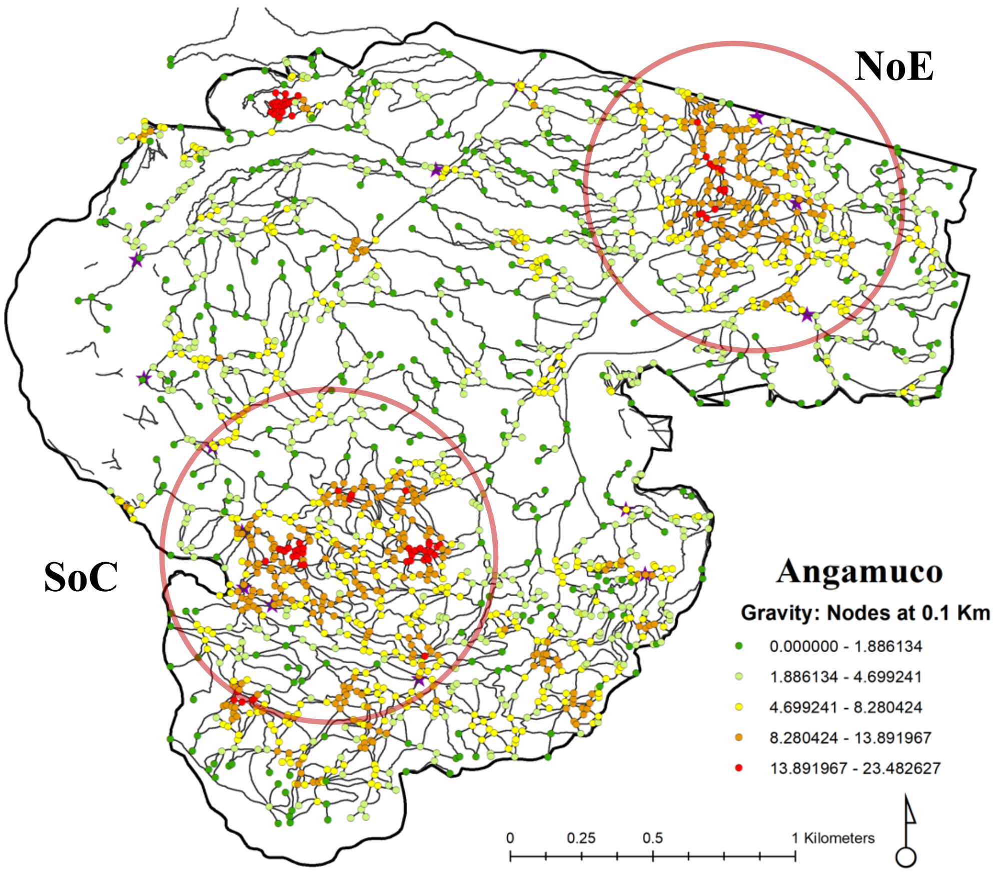


Figure 6.32. Gravity analysis of nodes. Higher value gravity nodes represented in red. The SoC area shows not one core but two small clusters of nodes as the gravity center. The NoE area shows nodes with high gravity value aligned on a road as the core center of gravity

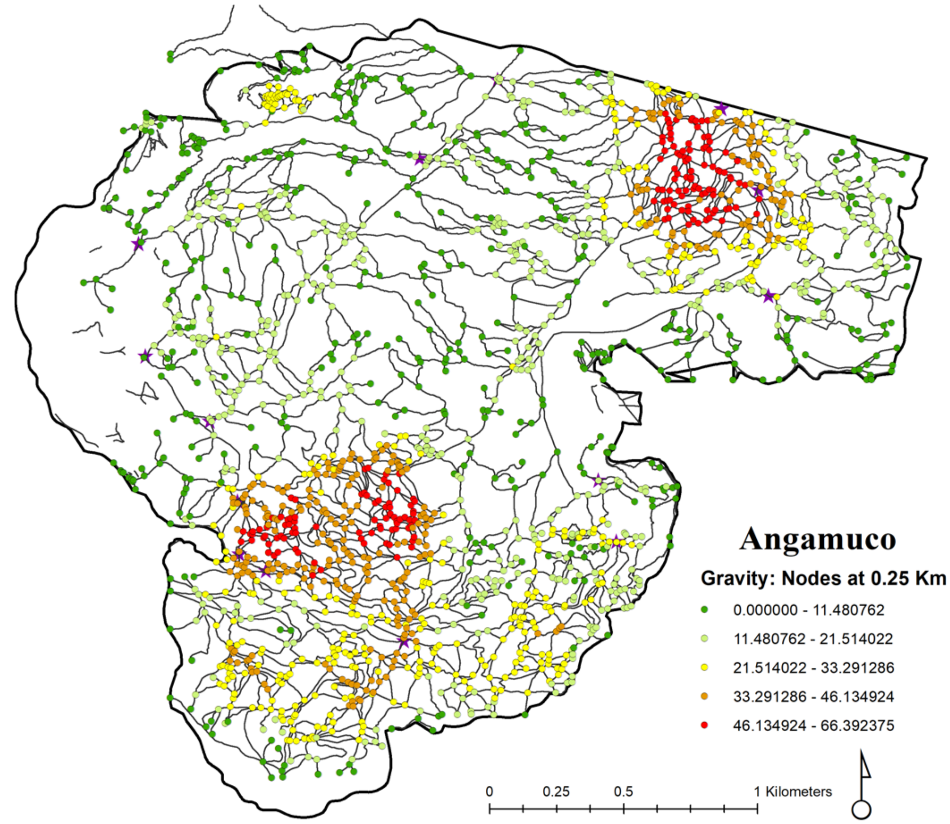


Figure 6.33. Gravity analysis of nodes. Higher value gravity nodes represented in red. The SoC area shows not one core but two small clusters of nodes as the gravity center.

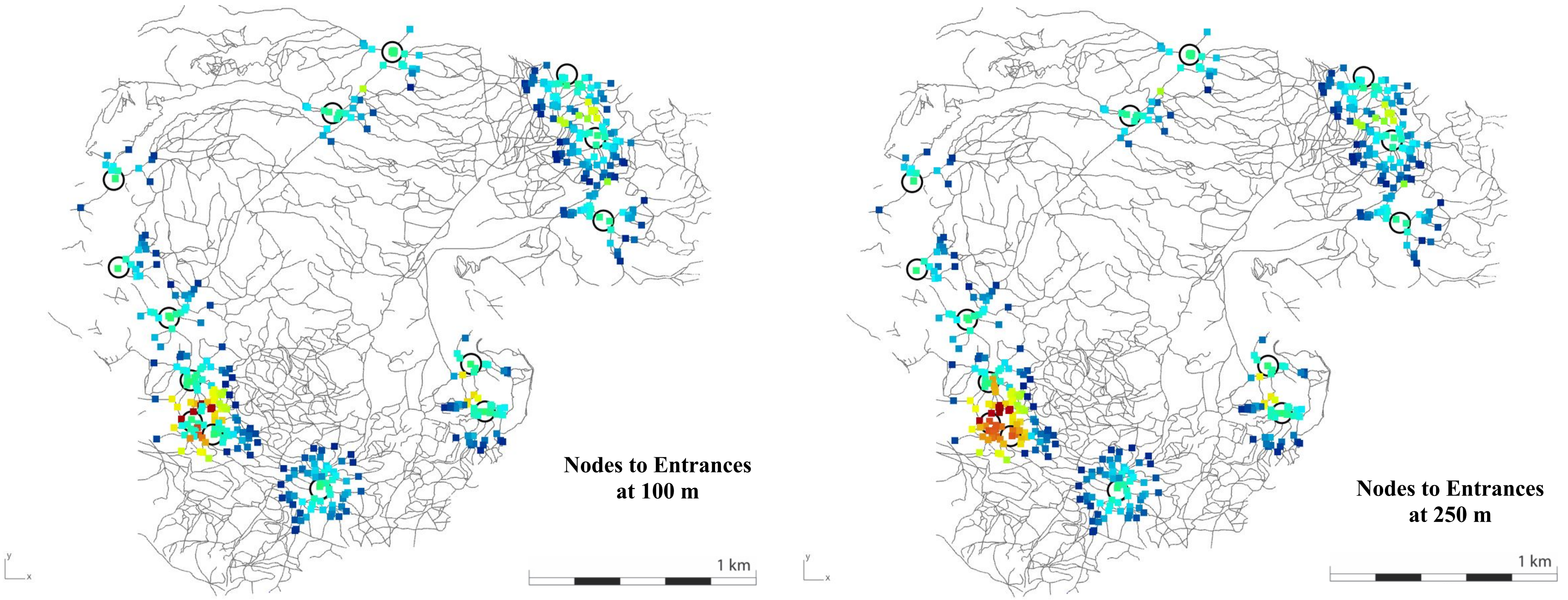


Figure 6.32.A. Gravity analysis of nodes to Entrances (black circles). Nodes are graduated by their gravity value from blue (low) to red (high).

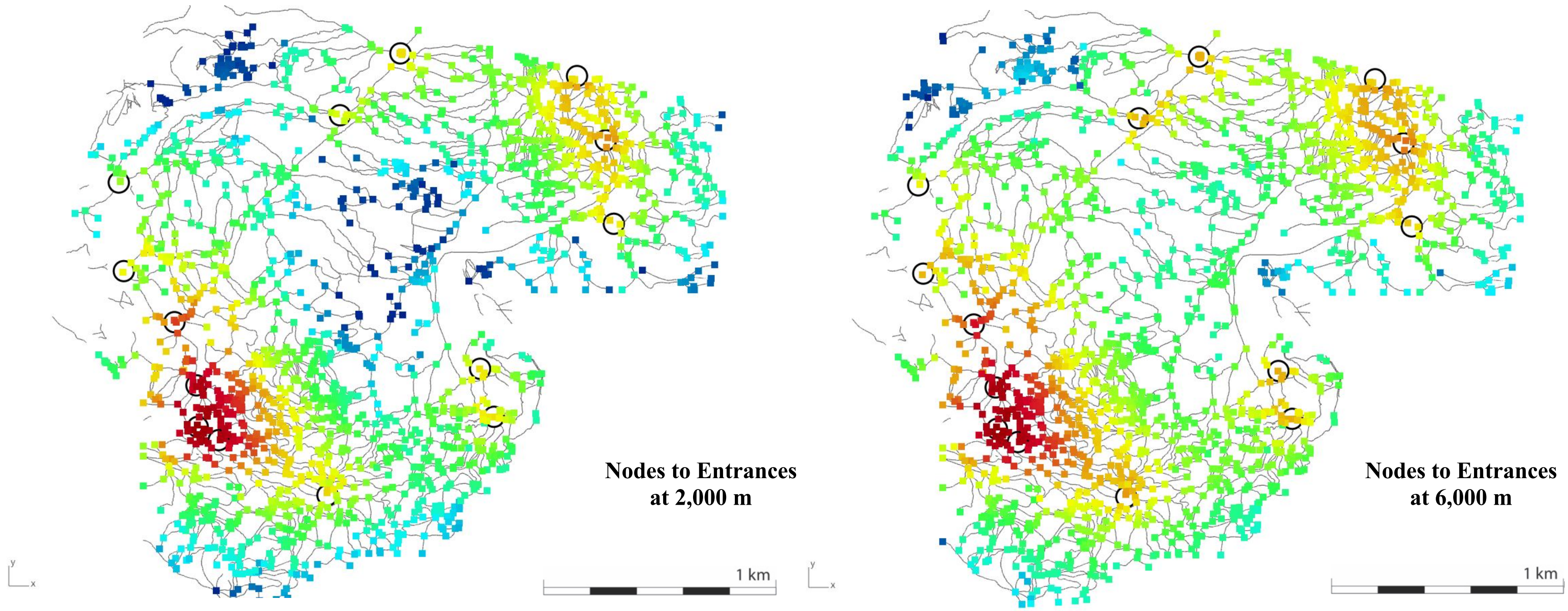


Figure 6.32.B. Gravity analysis of nodes to Entrances (black circles). Nodes are graduated by their gravity value from blue (low) to red (high).

6.1.4. Traffic-flow of Angamuco's road network

In order to better understand the road network, general patterns of movement, and identify important or influential areas of the city, it was essential to identify the most important and/or most transited roads of the city. Fieldwork helped detect certain characteristics of some possible major roads, but the proper extent or how many main routes were at the site was not entirely as clear.

A typical assumption when exploring movement within a city is that pedestrians will always prefer the shortest path to their destinations. As observed by others (Kazerani & Winter, 2009) this is not necessarily true due to a myriad of other factors that influence ultimately this preference, e.g. are routes safer? do they have more natural light? do they afford different views? do they go by specific locations?, and so on.

Calculating the many factors that influence how pedestrians choose their route is challenging, even for a network like the one for Angamuco that is semi-bounded (i.e., a network with known endpoints). In general terms, it is agreed that pedestrians on average will deviate from shortest paths using paths that are 20% longer otherwise (Sevtsuk, 2018a).

For Angamuco, I used two types of analyses: *Betweenness* and *Redundant paths* to find the major routes within the site. Through these two analyses I was able to discriminate the most-probable routes within the network. For example, I calculated all possible routes between two points with different detour probabilities.[16] Then, I assumed that the segments with most overlapping results comprise a highly transited route and connected locations that might have been more visited than other locations of the same category (e.g., entrances).

[16] See detour ratio below

6.1.4.1 *Betweenness* analysis

Betweenness is another centrality index that calculates the fraction of shortest paths between pairs of locations that pass by a particular location. Like all other centrality indices, the shortest path can be measured metrically (as in distance), or topologically (number of nodes/segments, or steps, it crosses.) (Kirkley et al., 2018). I used this index as developed for the UNA toolbox for ArcGIS and Rhino 3D to estimate the potential of passerby at the following locations: entrances, nodes, and *complejos'* centroids.

The results of *Betweenness* analysis are presented as the number of trips that pass by certain road segments. This analysis requires that one specifies the following: a) one or more origins; b) one or more destinations; c) search criteria (*nearest*: the closest destination from each origin; *all*: all the destinations for each origin; or, a *radius* distance); d) an *impedance* value (same as with *Gravity*); and e) a detour or deviation ratio. In addition, the same analysis was used to generate a model of pedestrian traffic. To this end, various origins were weighted by specifying a total number of hypothetical pedestrians (100 or 1,000) as an attribute. The results illustrate how many of those pedestrians would choose a certain segment and thereby show the distribution of pedestrians given a detour value.

For example, I was interested in identifying the most likely route between Entrances 3 (origin) and 5 (destination). The results are shown in Figure 6.33. All the segments that account for the shortest route are presented in red, and the total count of routes (rc) is 1. This means that all 100 pedestrians would choose those segments if they are only interested in taking the shortest path to Entrance 5. However, this changes considerably once detour values are incorporated in the model.

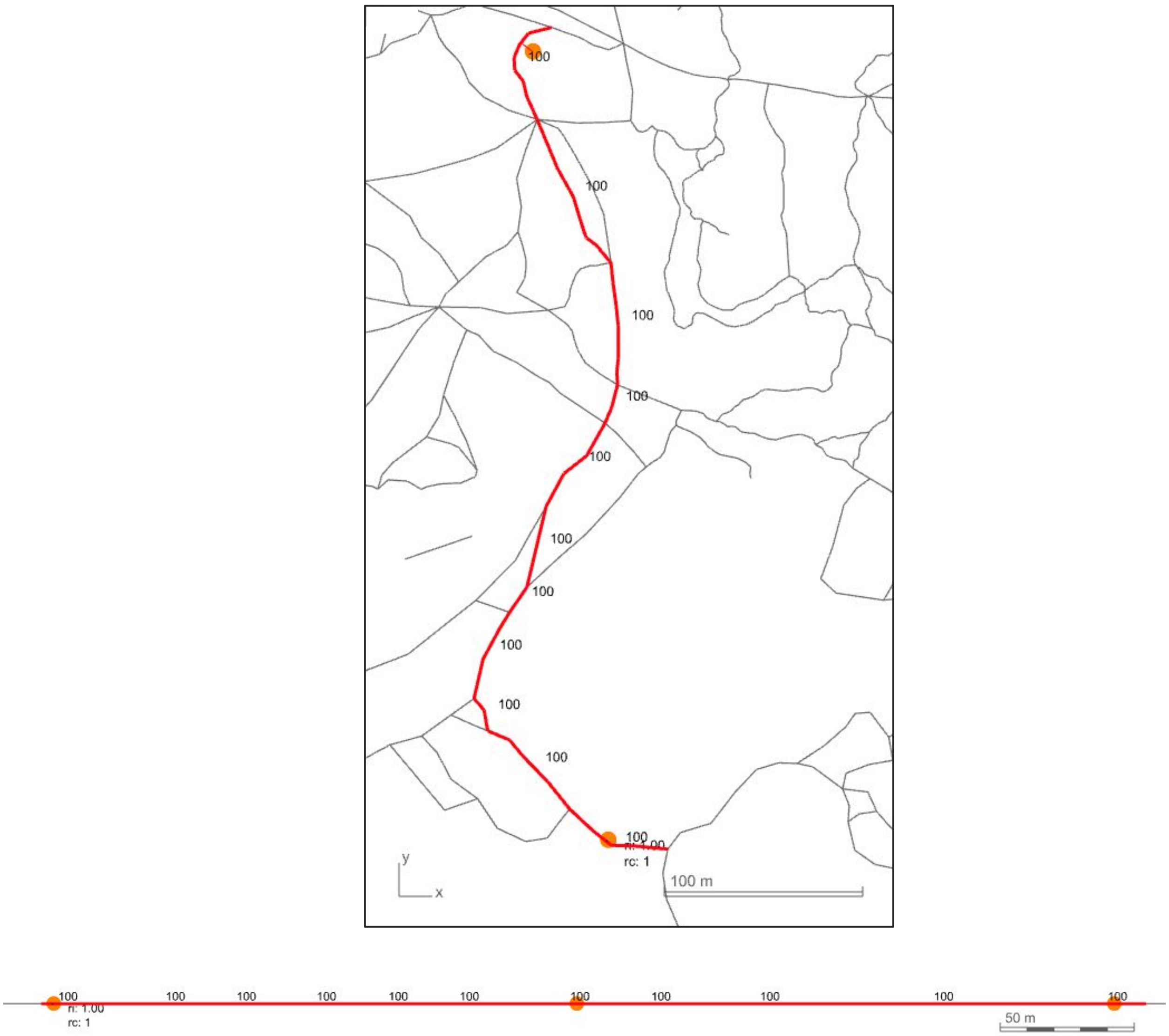


Figure 6.33 Detail of route between Entrance 3 and 5. Red segments show the combination of segments that account for the shortest route between these two points. Above a planview where Y axis represents north. Below a diagram of the total number of pedestrians by segment in the route.

Detour ratio

Detour ratio (a value between 1 and 2) is the proportion of allowed detours, or the ratio between the acceptable path length and the shortest path length (Sevtsuk, 2018a). It describes the percentage of the paths that must be no longer than the shortest path to be considered a deviation. For example, value of 1 means that acceptable and shortest path are the same, value of 1.5 means that 50% of the acceptable paths have to be longer than the shortest path. Thus, the total count of routes found between origin and destination that is up to 50% longer than the shortest route is computed as *route count* (rc).

By considering various detour values, more routes become available, and this better reflects the range of actual choices that pedestrians may have considered. The larger the detour value, the more path calculations have to be computed. This is further aggravated if the distance between origin-destination pairs are large. For example, the route between Entrances 3 and 5, goes from total count of 7 possible routes with a detour ratio of 1.1 (10%) to a total count of 319 routes when the detour value is of 1.5 (50%) (Figure 6.34).

In the same Figure 6.34 it is possible to see that how weights (number of pedestrians at origin node) can be used to trace pedestrian traffic. Looking at the left side of Figure 6.34, the four red segments (first, middle, and last) appear as being transited by the 100 pedestrians. At the first bifurcation from the south, the number of pedestrians splits into two: 71.42 continue in the more direct route (yellow), and 28.57 go on a small deviation formed by two small segments (green) that is only 10% longer than the shortest route.

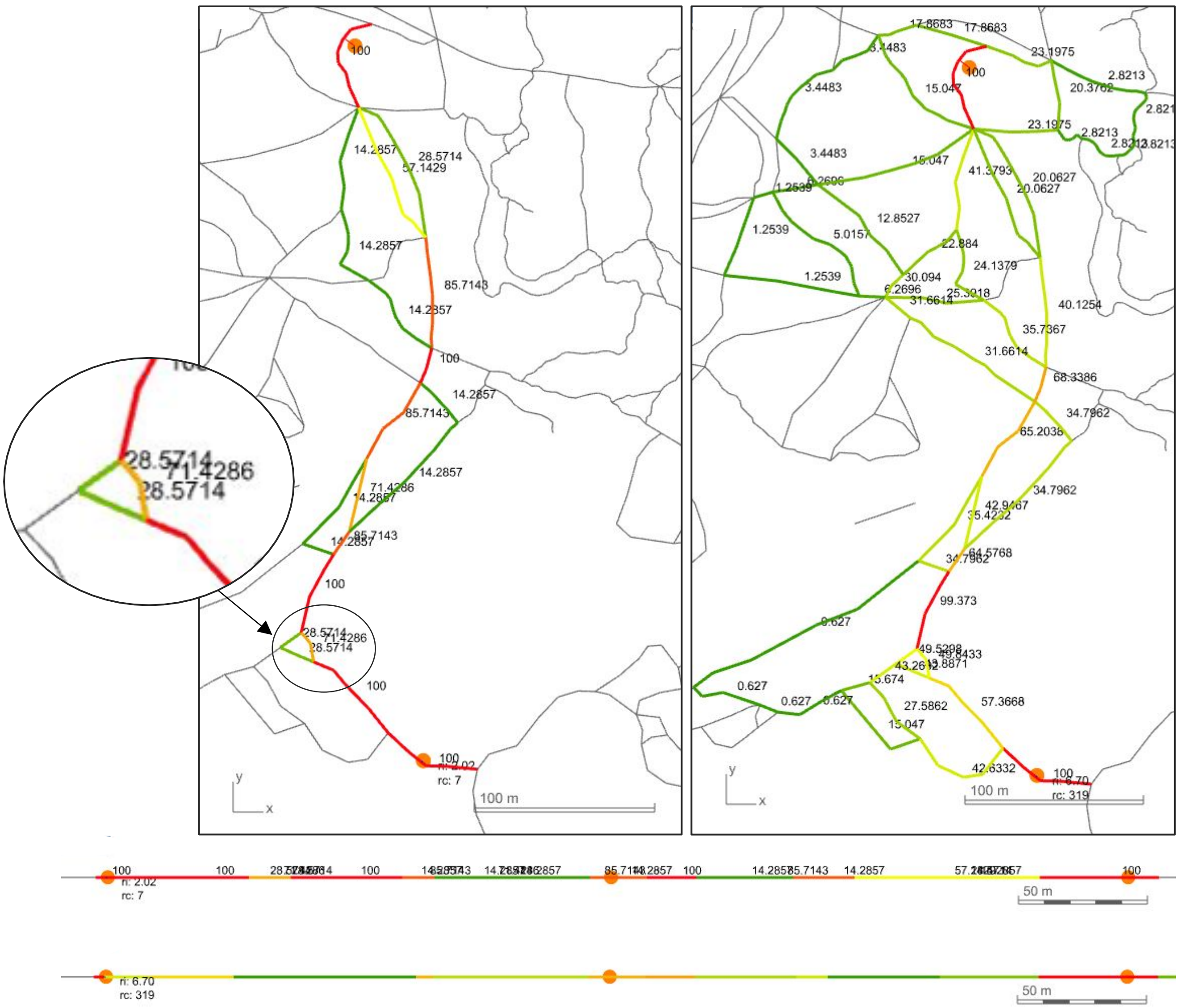


Figure 6.34. Two *Betweenness* analyses of the same pair of locations (Entrances 3 and 5). Left with a detour ratio of 1.1 and right with detour ratio of 1.5. Also, below the profiles seen form the East: top=1.1 and bottom=1.5. The inset shows section discussed above.

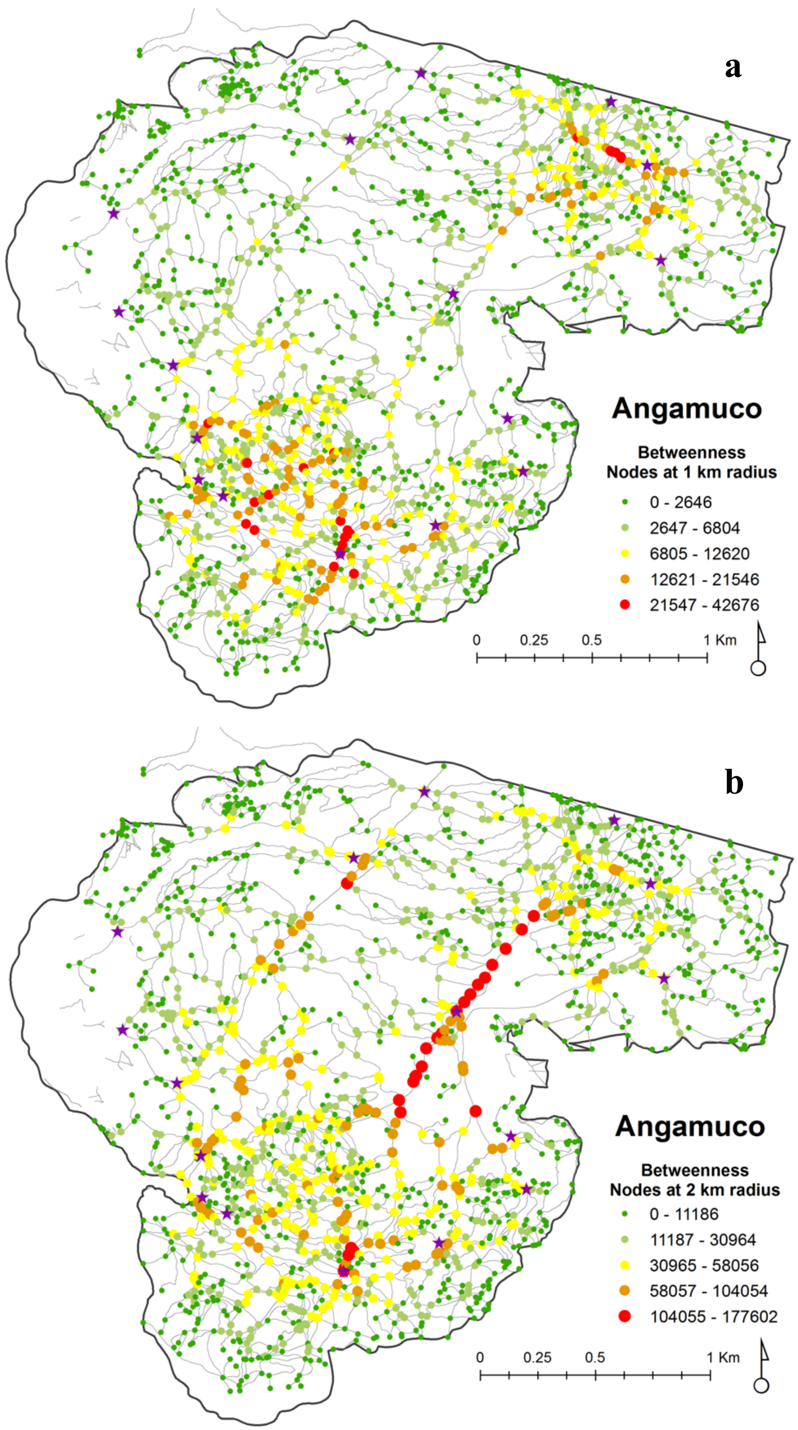
For this analysis, I used detour ratios between 1.1 and 1.2 since I am interested in the observation of the most likely transited road segments accounting for how fast or easy (less travel time) it is to reach desired destinations but also including a small possibility of deviation.

Exploring traffic

I calculated *Betweenness* from-nodes-to-nodes at 1 km, 2 km and no-limit search radii with a detour ratio of 1.2 (or 20% longer than the shortest route) (see figures Figure 6.35 a to c). The total amount of possible routes between all nodes was over 800,000. Nodes aligned with two parallel central roads going S-N that originate at the bottom of the site and pass by Entrances 1 and 3 have the highest level of *Betweenness* (see detail in Figure 6.36). This pattern is similar to what was observed through *Gravity* analysis. However, instead of seeing which nodes have an influence over their neighboring nodes (*gravity*), here we see which nodes are more likely to be crossed-by pedestrians regardless they destination, in other words, the most visited nodes of the site. These nodes are not distributed around the previously observed areas of well-connected network (SoC and NoE) but instead distributed along possible roads.

Both maps, Figure 6.35b and c, show a few aligned nodes with high *Betweenness* values (orange and red) lining up to form roads. However, moderately transited nodes (in yellow) also align to create roads that go E-W, following the escarpment in the southern hemisphere of the site. These appear to connect with the main two N-S roads (for clearer example see detail in Figure 6.36). It is noteworthy that all these alignments in the south connect with the main entrances.

Next, I explored another analysis of routes (boundary-to-boundary nodes).



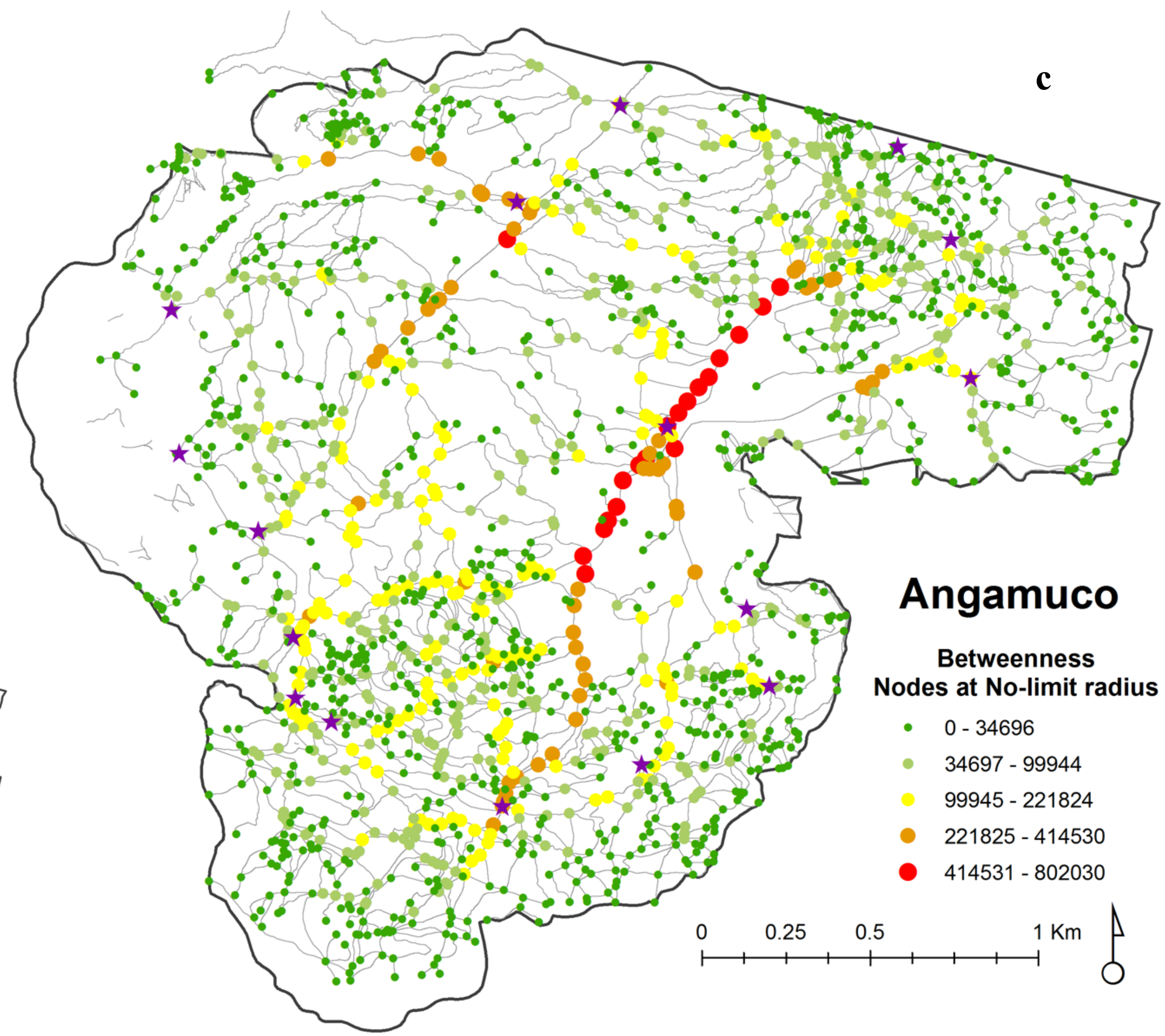


Figure 6.35. *Betweenness* analysis of nodes-to-nodes. Nodes are graduated by the number of trips they would have using a detour value of 1.2. Entrances are showed as purple stars.

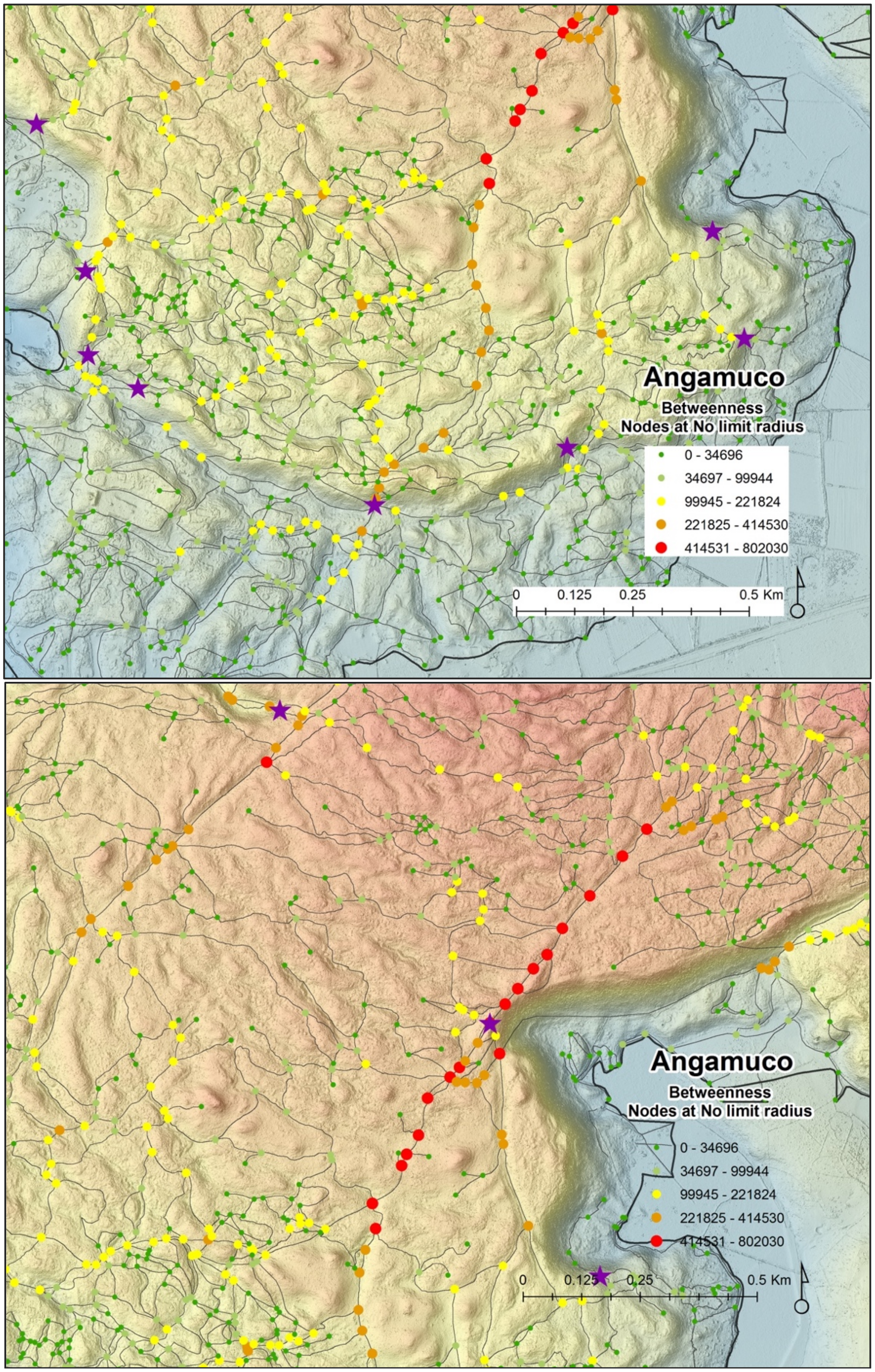


Figure 6.36. *Betweenness* analysis of nodes-to-nodes with a detour ratio of 1.2 and no limit radius. Alignment of most visited nodes (orange and red) form an incipient skeleton of possible main roads, especially moderately visited nodes (yellow). Most Entrances (purple stars) are connected to these alignments.

In order to explore long distance traffic, I calculated the betweenness of the most remote points in the network (boundary nodes or endpoints) with a detour value of 1.15. These points show a more diverse set of possible routes that reflects the wide variety of origins and destinations used. Figure 6.37 shows the results (in blue are the less transited segments and red the more transited) which are similar to those from the betweenness of nodes-to-nodes. Again, sections of the main N-S parallel major roads are distinguishable, although two other very long and straight segments in the eastern section of the site show that they might have also been heavily transited. In that sense, Figure 6.38 shows a detail of an eastern area with the individual counts of routes. Here we can see that segment S9X168, is the highest transited segment of the site (2,484 rc).

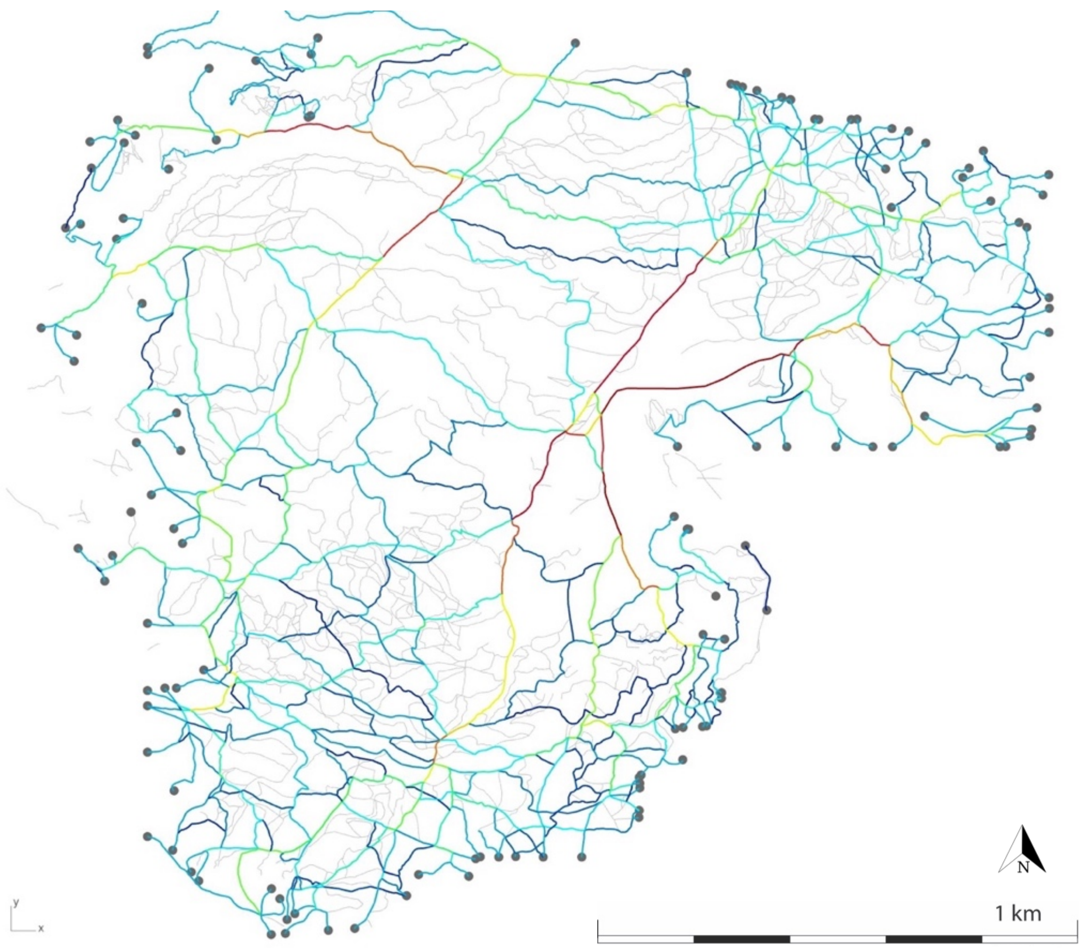


Figure 6.37. *Betweenness* analysis of boundary-to-boundary nodes using Detour ratio of 1.15. Boundary nodes represented in gray dots. Light blue (less transited) to dark red (more transited).

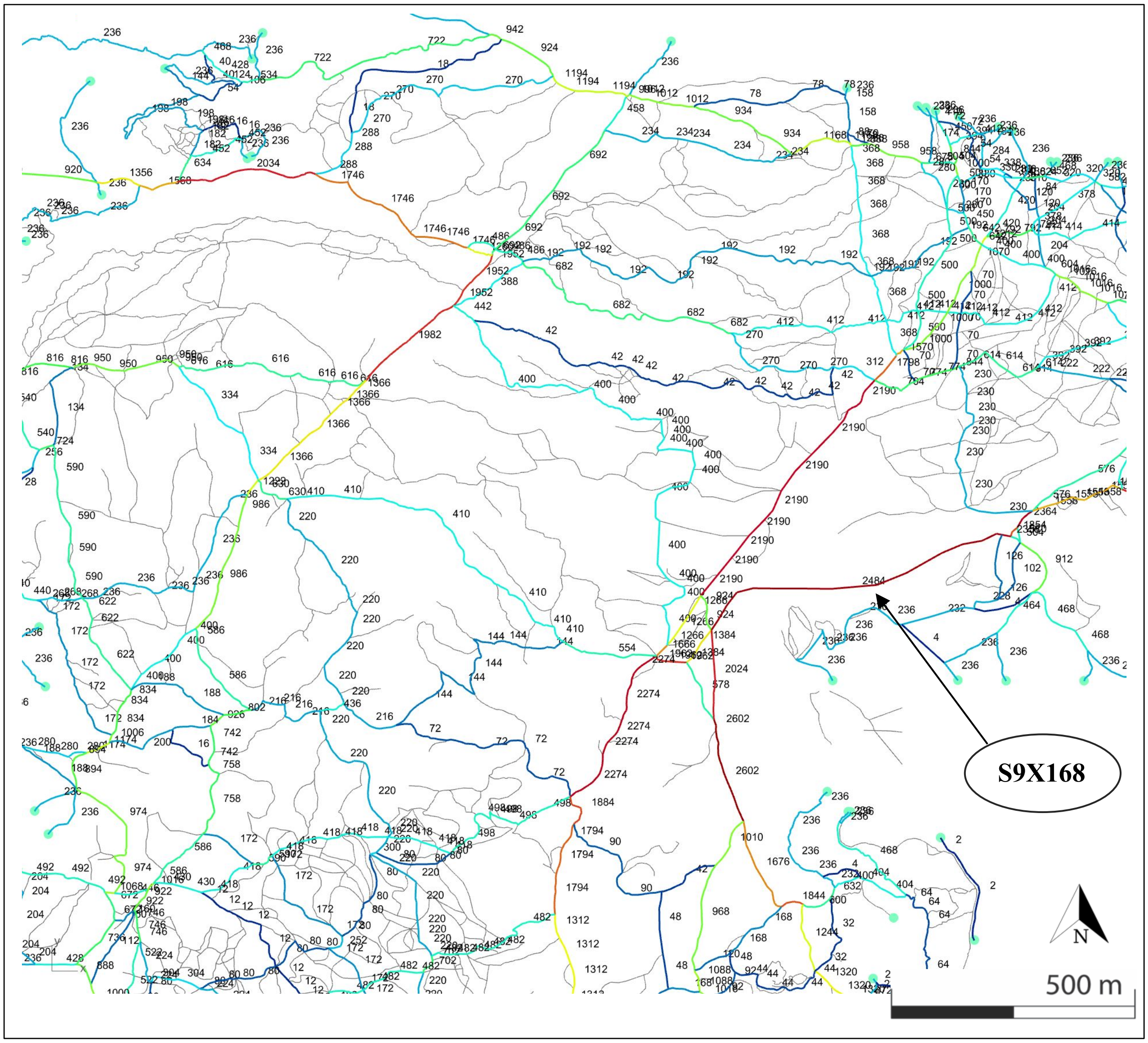


Figure 6.38. Detail of *Betweenness* analysis of boundary-to-boundary nodes using Detour ratio of 1.15. Boundary nodes represented in light blue dots. Light blue (less transited) to dark red (more transited) segments. Segment S9X168 is noted on the right side of figure.

Entrances

A second approach to explore possible transited routes is conducting a *Betweenness* analysis using each individual entrance (single origin), to all other entrances (multiple destinations) with different detour ratios (0, 1.05, 1.1, 1.15 and 1.2). In total, I performed 70 individual runs. Figures 6.39 and 6.40 show the most significant results. As a result, most of the routes used sections of the central parallel major roads (S-N) and few other perpendicular roads (E-W). By repeating the same calculation with small alterations to parameters, it was possible to identify the most transited segments. For example, when calculating betweenness for Entrance 12 (westernmost entrance) to 4 (easternmost entrance), the most used segments were generally the same, regardless of detour options (yellow to red segments in figure 6.41).

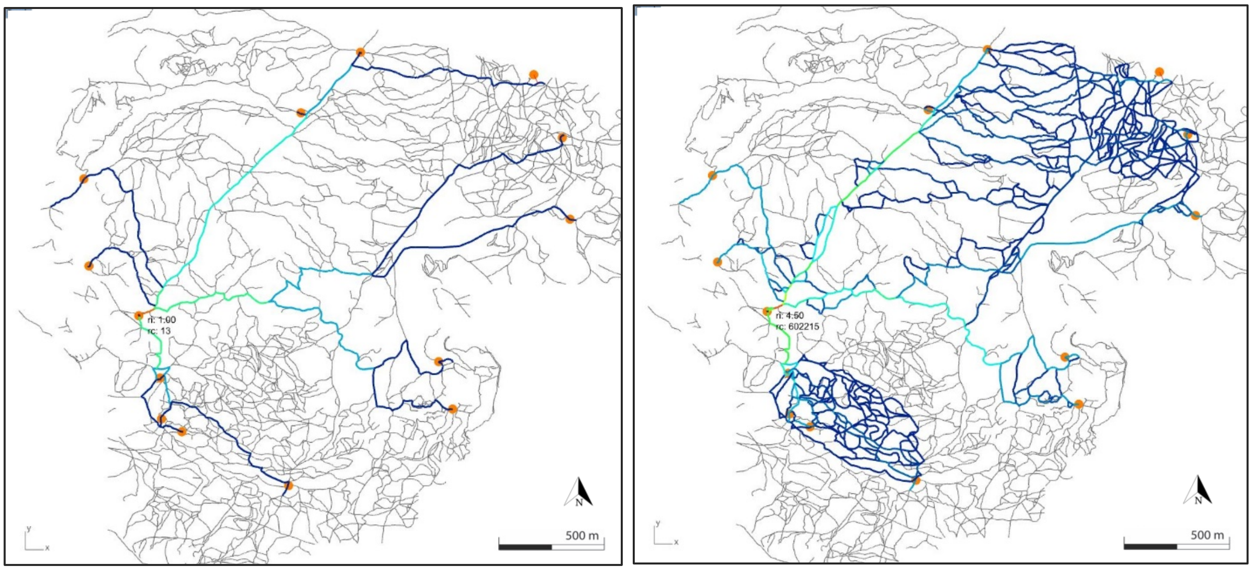


Figure 6.39. *Betweenness* analysis of Entrance 2 to all. Detour: left 0% and right 5%

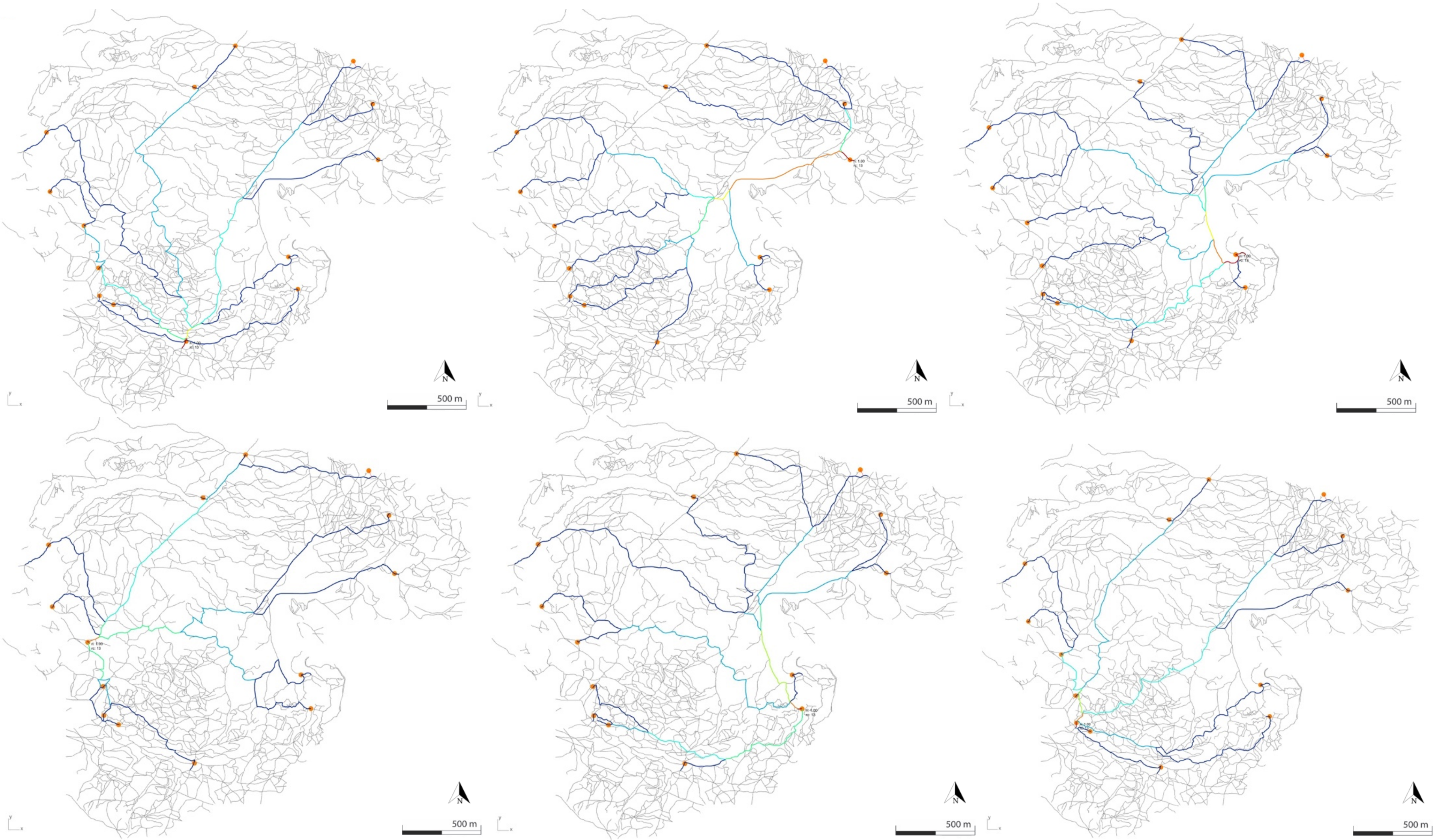
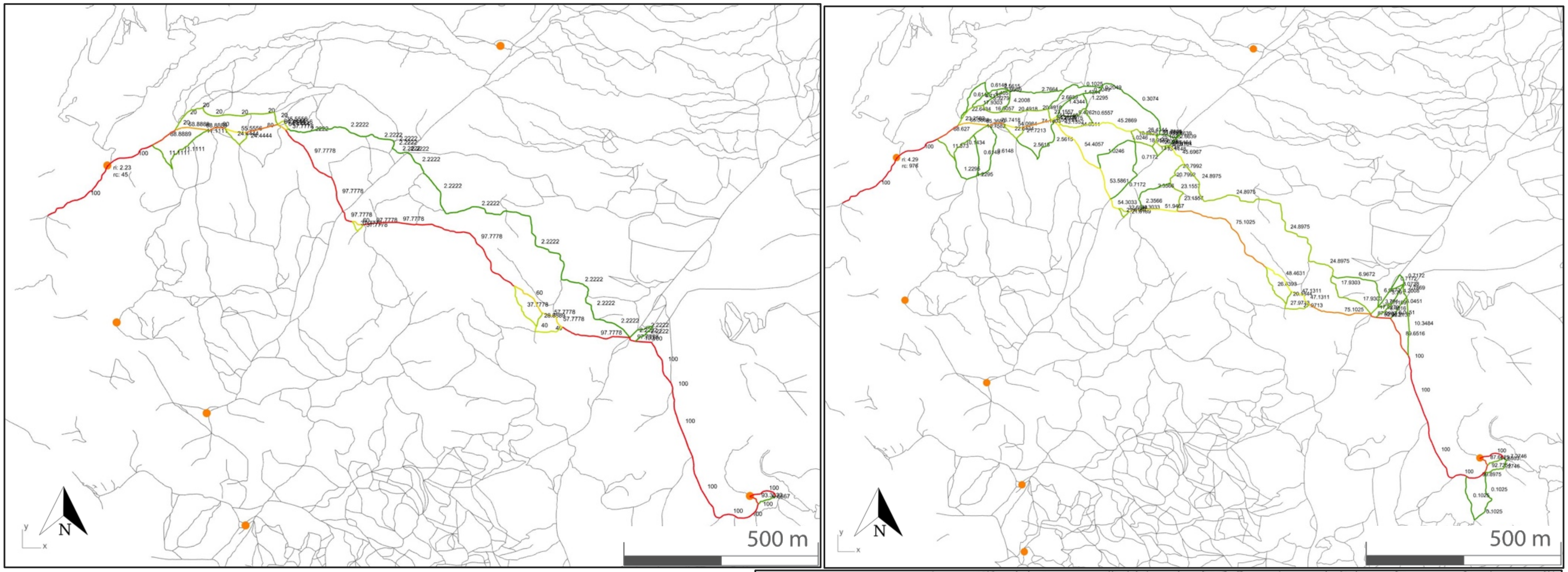


Figure 6.40. *Betweenness* analysis of one Entrance to all for most direct route. Top from left to right: Entrance 1, 3, and 4. Bottom form left to right: 2, 7, and 8.



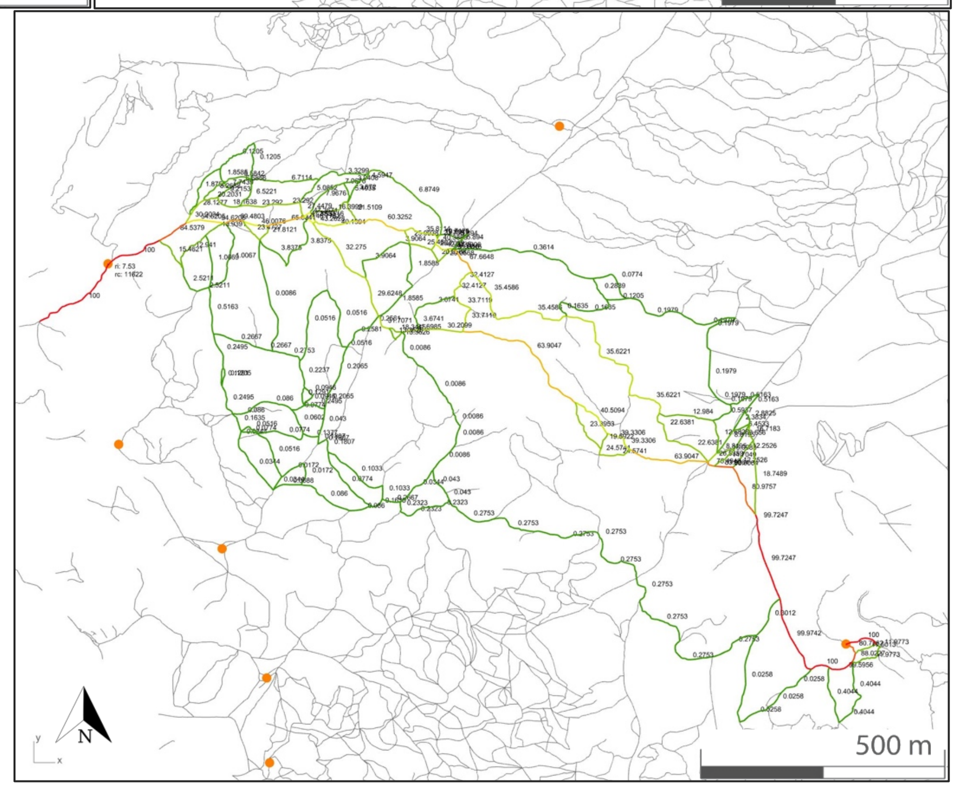


Figure 6.41. Betweenness analysis of Entrance 12 to 4 with detour values: 5% (top left), 10% (top right), and 15% (bottom right). Entrances in orange. Route options change considerably when adding detour options but the main segments remain the same.

Brief summary of observations of *Betweenness* analysis

The total number of routes (rc) is generally the same between similar O-D pairings (e.g., east to west, north to south,), which can be interpreted as a well-connected network, where even considering deviations there are enough other similar options to get to locations in the same area of the site.

The same most-likely-transited segments consistently appeared with different O-D pairings and detour options, for example, the central N-S main roads, the circulating road below the escarpment, and the connecting E-W roads across the site. Another interesting observation was that segment S9X168 on the east side of the site appeared to be a good option for traffic for many combinations of O-D (see Figure 6.38). This segment was not initially identified as important in the field or digital road extraction. During different *Betweenness* analysis, it continuously showed up as a road likely hosting traffic. I suspect because it is a straight and long (620 m) single segment.

Betweenness analysis is a very good first approach to see broad patterns of traffic. Next, Redundancy index helped me identify and extract the main roads of Angamuco.

6.1.4.2 Redundancy analysis

Redundancy Index (Ri) calculates the increase of linear distance beyond that of the shortest path given a detour ratio. With this index it is possible to find alternative routes between points expressed as the combined length of all routes between origin and destination, divided by the length of the shortest path (Sevtsuk et al., 2014). In other words, Redundancy index tell us how much more distance is added for a trip in the network, when including a detour percentage beyond the shortest path for that particular trip. For example, if an inhabitant of Angamuco travels from their house to the nearest water source, this test identifies how many other route options (road segments) that person could take if they decided to walk 5% more than they would have if they used the shortest route possible (see example in figure 6.42).

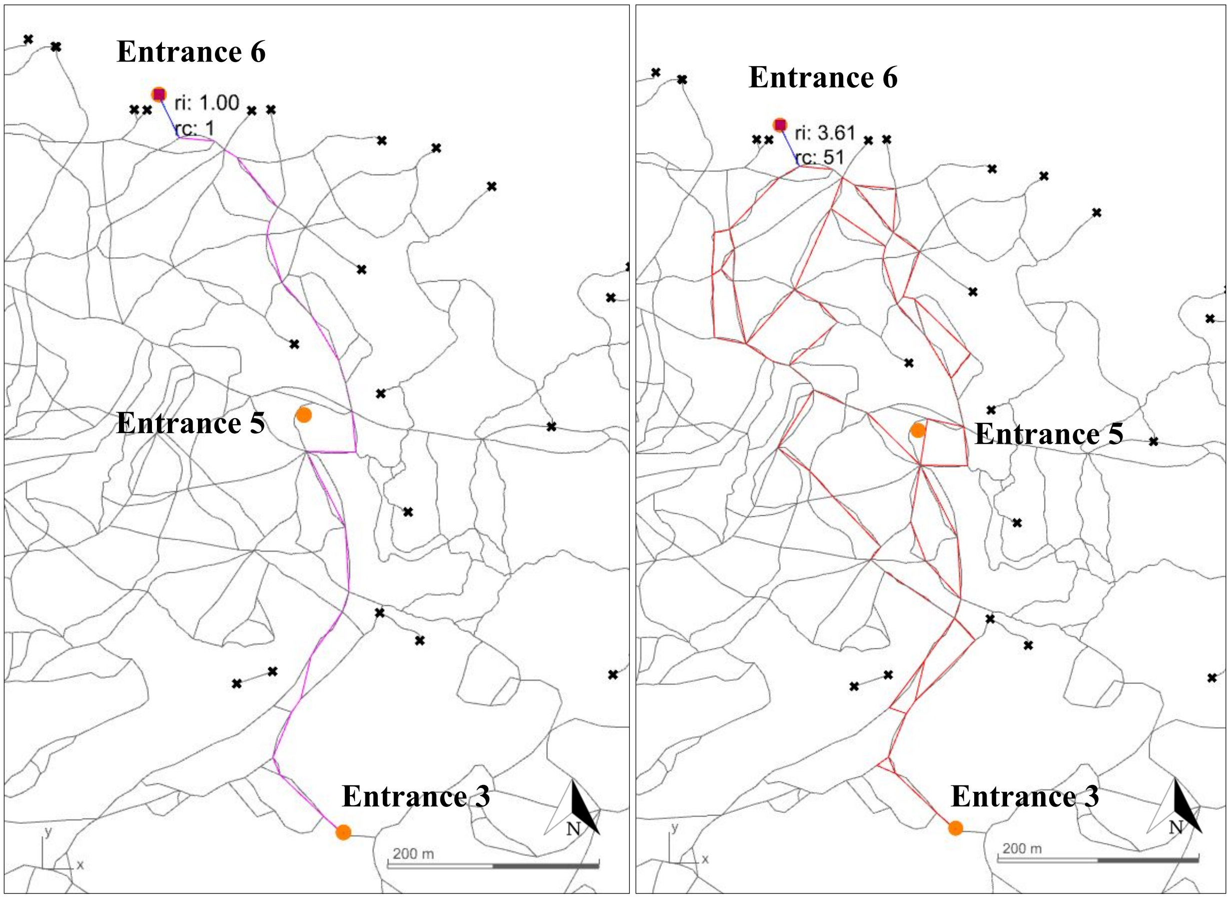


Figure 6.42. Both images are calculating the Ri between Entrance 6 and 3 (orange dots). The left side is not using a detour value, therefore only the nearest route and Ri is equal to 1. On the right side, there is a 5% detour value that exponentially adds to a total of 51 unique routes (Route count or Rc) and a value of 3.61 for Ri, or, 3.61 times the total distance of shortest path. It can be observed too that when calculated for the nearest path (left) Entrance 5 is not visited but when added a 5% detour then some of the new routes pass by Entrance 5.

For Angamuco, I calculated the Ri for several origins (entrances and nodes) to identify which of those origins might have been more transited or had more direct routes. Generally, if origins or destinations are known (e.g., the ceremonial center of a city, the location of wells, markets, or other important locations) then, it is easier to explore possible routes representing routine daily walks for commoners. The challenge was identifying such destinations. For Angamuco, we would need to first assign particular values or interest to all structures in the site.

For example, a pyramid would be of interest to people beyond their own neighborhood even if it is not visited on a daily basis. Therefore, it is relevant to explore the routes that best connect it to all other *complejos* or neighborhoods. Since I have only identified a few possible pyramids such analysis would be biased (e.g., results would be different if instead of 25 pyramids, there are actually 50 in the site). Instead, I performed Redundancy analysis on the following well-known locations:

a) Entrances,

b) Nodes, and

c) Boundary nodes (edges of the network, likely the most distant points in the network).

Redundant paths (Rp) is a different tool to calculate *Redundancy*. It also computes alternative routes between origin and destinations given a detour. However, in this case, only simple paths (without loops or repeated nodes) are considered. Other researchers have used this analysis to suggest pedestrian choice of routes in modern cities (Lerman & Omer, 2016; Sevtsuk et al., 2016; Tal & Handy, 2012).

The analysis using both of these indexes Ri/Rp focused on the entire network to illustrate how traffic may have looked when considering different detour ratios and on specific routes (mainly between entrances).

I used the Redundancy tools available through the UNA toolbox for ArcGIS and Rhino 3D. The detour values were limited to 5%, 10%, and 15%. Below I illustrate the use of *Redundancy* indexes using complejo polygons.

Complejos

In this analysis, all *complejos'* centroids were used as both the origin and destination with a detour ratio of 5%. The results suggest essentially that central *complejos* have fewer available options to reach other *complejos* as opposed to *complejos* in the outskirts of the city. This makes sense, the further away one's destination, the more road segments are available to reach it. Interestingly, several complejos on the southeast and southwest areas (next to water reservoirs) have limited route options to reach other *complejos*, as well like *complejo* 12 or excavation area D (Cohen, 2016; Fisher et al., 2016). This was an important habitational area for the elite just north to the grand Yácata and Plaza. It suggests that while this important complejo is in a well-integrated area of the site, its centroid is not well-connected to the network. Thus, the core area of houses for the elite (possibly priests, political figures, and/or royal family) was not totally accessible from many points in the network or was purposely kept secluded (Figure 6.43).[18]

[18]More detailed work needs to be done at the complejo scale to support this argument

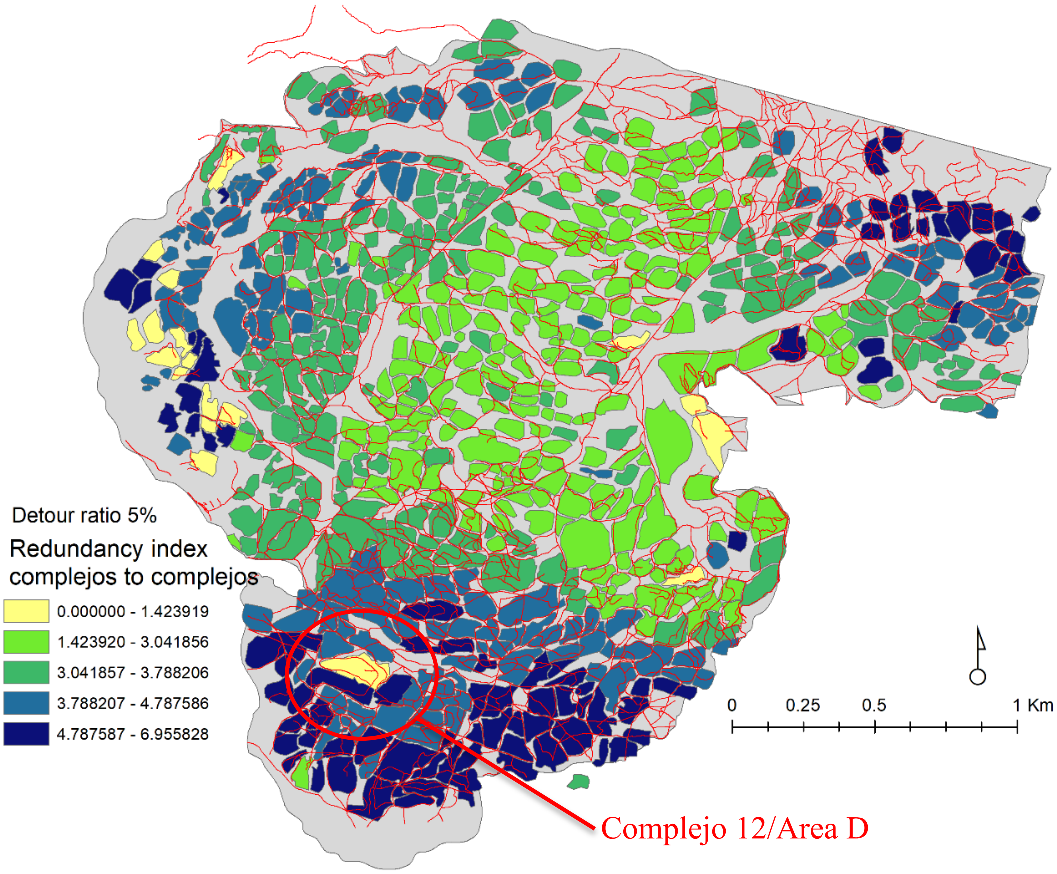


Figure 6.43. Map of Angamuco showing the Ri between *complejos* (each other) using a detour ratio value of 5%. The yellow *complejos* have less available redundant paths to reach from any other *complejo*.

Pedestrian traffic of Angamuco and identifying main roads

To identify the major roads of the site (most likely transited segments) I first needed to get a sense of what areas, nodes, and entrances were most likely visited. I used the locations with the lowest Ri as a proxy of the most secluded or least visited locations (origin), and the highest Ri values as the most visited ones (destination) to create origin-destination pairs. I did this for *complejo* centroids, neighborhood centroids, district centroids, city-blocks centroids,[19] boundary nodes, nodes, and entrances, plus pairings of distant entrances (see Table 6.8 and Table 6.9 for Redundancy results). I used various parameters for the detour value for each of these Ri

[19] See discussion of city-blocks in chapter seven, section 7.3.2.

calculations. Consistencies of the Ri values appeared between 5% and 10% detour. In total, I created 24 significant O-D pairings in the site.

TYPE OF LOCATION	ID HIGHEST Ri (ORIGIN)	Ri VALUE	ID LOWEST Ri (DESTINATION)	Ri VALUE
Entrances	6	11.21	12	5.81
	6	11. 21 Northernmost	1	5.99 Southernmost
	3	7.05 Easternmost	12	5.81 Westernmost
	1	5. 99 Same period	2	7.08 Same period
Nodes	N5X013	11.20	N3X154	5.25
Boundary Nodes	3052	11.63	9035	5.27
Complejo Centroids	199	6.95	505	2.13
Neighborhood Centroids	21	10.25	47	5.62
District Centroids	N	9.96	I	5.27
City-block Centroids	15	10.90	621	4.8

Table 6.8. Table of O-D pairings according to their Ri values. All Ri values are calculated at 10% detour and for those destinations participating in the network (e.g., not isolated from the network).

TYPE OF LOCATION	ID HIGHEST Ri (ORIGIN)	ID LOWEST Ri (DESTINATION)	Ri VALUE	TOTAL ROUTES COUNT
Entrances	6	12	7.62	8,615
	6	1	4.17	34,705
	3	12	5.34	2,242
	1	2	7.83	2,538
Nodes	N5X013	N3X154	9.13	16,139
Boundary Nodes	3052	9035	4.91	225,048
Complejo Centroids	199	505	1.63	23
Neighborhood Centroids	21	47	2.67	1,386
District Centroids	N	I	4.63	1,176
City-block Centroids	15	621	7.89	84,698

Table 6.9. Results of Rc for O-D pairings. All Ri values are calculated at 10% detour and for those destinations participating in the network (e.g., not isolated from the network).

Once the location pairs were identified (Table 6.10), I calculated the Rp for each pair at a 10% detour (5% for the entrances). Since each pairing had a unique number of total routes (see examples in Table 6.9 and Figure 6.44), I grouped paths based on the probability of being used. For example, between Entrances 1 and 2 there are a total of 11,228 individual paths at a 5% detour ratio. The top 20% of the redundant paths (segments that are used more times) have between 6,721 and 11,228 total routes. By contrast, between Entrances 7 and 10 there are only 93 redundant paths, and the top 20% were only visited between 76 and 93 times. Network segments with >80% of the total individual paths for each origin-destination pairing were considered "highly transited".

Hence, I created a four-tier road system based on the most transited segments for the entire network. The top three tiers are extracted from of the upper 20% of the redundant paths or the "highly transited" segments between the 24 most significant O-D pairings, and the last tier refers to the lower 80% of such O-D pairings plus all remaining segments (Figures 6.45 to 6.46):

1) *Main roads:* >81% of "highly transited" segments.
2) *Secondary roads:* 61% to 80% of "highly transited" segments.
3) *Tertiary roads:* 41% to 60% of "highly transited" segments.
4) *Common roads*: lower 40% of "highly transited" segments plus all other segments that did not appear in the redundant paths' analysis.

The total process for identifying the most transited roads took over a month at the DigAR Lab. The biggest challenge was the amount of computer power each of these analyses took (Ri and Rp), which, at times, was as much as 20 hrs per pair of significant O-D. Because of this, calculating the Ri or Rp was practically impossible for large data sets like nodes or complejo centroids. So, I used a random sample for each of these datasets instead.

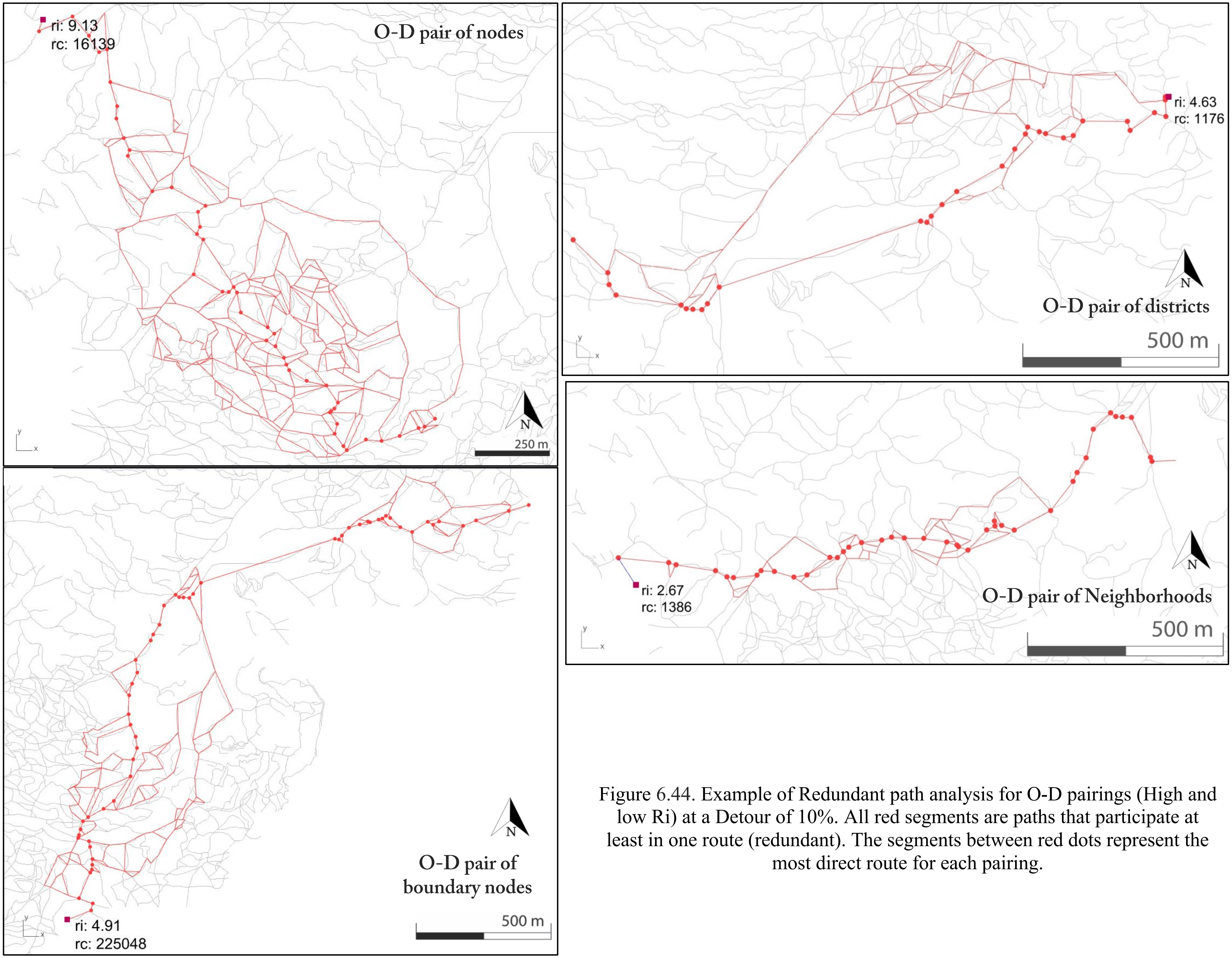
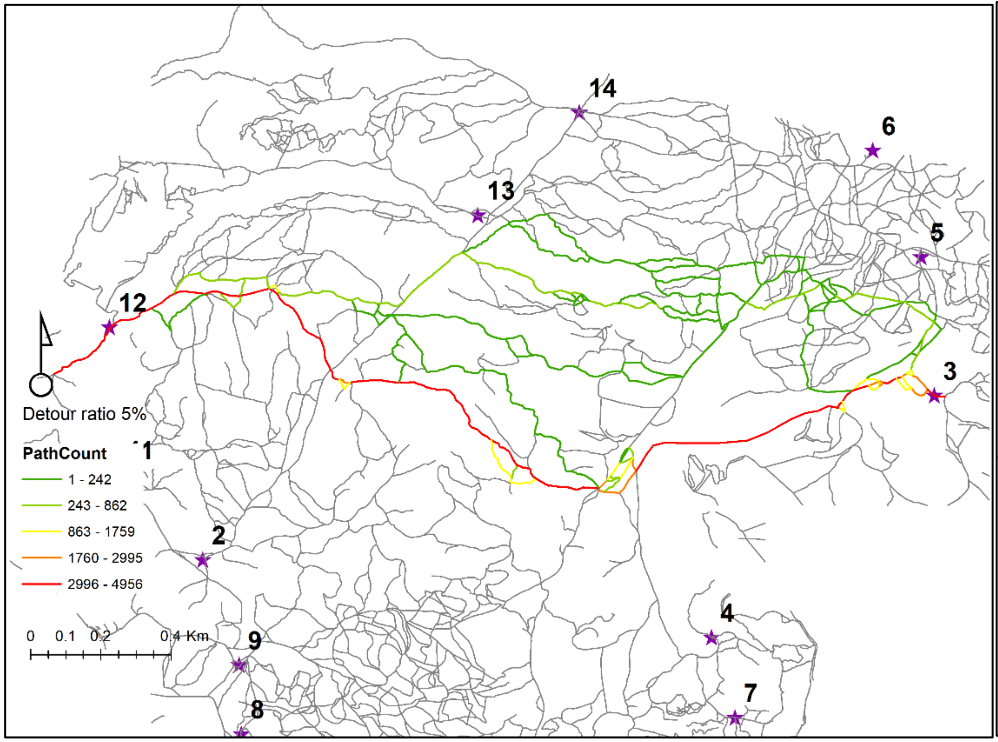
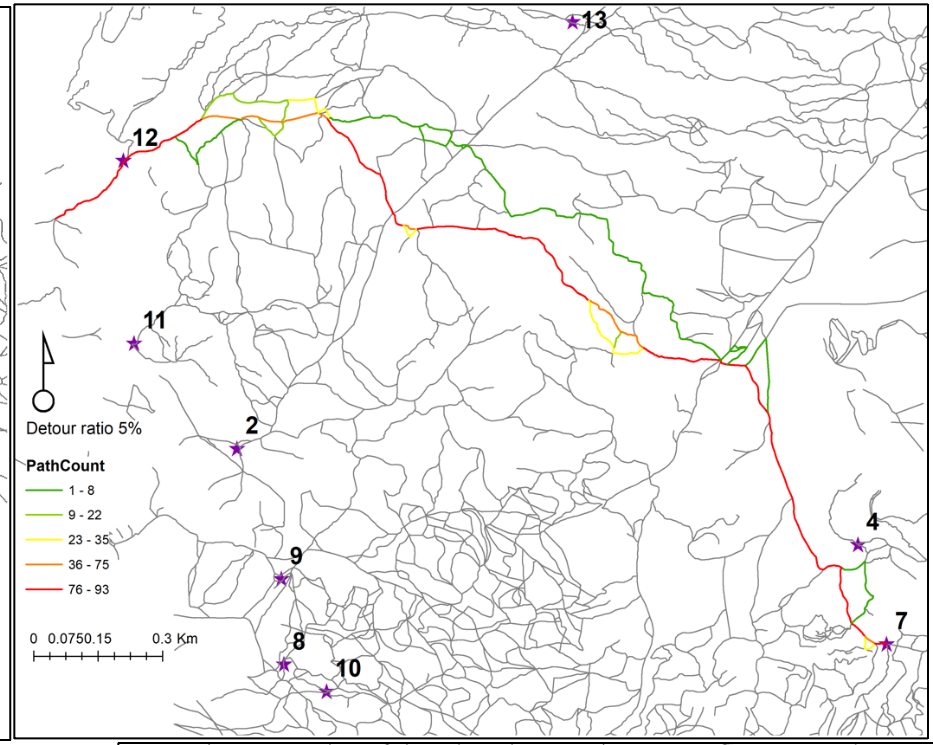


Figure 6.44. Example of Redundant path analysis for O-D pairings (High and low Ri) at a Detour of 10%. All red segments are paths that participate at least in one route (redundant). The segments between red dots represent the most direct route for each pairing.





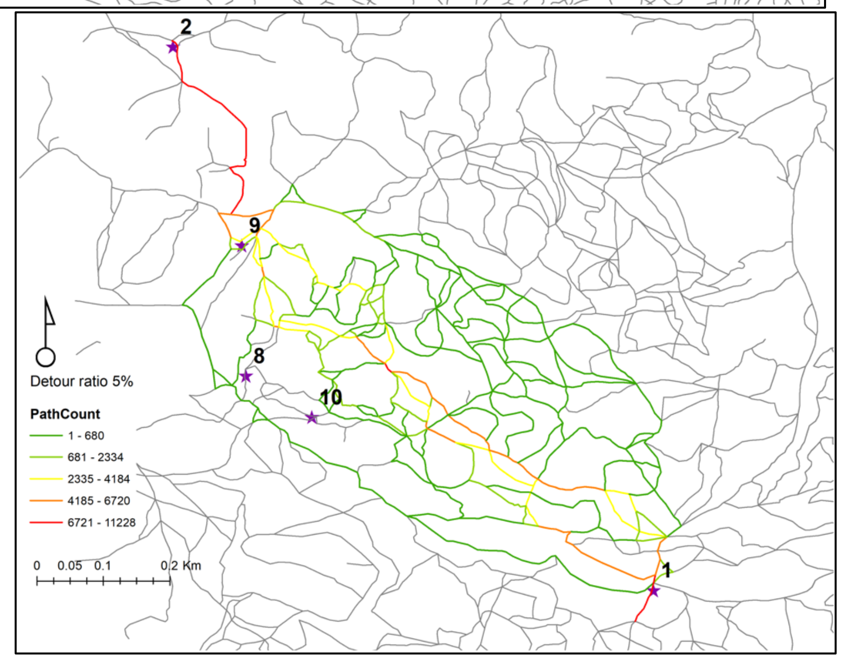


Figure 6.45. Example of Redundant path analysis for O-D pairings of opposite entrances at a Detour of 5%. Rp is graded from green (least rp) to red (most rp).

LOCATION	ID	Ri VALUE (AVERANGE REDUNDANCY)	LOCATION	ID	Ri VALUE (AVERANGE REDUNDANCY)	LOCATION	ID	Ri VALUE (AVERANGE REDUNDANCY)
Entrances	6	11.21274	City Blocks	52	10.893155	Boundary Nodes	3052	11.627321
	1	10.551686		82	10.533585		3073	11.222876
	11	9.705404		88	9.750742		3024	10.777014
	9	8.041987		773	9.443823		3036	10.776426
	13	8.021296		800	9.319349		3053	10.548635
	14	7.389547		42	9.305157		3057	10.393814
	2	7.085316		806	9.211915		3016	10.390955
	7	7.061513		874	9.197546		3015	10.382413
	3	7.055767		844	9.196681		9013	10.355572
	5	6.824387		701	9.050073	Nodes	N5X013	11.203172
	4	6.812071		759	9.036426		N4X021	11.063824
	8	6.388718		1	9.030289		N4X008	10.851004
	10	6.261545		5	8.977148		N8X026	10.850949
	12	5.817689		744	8.864586		N5X117	10.687558
Districts	N	9.964997	Complejos	199	6.955828		N5X007	10.671309
	O	9.938018		200	6.955828		N3X3027	10.653044
	C	9.937569		201	6.955828		N5X003	10.276475
	B	8.566679		237	6.456912		N9X120	9.422769
	F	8.471825		238	6.358395		N3X055	9.183602
	D	8.056029		239	6.358395		N5X037	9.116988
	A	7.630086		610	6.345996		N8X392	9.109978
	H	7.375316		569	6.299671		N3X060	8.934909
	G	7.259947		195	6.275365		N3X3003	8.927905
	J	7.051714		196	6.275365		N3X128	8.911405
Neighborhoods	21	10.25565		614	6.266324		N9X153	8.870032
	3	9.988115		613	6.249314		N3X2002	8.858273
	42	9.909152		653	6.2307		N8X516	8.849008
	22	9.873393		581	6.096076		N8X576	8.844168
	34	9.856308		608	6.060655		N8X852	8.786101
	24	9.794291		607	6.053511		N5X326	8.782524
	43	9.739657		652	5.884615		N5X242	8.780375
	4	9.676316		6	5.805434		N8X593	8.757898
	33	9.404281		240	5.805132		N8X746	8.757474

Table 6.10. Table of most significant locations and their Ri values.
Ordered by highest Ri value (or the locations that might represent more route options)

TYPE OF LOCATION	O-D PAIRING IDs	RATIONAL	DETOUR	Rc VALUE	Rp VALUE
Entrances	2-14	Apart N & S	5 %	136	1.75
	1-6	Apart N & S	5 %	34,705	4.15
	3-12	Apart E & W	5 %	2,442	5.34
	8-4	Apart E & W	5 %	2,489	4.53
	12-6	Hi/Low Ri	5 %	8,615	7.61
Nodes	N5X013 – N8X003	Hi/Low Ri	10 %	237	3.12
Boundary Nodes	3052 - 9035	Hi/Low Ri	5 %	72,109	5.13
Complejo Centroids	199 - 516	Hi/Low Ri	10 %	106,586	5.79
Neighborhood Centroids	21 – 47	Hi/Low Ri	10 %		
District Centroids	N – I	Hi/Low Ri	10 %		
City-block Centroids	52 - 237	Hi/Low Ri	5 %	3,303	8.39

Table 6.11. Results of Rp analysis for most significant O-D pairings.

Brief Summary of Ri and Rp analyses

Using a combination of *Betweenness* and Redundancy analyses I was able to identify the main roads of Angamuco. There are a few interesting observations that are worth mentioning:

1) The highest value of Ri is between Entrances 1 & 11 (10.24); and 2 & 5 (10.67) and the smallest is between Entrance 3 & 7 (1.43); and 3 & 4 (1.39). Therefore, Entrances 1, 11, 2 and 5 might actually be the most visited ones.

2) *Complejo* 12, and those close to water reservoirs on east and west side of the city, have lower Ri values (at 5%). This means that they have fewer available routes, even if they were heavily transited. The roads to/from them were limited and possibly controlled/surveilled.

3) A total of 590 segments can be considered to be making up main roads (including secondary and tertiary) or ~22% of all the segments in the site, which already can be used to indicated which areas of the city were most likely visited. The segments/nodes that might have afforded more public interaction on a daily basis (potential areas for socialization). Segments with low Ri and Rp values, or roads with low or occasional traffic may hint towards areas that were more private, controlled, and segregated where a centralized government might have not influenced so easily.

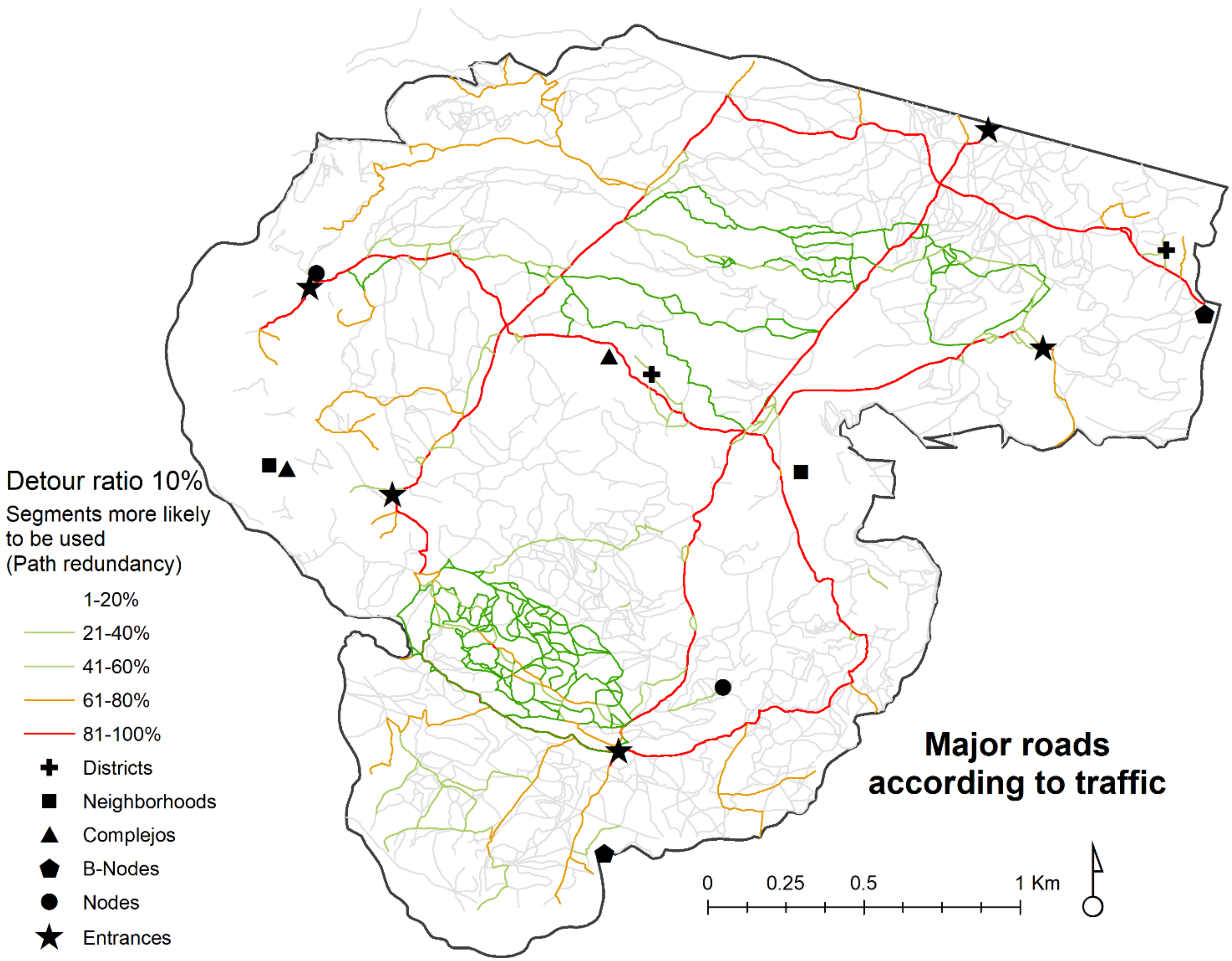


Figure 6.46. Map showing the most transited roads of the site going between the 18 significant O-D pairings. The paths are graduated by color representing the segments more likely to be used by pedestrians in any of these O-D routes. In this map, the boundary nodes are also graduated by their Ri value (red to green).

6.1.5. Evidence of planning

6.1.5.1. *Straightness* Analysis

The final part of Urban Network Analyses conducted in this research aims at exploring the possibility of any evidence of planning. I investigated this aspect by making reference to another centrality index, *Straightness*, that characterizes direct routes based on their shape.

Straightness analysis essentially displays how shortest paths resemble straight lines, or how much longer a path is when compared to a straight line. This index computes the positive deviations in a route that result from comparing the geometric restrictions of the network and an ideal straight line (Euclidean) between the same O-D paring (Sevtsuk, 2018b). The more distance between the two points on the network, the more the *Straightness* analysis will resemble a straight line. The UNA straightness index returns an *s* value for each node in the network. High *s* values indicate nodes that can reach many destinations along straight travel paths while nodes with lower *s* are those that would require more intricate routes (Figure 6.47).

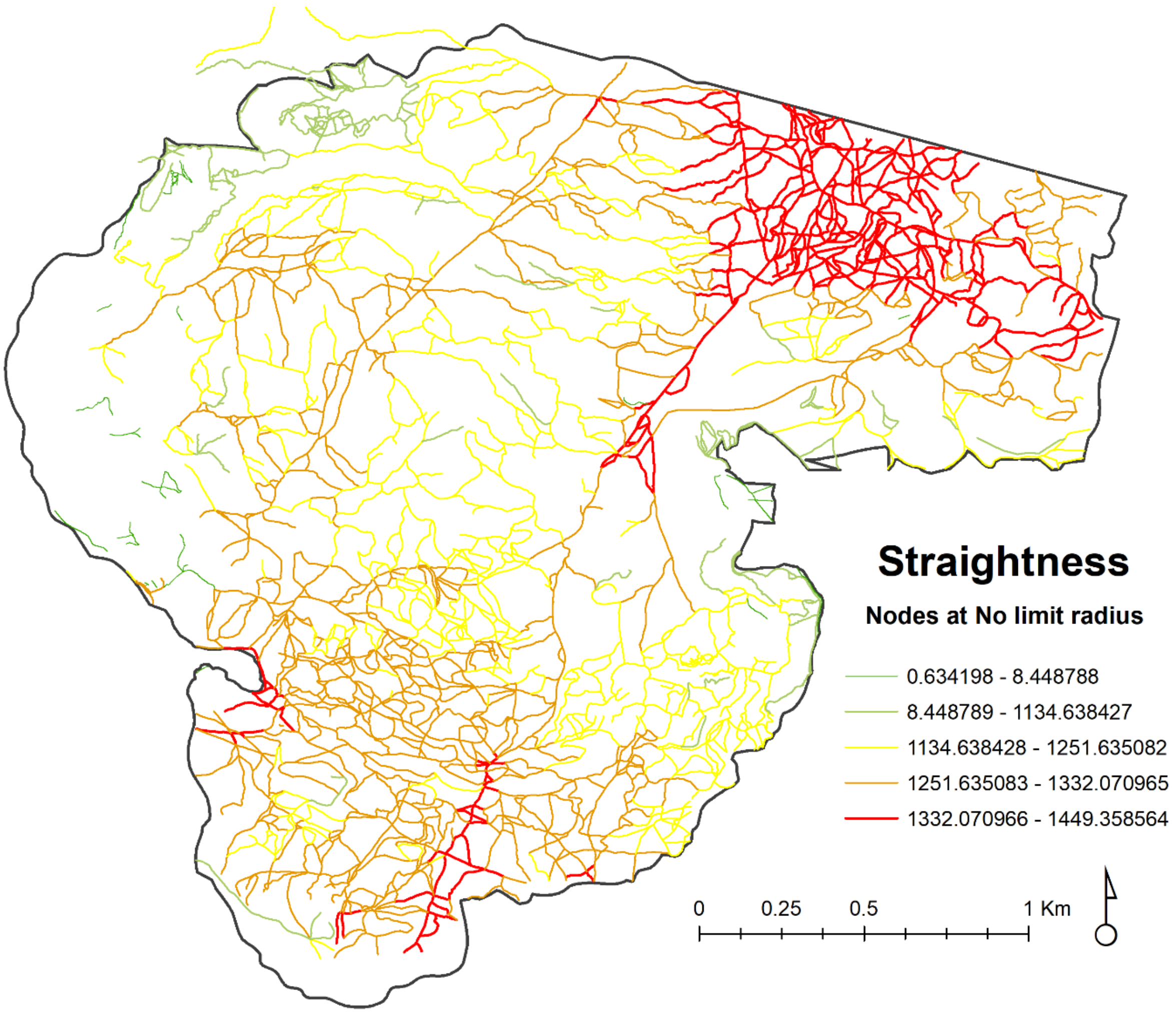


Figure 6.47. Map showing results of *straightness* of nodes to nodes. The values have been spatially joined to road segments to illustrate roads better.

Figure 6.48 shows the results of a *straightness* analysis between nodes in the site with no radius limit. Here, two sections of the main N-S central road show high values. Furthermore, several sections of the network along the westernmost N-S central road (and a few other routes in the southern part of Lower Angamuco), have high *s* values. Again, the two areas of dense networks

(SoC and NoE) stand out. In this case it is possible to see that several straight roads form their basic framework (figure 6.48).[20]

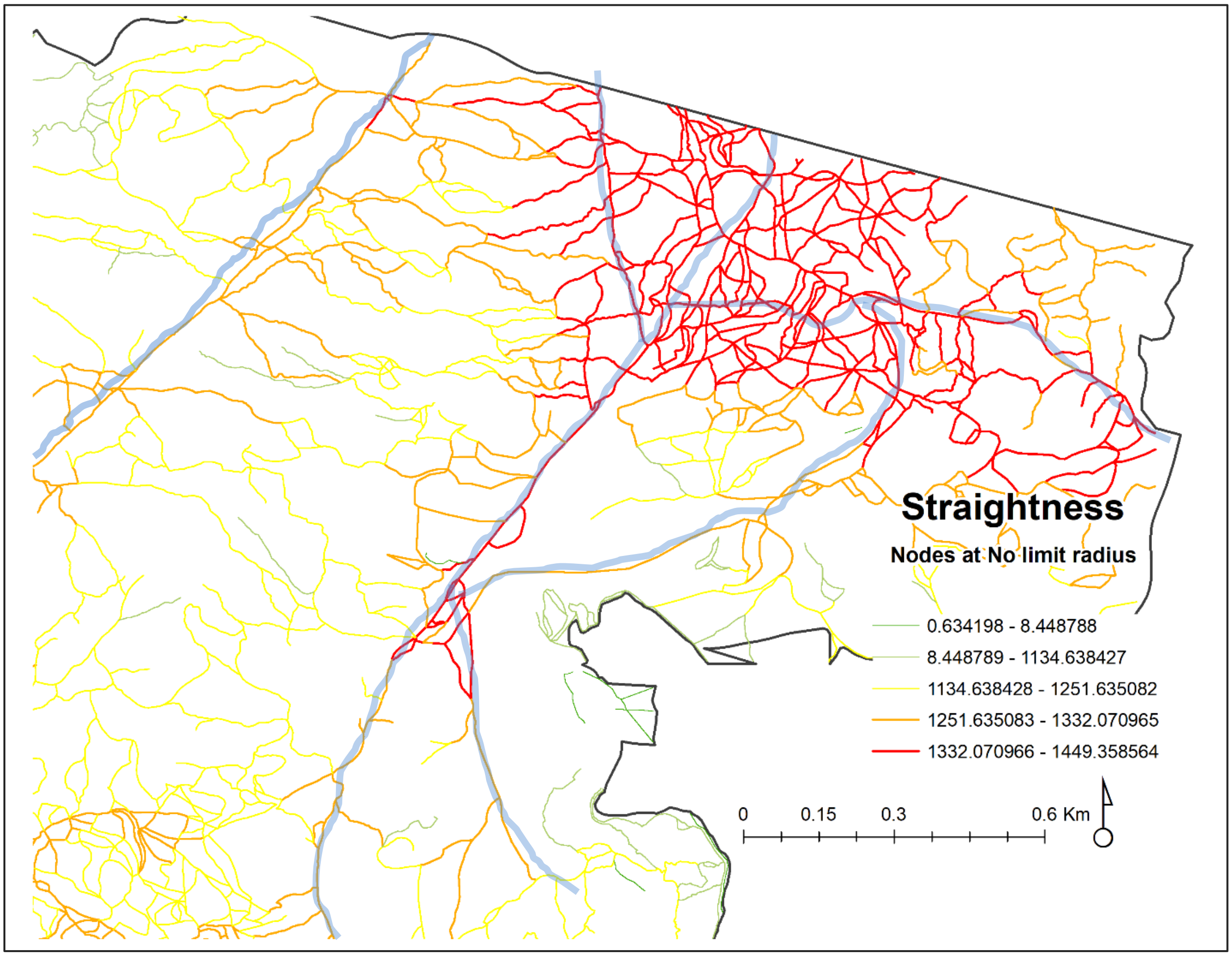


Figure 6.48. Detail map of *straightness* results of nodes to nodes. Blue shaded roads are most likely planned given their higher *s* value compared to surrounding roads.

Looking closely (Figures 6.49 & 6.50) *straightness* analysis not only provides straight segments, but the combination of segments that together create a straight route. This can be seen within the SoC area were many straight or more direct segments are present (Figure 6.49).

[20] Straightness analysis of routes traveling between complejos or city-blocks have been also calculated but they do not diverge much from nodes-to-nodes analysis and that is why I am not including the results here.

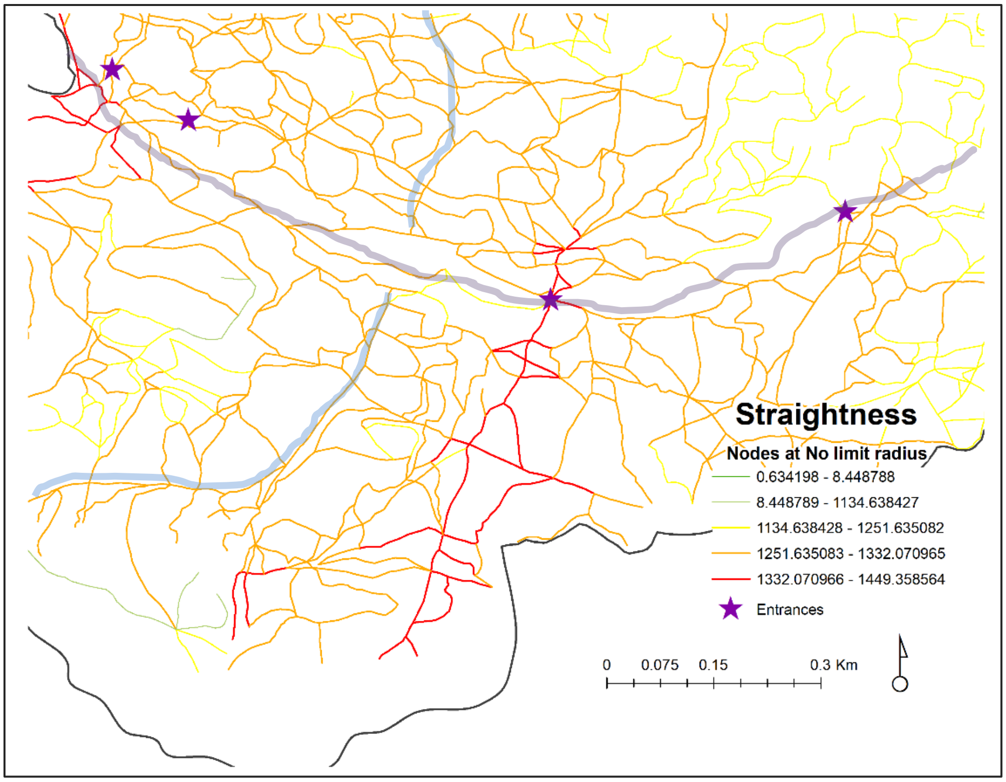


Figure 6.49. Detail of *straightness'* results of nodes to nodes. The section of central N-S road that passes by Entrance 1 is most likely planned. Blue shaded route is straight but disconnected. Purple area represents escarpment.

Nodes with lower *Straightness* values can be interpreted as less accessible locations, or even less-public intersections. The analysis reveals that many centrally located are hard to reach without crossing through several nodes and segments or visiting other places. I interpreted these locations (and more precisely, the groups of neighboring segments with low straightness value) as places where the network is less efficient. These are location where network appears to be more organic and where the influence of the topography and the landscape is higher. It represents less construction effort or coordination from the community members (see Figure 6.50 for an example). The opposite, a series of flatter, more straight segments, with more direct routes would require less travel time and less decision making. They are, in fact, roads built and negotiated within a larger community, perhaps directed by a ruling government.

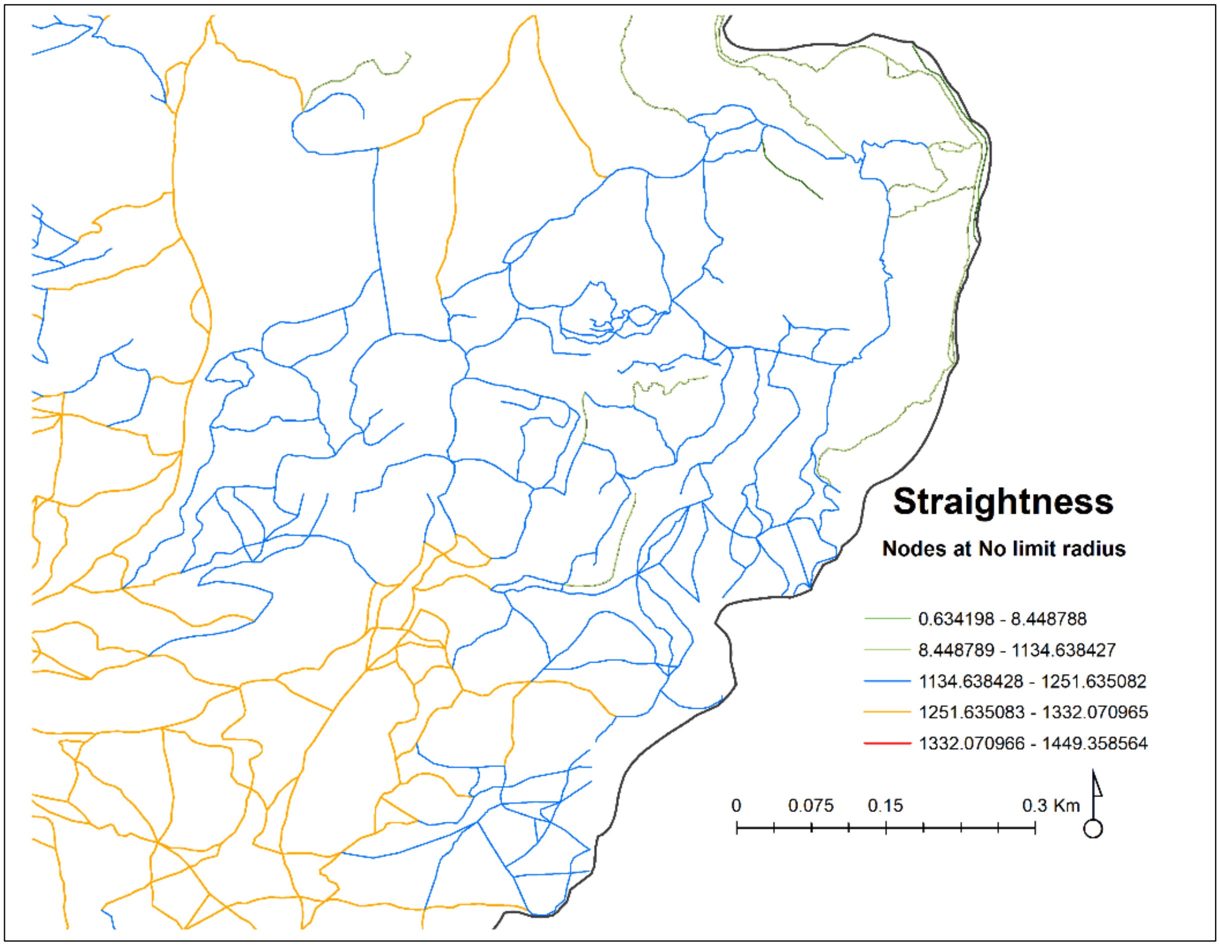


Figure 6.50. Detail of *straightness'* results of nodes-to-nodes. Roads in blue and green have a lower *s* value, and are most likely created following the topography, evolved organically as the immediate community needed them as opposed to planned projects from the state.

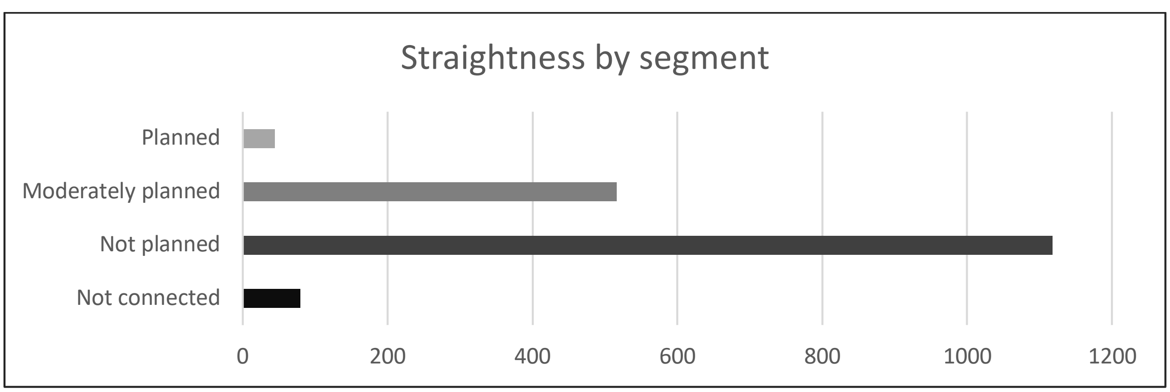


Figure 6.51. Total counts of segments according to their average s value. This is an interpretation of the total number of segments that might have been planned in Angamuco.

In order to identify the distribution of planned vs not planned roads, I used the results from the *Straightness* analysis (*s* values) from nodes-to-nodes with no-radius limit. I then divided the *s* value by the total number of segments that are connected in the network (that is, excluding segregated segments). The result is the average *s* value in a proportion of segments of the entire network. Having these values, I aggregated them into four groups (Figure 6.51):

1) Not connected: segments that are segregated from the main network (average *s* = < 0.5);

2) Not planned: segments following natural topography (average *s* = 0.6 – 0.75);

3) Moderately planned: segments modified from topography (average *s* = 0.76 – 0.89);

4) Planned: segments where natural topography is completely modified (average *s* = >0.9)

As a result, 63% of all the segments in Angamuco appear not to have been planned and emerged from the daily negotiation with the landscape and the immediate community.

In sum, *Straightness* analysis is a good approach to identify the possibility of road planning. The results obtained are consistent with the observations of network patterns in previous analyses and consistent with field observations. On the one hand, *Straightness* analysis is a very good first approach in identifying major areas where a centralized state might have directed the layout of architectural features, including roads. On the other hand, this analysis further supports the idea that the road network of Angamuco is the result of a combination of community negotiated routes of access and movement and routes created through the direction of a central governing entity.

6.2. Brief summary of Urban Network Analyses

The combination of several Urban Network Analyses provided several important observations of the general patterns of the road network. Particularly, Closeness, Cluster, and Reach analyses were instrumental in identifying that the complete road network of Angamuco was not static and uniform. At least, it was possible to identify two types of network composition (a dense road network and a more spread network) discussed in the next chapter. These observations add to other provided by ceramic analysis and field observations from survey and excavation about a road network that changed according to needs from the community, adapting to the landscape, or other socio-political factors such as patterns of settlement.

Other analyses like Gravity, *Betweenness*, and Redundancy helped identify the major roads and most likely visited locations within the site. This is very valuable information, since it provides a global perspective of the integrity and mobility within the city. Future research can also use this information to investigate areas of the city previously considered less important or influential.

Lastly, results of Straightness analysis combined with observations from other analyses provided more evidence of planned routes which reinforce the idea of a negotiated landscape dominated by a decentralized community.

In the next chapter, I summarize results and observations from survey, excavation, ceramic analysis, and UNA in an attempt to offer a detailed interpretation of the engagement of Angamuco residents with their landscape by the use and creation of their movement infrastructure.

CHAPTER SEVEN: Results and interpretation

Understanding the road network of Angamuco

Angamuco´s road network is complex, diverse, and extensive. More importantly, the network is multi-scalar, meaning that different social phenomena occurred at different scales and ranges of the network. For this reason, not all questions can be answered with a global perspective of the network. Considering this, I designed my research to investigate the network from three different scalar dimensions.

First, there are patterns of movement and traffic that are better observed from the global scale of the network. For that, I developed strategies to identify and study the network in its entirety. The best way to do this is by the application of computational tools such as image analysis to identify the roads, and Urban Network Analysis (UNA) to understand them.

Second, is the community scale, similar to neighborhoods, where it is easier to identify the degree of community organization for settling and communicating through roads. At this scale, it is possible to observe familiar and community spatial layouts. In order to explore issues like social organization, I incorporated various methods from UNA to field survey and mapping areas of the site.

Third, and finally, individual segments and nodes were investigated directly through excavation and field mapping. Specific characteristics of how roads were built, their chronology, and their material deposits could only be recovered at this scale of the analysis.

In the previous chapters, I presented the processes for collecting data at these three scales —survey, excavation, and digital road extraction. I also discussed several laboratory, field, and computational analyses that I used. In this chapter, I discuss the results and the data from these analyses at such three different scales. Those observations are illustrated with unique examples and summarized in five main conclusions: a) the road typology, b) social divisions of the site, c) transformation of the landscape, d) interaction and socialization, and e) general patterns of the movement infrastructure of Angamuco.

In the first part of this chapter, I make a summary of the results collected during the survey and field mapping of movement infrastructure. This includes a proposed typology of segments and nodes. This section alone represents a significant contribution to the study of road networks in archaeology, particularly for large urban centers in Mesoamerica.

In the next section of this chapter, I review the general characteristics of the network as they became clear from a global approach through Urban Network Analyses. Most of the discussion in this section centers on the major arteries and the general patterns of road placement in the site.

In the following section, I present my arguments on how the study of the road network provides essential evidence for the urbanism of the site. This discussion is framed within the general socio-spatial division of Angamuco originally proposed by the LORE-LPB project. Here, however, I present an alternative to the *complejo* model. I also describe in detail the role of the entrances (access points) to the site and the impact of the natural, topographic feature (the escarpment) that divides the city into lower and upper Angamuco areas. Then, I provide an in-depth description of two *complejo* examples and examine the internal circulation between households and more intimate shared spaces at a community scale.

Next, I take up the initial ideas of landscape transformation presented in chapter five (stratigraphy), to explore how the inhabitants of the site embarked on massive projects of modifying their living spaces to afford movement. I especially emphasize road transformation and rebuilding (Units U1A01 and U1I03), and road blockages (Entrance 2).

The final section is devoted to a discussion of interaction and socialization at the site, framed around the areas that I suggest afforded more face-to-face daily contact between pedestrians.

7.1. Results of PACUA sample

I produced and compared two different road datasets during this dissertation. The first one ("PACUA") represents a total of 419 segments and 379 nodes registered, mapped, and measured directly in the field with a total extension of ~23 km (Figure 7.1). The second database ("DIGAR") is the result of the digital extraction of 2,619 segments and 1,803 nodes for the complete dimensions of the site. These roads together have a total extension of ~157 km (Figures 7.2 and 7.3).

This comprehensive summary of nodes and segments not only describes the movement infrastructure physically, it also provides the basis to understand how their material and spatial characteristics can be used to study social interaction and organization.

In chapter four, I described in detail the many attributes that were collected for each segment and node in the field. This work included collecting data for over 14 combined categories of attributes (Table 7.1). The results of this intensive road mapping provided a very informative summary of roads' qualities that served to create a typology of roads for the site.

MAIN ATTRIBUTES	NODES	SEGMENTS
Provenience	✓	✓
Area dimensions	✓	
Width		✓
Connecting segments	✓	
Shape	✓	✓
Slope		✓
Associated architecture	✓	✓
Construction style		✓
Effort		✓
Visibility	✓	✓
Surface materials	✓	✓

Table 7.1. Main categories of the attributes collected in the field. Some of them have their own set of subcategories. For a complete list of attributes collected see chapter four.

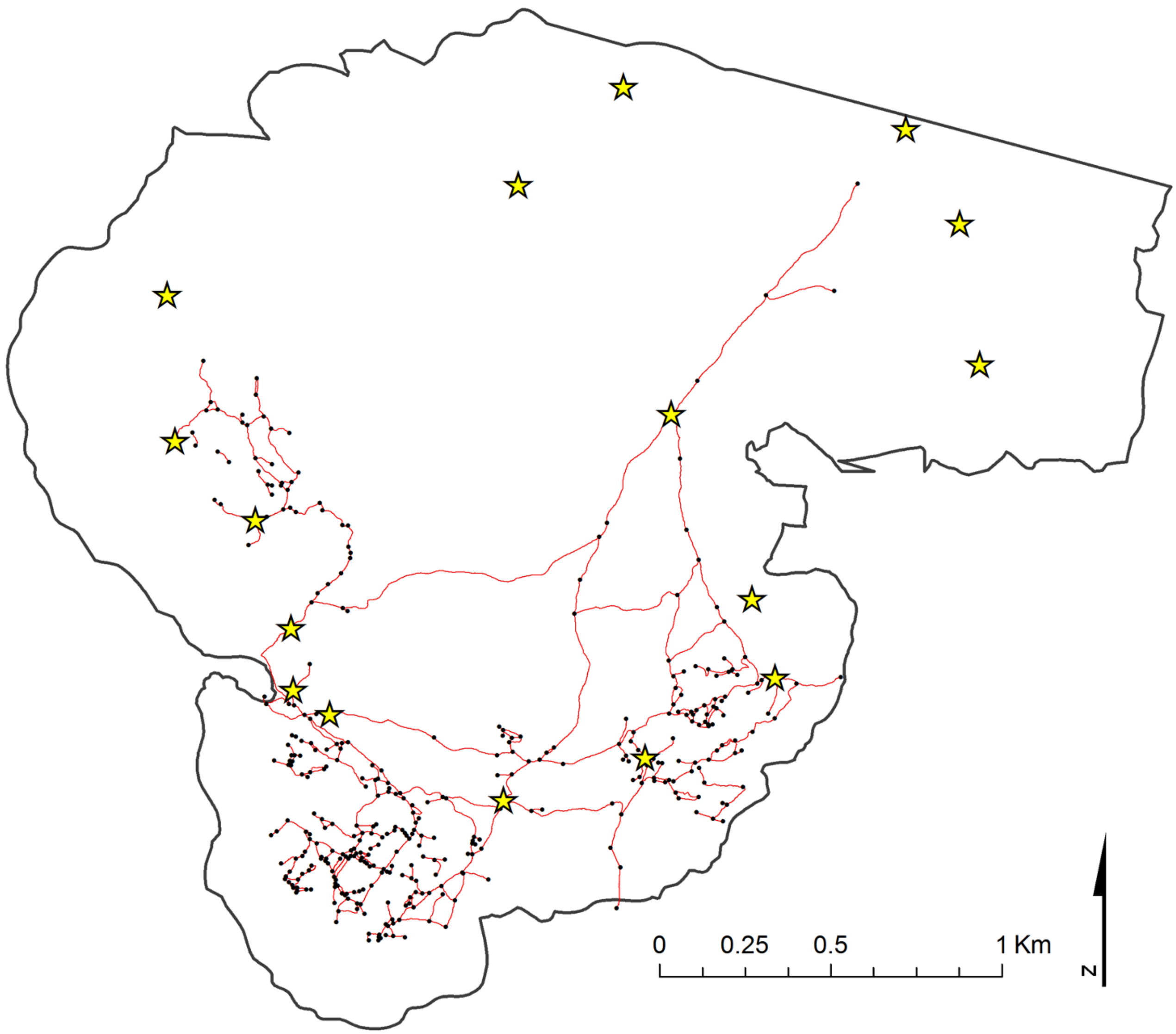


Figure 7.1. PACUA dataset. Nodes are represented with black dots and segments with red lines. Yellow stars are entrances for reference.

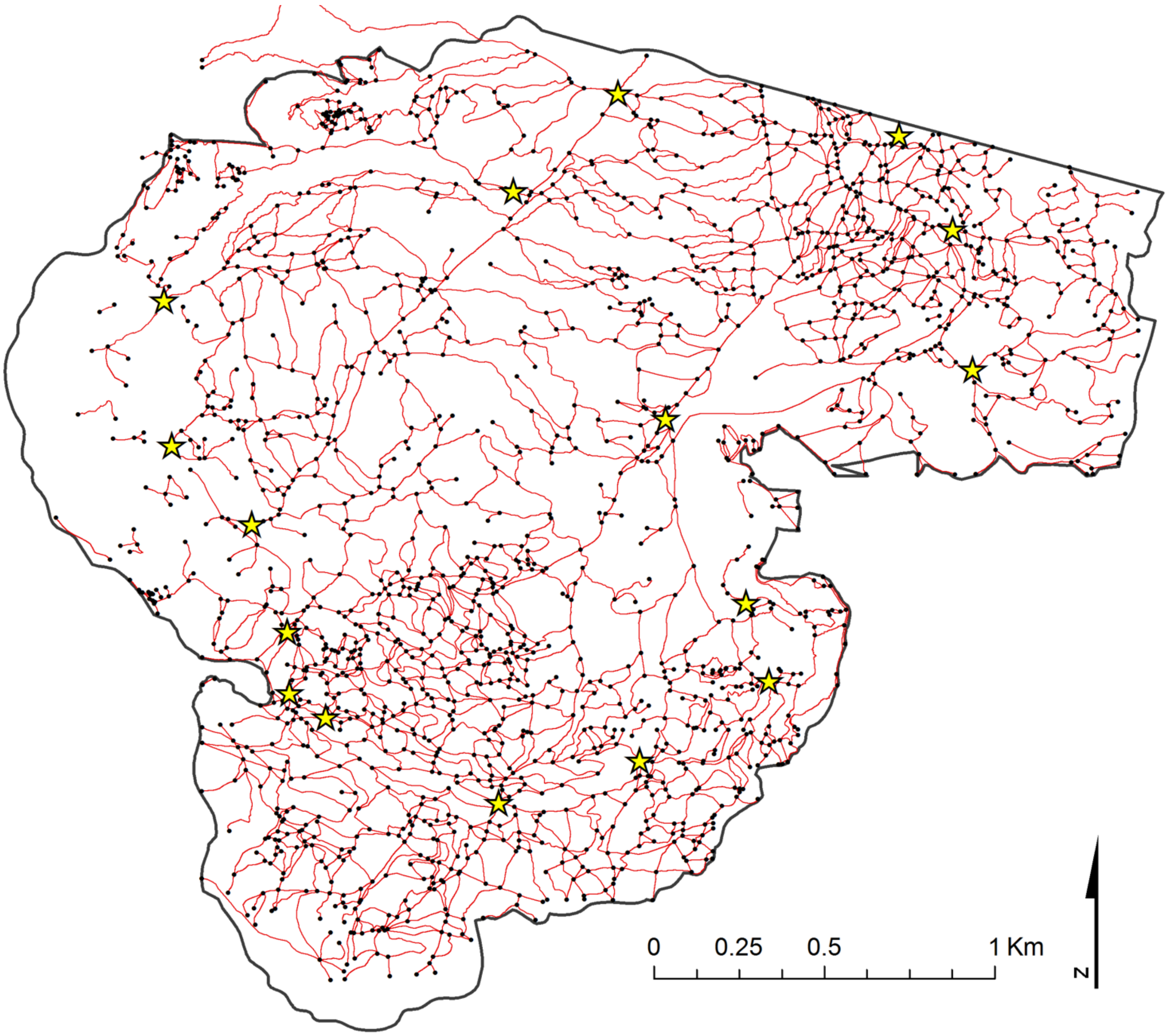


Figure 7.2. DIGAR dataset. Nodes are represented with black dots and segments with red lines. Yellow stars are entrances for reference.

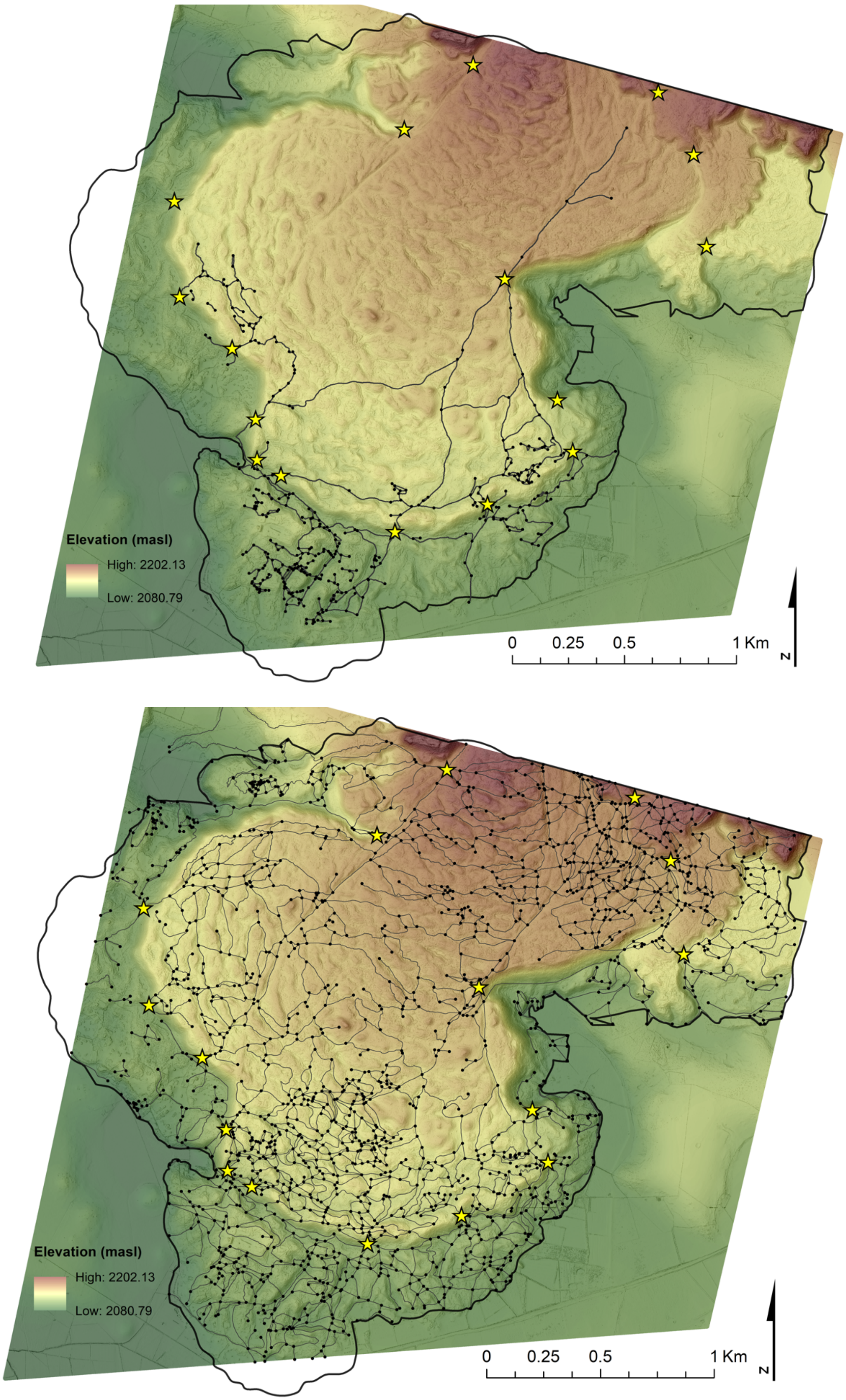


Figure 7.3. Comparative of the two datasets showing elevation DEM (Top PACUA dataset and bottom DIGAR dataset). Nodes are represented with dots and segments with lines. Yellow stars are entrances.

In order to create a typology of roads, it was fundamental to identify what characteristics of the roads were relevant. However, it was also critical to define the goals of understanding road variation and the purpose for road classification.

In urban studies, several researchers have proposed street typologies based on:

1) physical qualities, for example, shape, length, the type of sidewalk, etc.;

2) function, for example, for use by cars or pedestrians, residential or commercial, etc.;

3) location, for example, city center, rural, etc.;

4) special conditions, for example, the number of shops on either side, car traffic rules, etc.

In most of these cases, the goal has been to understand the functional, efficient, or even aesthetic design of the network (Oliveira, 2016; Scheer, 2010; Shrestha, 2011). In other cases, the goal has been to predict and understand movement behavior, especially to prevent hazardous events (Lavery et al., 1996; Strohmeier, 2016). There are fewer proposals that aim to understand human interaction and socialization (Mehta, 2013b). In any case, all of these examples are grounded in contemporary case studies where the material aspect of the streets can be easily related to modern mobility needs and often verified through ethnographic data.

My intention with this research was to explore the material evidence on roads and to explore:

1) social interaction, not only among those who use the roads but also among those who build them;

2) evidence of planning or designing of roads;

3) route selection and decision making; and

4) temporal determination of using and building of roads.

With these goals in mind, a road typology entirely based on road materiality, and not based on their location was much more effective. There are a few good examples in archaeological literature (e.g. Branting, 2004; Erickson, 2001; Kaiser, 2011; Keller, 2006; Louf & Barthelemy, 2014). However, all these cases are very particular to their case study, for example, based on unique characteristics of their users, the transportation modes (e.g., Roman roads had carts), distinctive construction materials (Mayan roads used limestone and stucco, relatively easy to sculpt), etc.

Thus, this body of literature was helpful both for designing my data collection and for observing the results. Nevertheless, did not provide a sample typology that I could base on. Hence, I ultimately created a unique road typology specific to the Angamuco road characteristics.

In the next section, I present a discussion of all those types and their occurrence at Angamuco.

7.1.1 Typology of segments

Segments are linear features that start and end at nodes and allow travel in between. I created the following classification of segments based on five characteristics before I started survey (a priori categories): 1) size, 2) shape, 3) slope, 4) experience of travel, and 5) construction style (Table 7.2). Each of these has their own set of types. They are all mutually exclusive and are not hierarchical. In this section, I present the results and interpretations of these observations, that is, the total counts and distributions by type/sub-type.

	CATEGORIES	TYPES	N *	DETAILS	RATIONAL
Segments	Size (width)	*Pasillo*	27	0.5 – 1 m	1 person
		Sendero	240	1 – 3 m	2 people
		Camino	74	3 – 4 m	Up to 4 people
		Calzada	14	> 5 m	More than 5 people
	Shape	Straight	127	Same direction	Direction
		Curved	80	Change direction	
		Sinuous	102	Multiple directions	
	Slope	Flat	81	Easy	Effort
		1-direction slope	174	Moderate	
		Irregular	53	Difficult	
	Experiential	Concealed	132	Next node is not visible	Navigation
		Exposed	212	Next node is visible	
		Easy	102		Effort
		Moderate	149		
		Hard	13		
	Construction style	Simple *banqueta*			
		Double *banqueta*			
		With retention wall / terrace			
		Partially created by topography			
		Fully created by topography			
		With walls			
		Raised causeway / Huatziri			

Table 7.2. List of categories, types and subtypes for segments on PACUA sample.
*Not all the counts by category total 419 surveyed segments.

Segment Size

A sensible classification of roads is by their size. The length of roads has been used to define which roads are more important in modern cities (Hillier et al., 2010; Sevtsuk et al., 2016). LORE-LPB previously proposed an elementary classification of roads in Angamuco based on length (Fisher et. al. 2019a). This method works in contemporary settings where roads can be identified by a name, so it is relatively easy to define their extension and boundaries. However, assigning hierarchies based on length actually presents a significant conceptual problem.

A *road* is not as easy to restrict in the archaeological assemblage. In archaeology, roads are encountered as a sequence of lines[6] with similar characteristics than as a clear defined track. Alas, those characteristics are not known by the archaeologist a priori. It is true that in their conception, people did not think of segments as they were creating their roads. Most likely, the main motivation was to create routes between destinations. Unfortunately, the builders' motivations are not necessarily explicit in the landscape, particularly for a Mesoamerican urban center. One motivation could have been to create the fastest route, or the safest, or the prettiest, and those are qualifications that need to be explored from the assemblage. Thus, I was hesitant to use length as a way to classify roads in Angamuco.

As I explored in chapter six, there are many other approaches to measure the importance of roads within the network (e.g., integration, connectivity, etc.). Here, I am presenting the attributes measured at a sample of roads during field survey that are not possible to extract from digital analysis.

An alternative to length for classifying roads is width. In order to define which of those two measurements is more sensible, I explored their distributions. In Figure 7.4, I present the distribution of the individual measurements of 419 segments, width on the left and length on the right. On the one hand, width measurements show a non-normal distribution with a mean of around 2 m wide. On the other hand, the distribution of segment lengths suggests a bigger range of variance (i.e., there are more segments of many different lengths).

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[6] Same as *continuities* in (Figueiredo and Amorim, 2005) or *segments* in this dissertation.

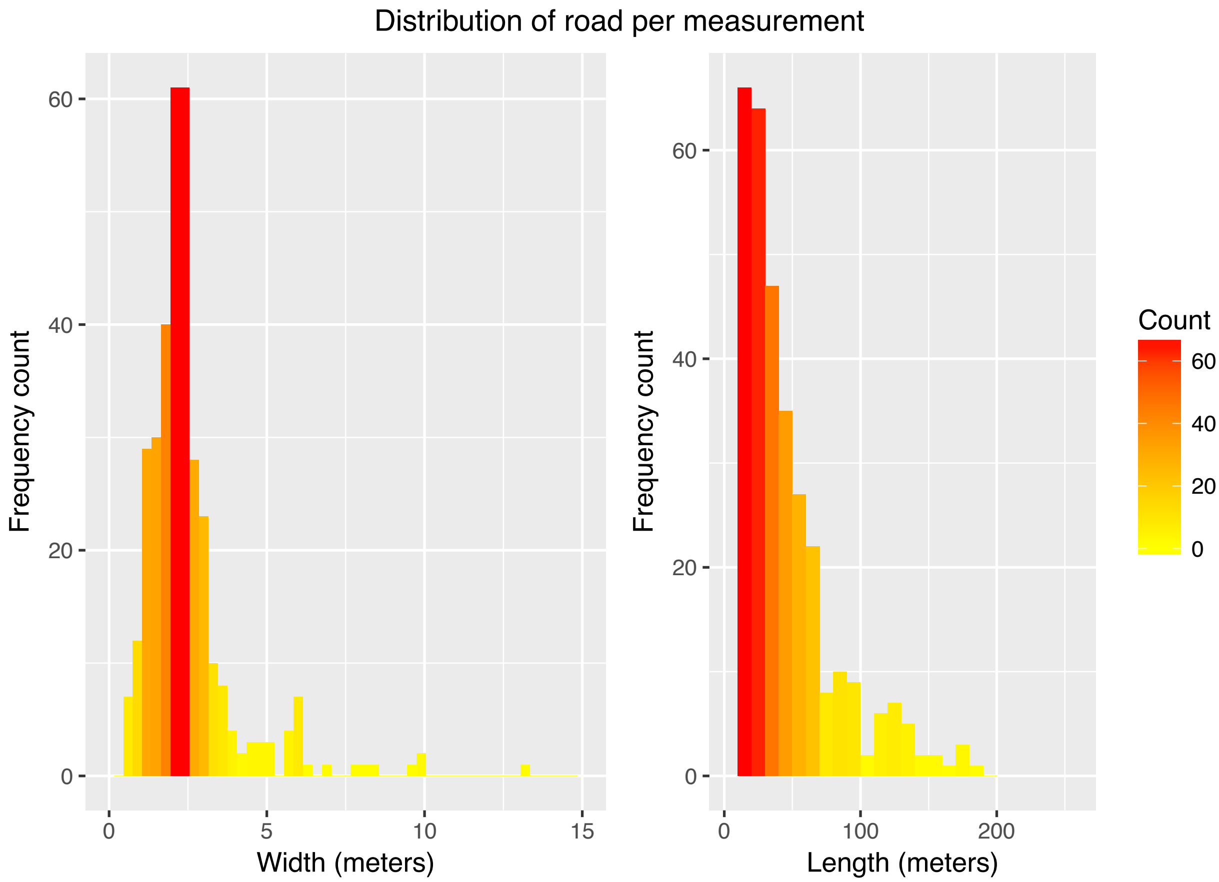


Figure 7.4. Histograms showing distribution of widths (left) and lengths (right) of PACUA

I explored the distribution of segment widths more closely through the Jenks natural breaks classification method (Chen et al., 2013) and found that widths were more likely to cluster in four classes (Figure 7.5). While there are a few outliers, for example, segments as wide as >13 m, the total number of measurements grouped in classes aligns closely to the a priori four-type classification of roads.

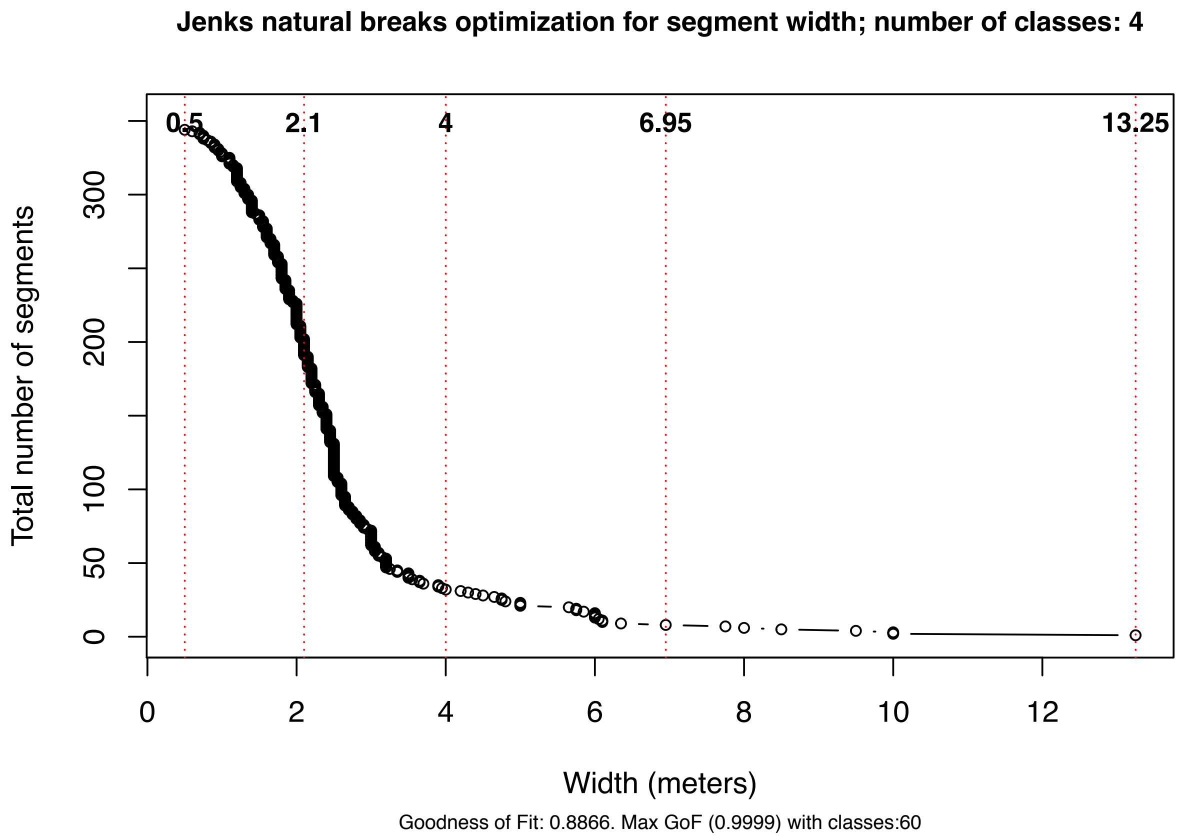


Figure 7.5. Jenks natural breaks classification for the widths of PACUA segments.

The three categories observed in the distribution are roads with widths between 0.5–2 m; between 2–4 m; between 4–7 m, and larger than 7 m. These categories are actually very similar to the *pasillo, sendero, camino, calzada* classifications I created a priori for the road-survey field forms. The basis for the width types is the number of pedestrians that can walk alongside each other (see examples in Figure 7.6). This rationale not only contributes to the discussion of interaction while walking, it can also be associated to the motivations for creating roads. Thus, the four classes by width size identified in the PACUA segments' datasets are (Figure 7.7):

1) *Pasillos*. These are the narrowest roads, between 0.5–1 m, which is enough room for a person to walk. Most of them are located within *complejos*, or as part of the interior

circulation among households. The interior of *complejos* were not surveyed, thus, they are not well represented in the sample.[7]

2) *Senderos*. The most common type, are between 1–3 m wide, which is enough room for two people to walk together or for two people crossing each other without having to move out of the way.

3) *Caminos*. These are wider than *senderos*, between 3–5 m and can fit as many as four people walking beside each other.

4) *Calzadas*. The largest of roads, this type is larger than 5 m, but can be as wide as 16 m (usually ~10 m). They are mostly located at valleys and are more straight than other segments.

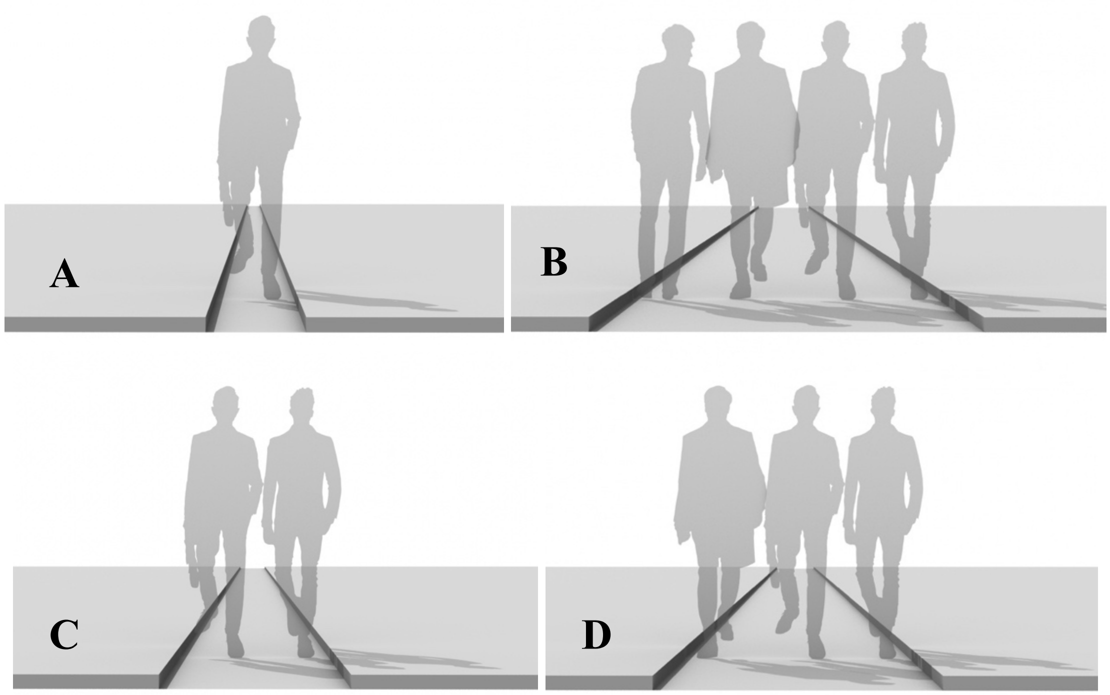


Figure 7.6. Examples of width for: A= *Pasillo*; B = *Camino*; C & D = *Sendero*. Drawing by Zac Culler.

[7] The road survey concentrated in roads outside complejos.

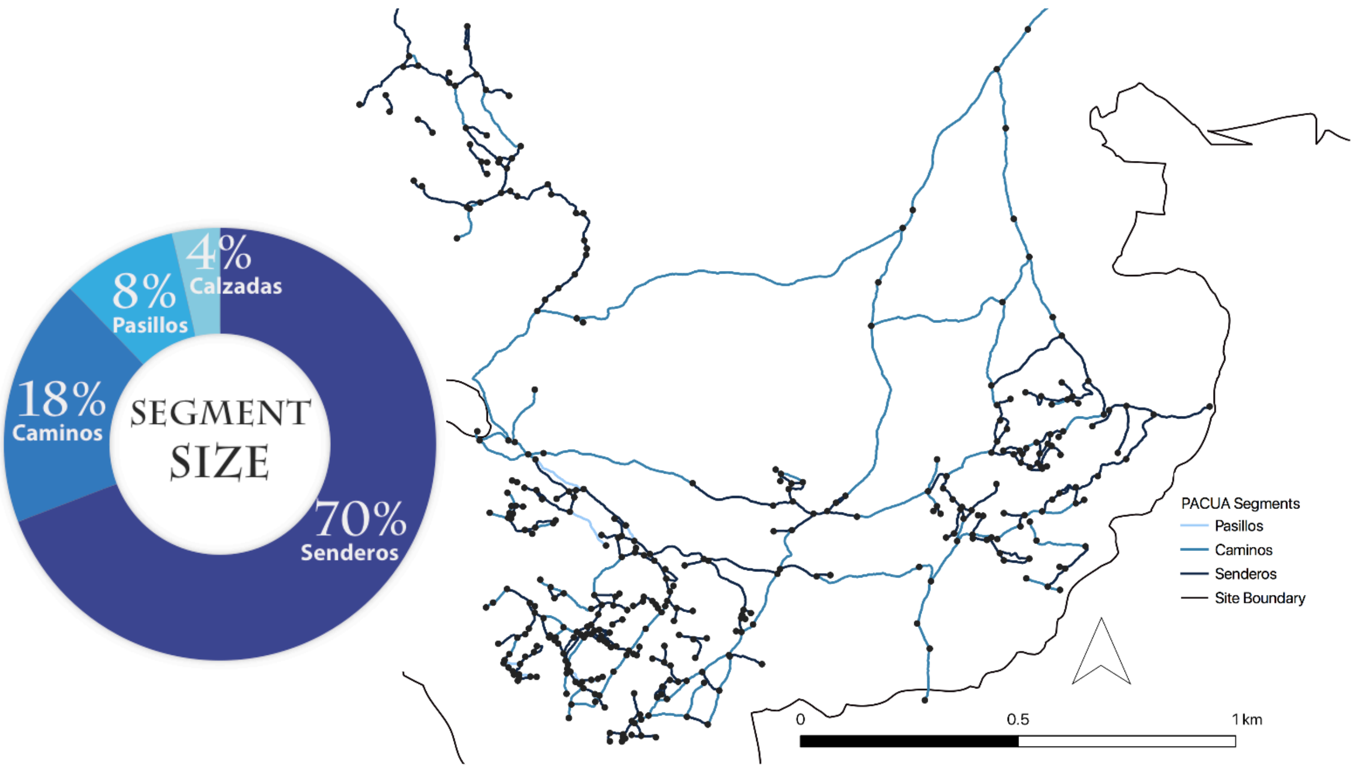


Figure 7.7. Proportions of segments by size in PACUA sample.

Senderos are the more recurrent type of segments in the sample and presumably in the rest of the site. If indeed, *senderos* are smaller roads, less intrusive in the landscape, and more suitable for single users, then it is reasonable to suggest that the high abundance of *senderos* support the idea of a more organic sprawl of a network.

In general terms, the urban layout of the city seemed to have responded to individual and community needs and not necessarily to a planned or designed network structure. This is, of course, an expected result, but more importantly, these *senderos* connect most *complejos* with each other. *Senderos* are analogous to the tertiary roads observed in the traffic-flow analysis in chapter six (or, the group of least used segments among the "highly transited" roads).

Segment shape and slope

Shape and slope are the only segment attributes that can be extracted from the DEM. I also collected this information from the field survey to get a sense of the direction and navigation while walking around the site. Defining the shape of a segment was guided by the experience of walking and not the exact geometry. For example, a segment was considered straight even if it had small curves that do not require a complete change of direction and horizon view.

There are three shape types that are related to the way the segments were built:

1) Straight follow one general direction.
2) Curved force the pedestrian to change their horizon view once.
3) Sinuous have multiple changes in direction and horizon view.

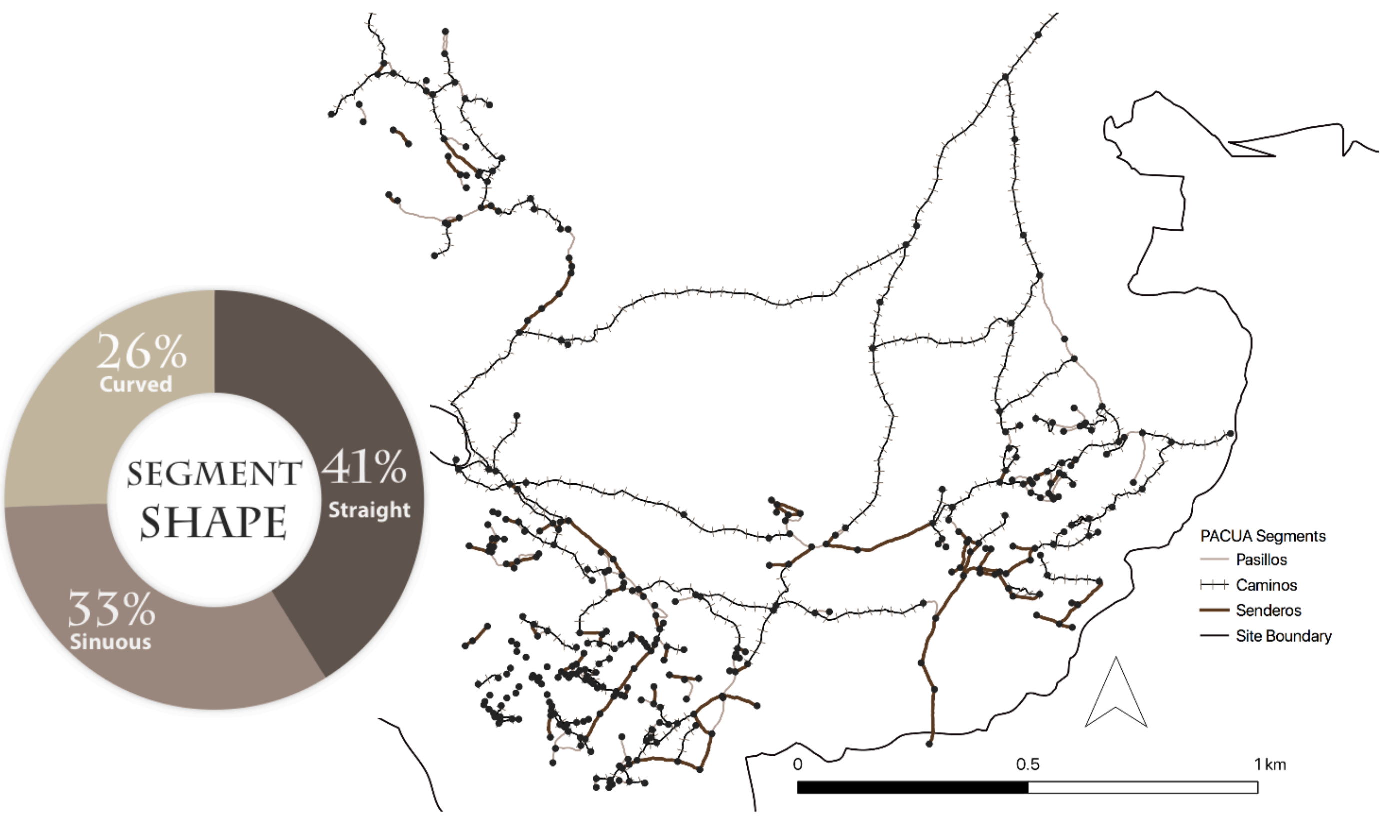


Figure 7.8. Proportions and location of segments by shape.

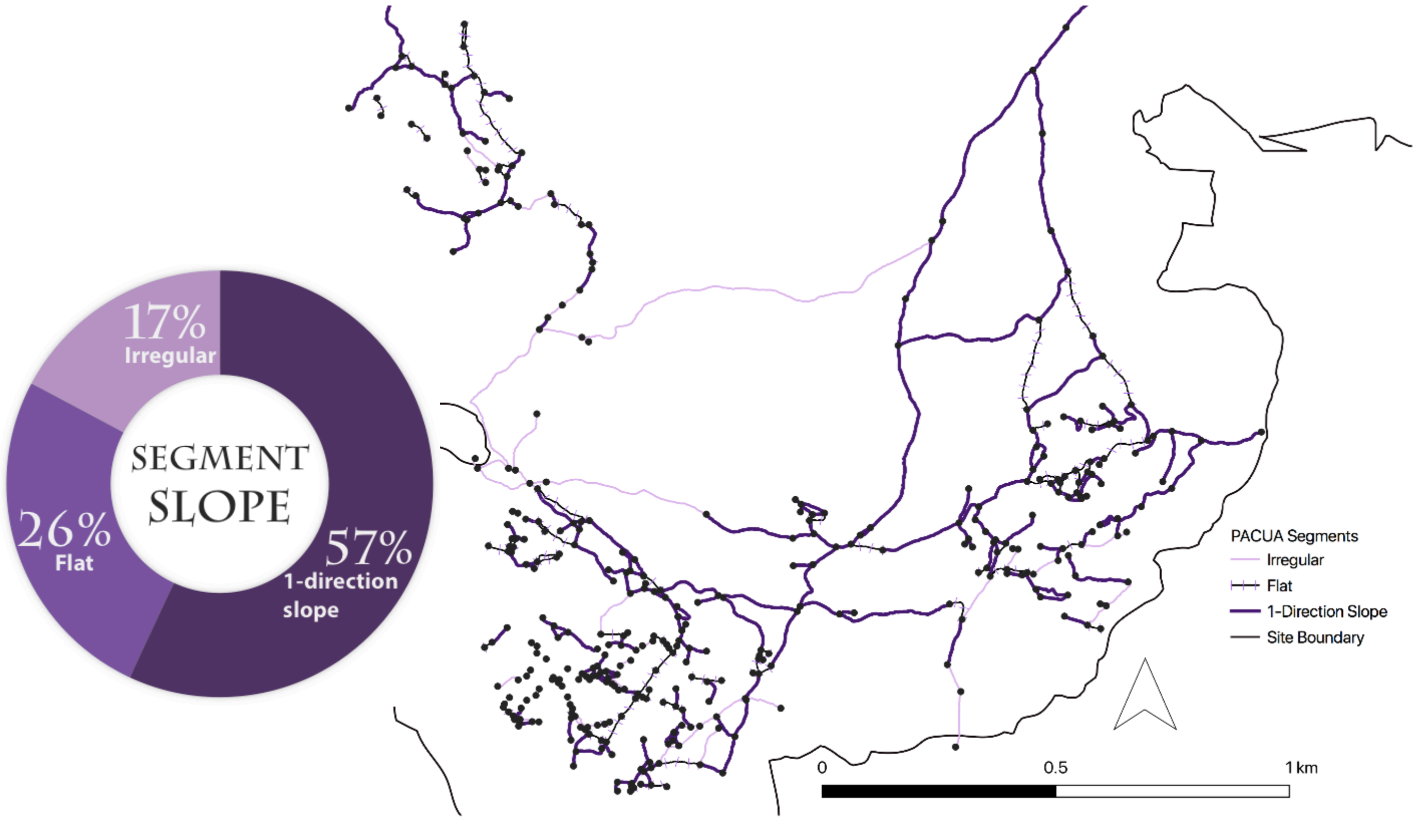


Figure 7.9. Proportions and location of segments by slope.

Slope, on the other hand, is an attribute related to how the pedestrian engages with the landscape and the effort of traversing through the site. A steep slope requires people to spend more energy controlling their descent or climb, even if certain architectural features help manage this energy consumption (e.g., pavement, stairs, ramps, etc.). Similar to shape, the main categories were not based on metrics but on the general sensation of traveling through the site.

There are three slope types that were observed in the sample:[8]

1) Flat are easy to traverse, mostly flat.
2) One-direction slope. The slope can be gentle or steep but is usually not extended for a long distance. These segments require moderate effort.

[8] These characteristics are also described in section 4.5.1 of chapter four

3) Irregular can be difficult to walk because there is more than one slope. Usually, these segments are long enough to fit more than one slope. So, their length adds to the effort of walking.

I relate flatness and straightness of segments, both to evidence of planning (Figures 7.8 and 7.9). Thus, I expected that they showed similar proportions in the sample. However, their abundances are contrasting. The most abundant type by shape were straight (41%) —almost half, while one-direction slope was the most abundant type by slope with 57% and not flat (26%) which should be similar to straight. How could this be explained?

Firstly, one-direction slope is in itself a complex type, with many different subtypes that were not further classified during fieldwork (e.g., along a ridge, across a natural topography, etc.). I interpret this as a sign of a complex network with many interacting movement needs. Secondly, the large amount of one-direction slope segments can be attributed to the rough and complicated natural topography. Thirdly, and more notably, the proportion of flat segments (26%) might indicate a combination of two factors: the people were very involved in landscape transformation and there was also an overarching sense of road placing and planning, even if the actual construction work was carried out by small groups of people.

Segment experiential attributes

As I mentioned before, the experience of traveling is challenging to measure. I selected two segment attributes that may be used as proxies to the experience of travel.

The first is visibility of the next node.[9] This is where an individual may have decided to change travel-direction, or where a decision-making occurs. Being able to see your destination

[9] Based on Llobera (2013)

(even if it is a transient destination) might have affected the confidence and engaging with a pedestrian travel.

At the node where a segment began, I registered whether the following node in the direction of travel was visible (the actual direction of travel is irrelevant). The visibility of the next node is subject to several factors beyond distance. For example, topography and architecture create mounds and ridges that can obscure visibility. Other geometric characteristics, such as slope or curvature of the segment, also contribute. Certainly, vegetation and architecture could not be used to measure visibility because those two factors are drastically different today. Regardless, I interpreted the visibility of the next node based on how exposed or concealed the segment was in an attempt to understand the ease of navigation.

Thus, the two types of visibility are:

1) Concealed. The next node is not visible due to distance, slope, or shape of the segment.
2) Exposed. The next node is visible.

The other experiential attribute was recorded as the general effort of traversing through the segment due to its slope. A general subjective qualifier was assigned for each segment.

1) Easy.
2) Moderate.
3) Hard.

The total segments in which it is possible to see the next node (which might be a point of decision-making) are significantly larger (62%) than those that are concealed (38%) (Figure 7.10). If we accept that residents of Angamuco memorized routes for their daily commutes, most of the network was exposed and available to many people. When it comes to effort, the number of segments that are hard to traverse is actually very small (5%). The largest number of segments seem to be of moderate difficulty (56%). These two results —segments are generally exposed, but moderately hard to traverse— suggests that most of the road network was developed following the already rough and irregular topography, and thus, not planned.

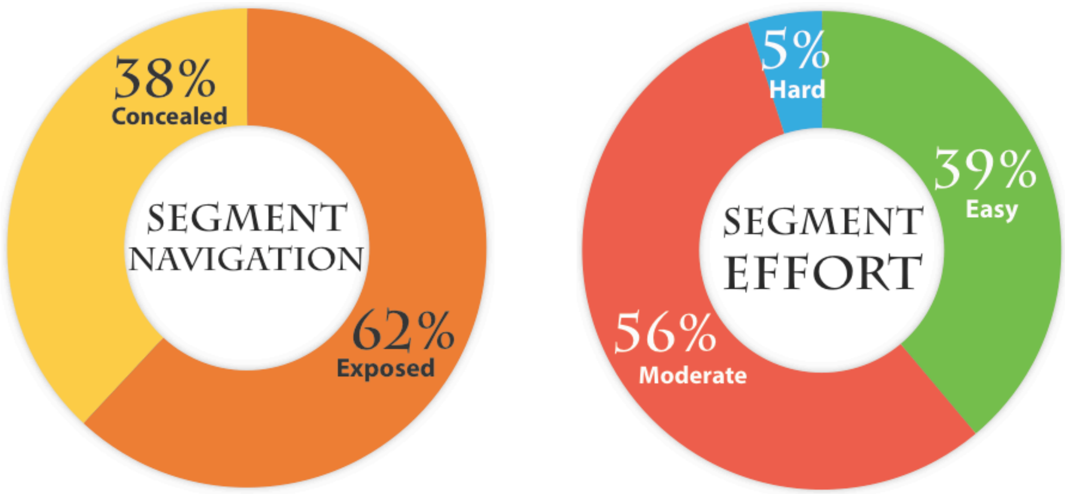


Figure 7.10. Proportions of segments by navigation and effort of travel.

Segment construction style

Construction styles might respond to resource control, number of individuals engaged in the construction project, and whether a large amount of labor was available for the construction and maintenance. All these factors are associated with the social organization of the city.

Next, I present a summary of the different construction styles observed after survey at Angamuco.[10]

There are essentially two architectural elements in all segments:

1) Walking surfaces. They can be paved, tamped down, or eroded.

[10] This list is not organized by hierarchy.

2) Boundaries. The limits of the walking surface on each side of the road can be marked with a wall, an alignment of rocks, a curb (*banqueta*), other topographic changes (natural or man-made), a combination of any of these, or also an absence of any clear demarcation.

In total, I identified the following seven different construction styles:

1) Simple *banqueta*

Figure 7.11. Simple-*banqueta* road type

Apart from the simplest road which has no architecture at all, the type that is most prevalent in Angamuco is the simple *banqueta* road. *Banquetas* are similar to curbs in modern streets that help delimit the boundaries of the walking surface. This type only has a *banqueta* on one of the sides, the opposite boundary is not necessarily clear but could have been marked by vegetation or differentiation in the ground erosion. I suspect that the function of the *banqueta* is mainly to mark the space for walking.

On the surface, *banquetas* are alignments of medium to large size rocks. The rocks are not necessarily next to each other. In fact, there are usually gaps in between and they are not staked, faceted, or prepared. Since they do not require much work, a single person could create these *banquetas* in a matter of hours depending of the length of the road.

During the excavation of this project, I observed that some *banquetas* extend underground. This means that they were built as small retention walls, then filled and covered with material to create a flat area, leaving only a walking surface and simple alignment of rocks exposed on the surface.[11] This work is not common, and I would not expect this was the norm in Angamuco. It might have taken considerable amount of work and resources for little functional or aesthetic reward. In any case, the small walls that might serve as foundations for *banquetas* are completely covered and not identifiable on the surface.

2) Double *banqueta*.

Figure 7.12. Double-*banqueta* road type.

Identical to the simple *banqueta* type, however with *banquetas* on both sides.

3) With *talud* (retention wall / terrace)

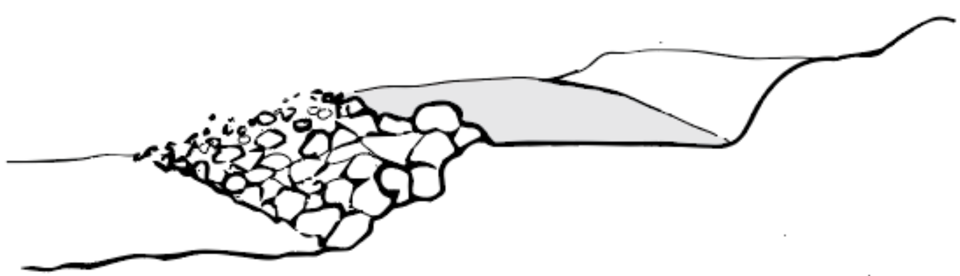


Figure 7.13. With retention wall or terrace road type.

This type of road segment is shaped by an inclined retention wall on one of its sides (*talud*). The wall is usually a reinforcing feature built to control the slope and includes a mix of medium

[11] See unit U1A02 in chapter four for an example.

to large rocks and sediment. At the top, the walking surface resembles a terrace (agricultural terrace in the LORE-LPB architecture typology in Fisher et.at. 2019a). It is possible that this surface was used for both growing crops, such as maguey or beans, as well for as a walking surface. The *taluds* we observed are smaller versions of the retention walls found elsewhere in Mesoamerica (see example in unit U1A02). Overall, this type of road seems to have been created at lower parts of slopes and is usually parallel to sunken *calzada*s created by the topography.

4) <u>Partially created by topography</u>.

Figure 7.14. Partially created by topography road type.

This type of road makes use of the natural (or artificial) topography to delineate one of the boundaries, with the other side marked by a retention wall, *banqueta* (like the example in Figure 7.12) or left open.

5) <u>Fully created by topography.</u>

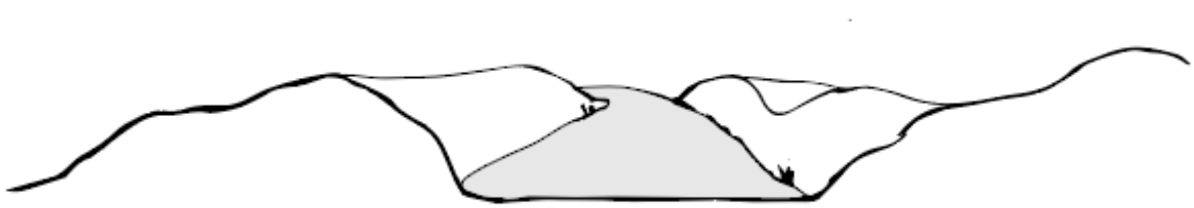


Figure 7.15. Fully created by topography road type.

In this case, both sides are marked by topography. There are two versions of this type. One in which the natural topography creates a valley or sunken *calzada* that then is used as a road. The second, is one in which a hill is cut-through to build a road. In the latter case, the two sides of the road are the internal walls of the hill. There are several examples of sections of roads like these two in Angamuco.

6) With walls.

Figure 7.16. Road type with two walls.

This is the clearest evidence of road construction at the site. These roads are delimited by newly constructed walls erected using the material from the area. These walls can be as tall as 1 m and as wide as 1.5 m each. On the surface, they seem to have been constructed similarly to other walls and features in the site. That is, using larger boulders as foundations and piling up medium rocks on top, with mud as mortar.

7) Raised causeway / *Huatziri*.

Figure 7.17. Raised causeway or *Huatziri* type.

The last road type is very similar to the *Huatziri*, a unique form of a single, tall (~2.5 m) linear platform that functions as a large wall with a walking surface on top. This structure is sometimes slightly trapezoid showing two *taluds*. Its width is of ~2 m and the flat top is either compacted or paved. There are examples of them in other Purépecha cities, including Ihuatzio and Infiernillo, where they were probably used as processional walkways for ceremonial activities (Cárdenas García, 1992; 1993; 1999; 2004; Du Solier, 1936; Marquina, 1929; Michelet, 2008). Other examples in Mesoamerica found in the Mayan area with similar raised causeways are called *sacbeob* (Hutson, 2014; Hutson et al., 2012; Keller, 2006).

The examples of this type in Angamuco are not very clear. Some are comparable to versions of terraces. They do not seem to function as limiting walls as suggested for the *huatziri*. I believe that, in Angamuco, some roads are raised for emphasis or to traverse through flood-prone areas (see example in unit U1I03).

7.1.2 Typology of nodes

Nodes are the other component of a road network and Angamuco has a wide variety of types based in several physical and topological attributes. As with my method for segments, I aimed at collecting the attributes that could reflect different aspects of node use and the possibilities for interaction afforded by the node. I have classified all nodes in the PACUA sample based on four characteristics: 1) size, 2) shape; 3) connectivity, and 4) topology (Table 7.3). Each of these have their own set of types or classes, which are mutually exclusive, and are not hierarchized. Again, here I present the results of the field collection and an interpretation of the total count and proportions of all types/subtypes of nodes.

	CATEGORIES	TYPES	N *	DETAILS	RATIONAL
Nodes	Size (area)	Small	15	< 0.5 m²	Interaction
		Medium	172	0.5 - 3 m²	
		Large	129	> 3 m²	
	Shape	Plaza-node	59		Planning and temporality
		Simple-node	60	Patio, entrance, or end-node	
		Y node	144	a and b	
		X node	20	a and b	
		T node	33	a and b	
		Multi-node	-		
	Connectivity	1-segment	64	Number of connecting segments	Traffic
		2-segment	92		
		3-segment	193		
		4-segment	20		
		Multi-segment	11		
	Topology	Superposition	34		Relative temporality
		Not clear	282		

Table 7.3. List of categories, types and subtypes for nodes on PACUA sample.
*Not all the counts by category total 379 surveyed nodes.

Node size

The area of the node is directly related to the number of people that can fit within it at once. This is especially significant for understanding interaction and movement within the network. For example, if the crossroad is very small, there is little incentive for a traveler to take a break there or to stop if they encounter someone. By contrast, a very large node can become a space for travelers to gather, for a temporary market to be set up, or other social activities.

I have classified the nodes at Angamuco based on three area (m^2) sizes:

1. <u>Small</u>. These nodes are created by the segments themselves and usually associated to *pasillo*s and *senderos*, with an area smaller than 0.5 m^2.
2. <u>Medium.</u> The average area is between 0.5 and 3 m^2.

3. Large. The average area is larger than $3m^2$. They can be as big as 150 m^2 when also used as plazas.

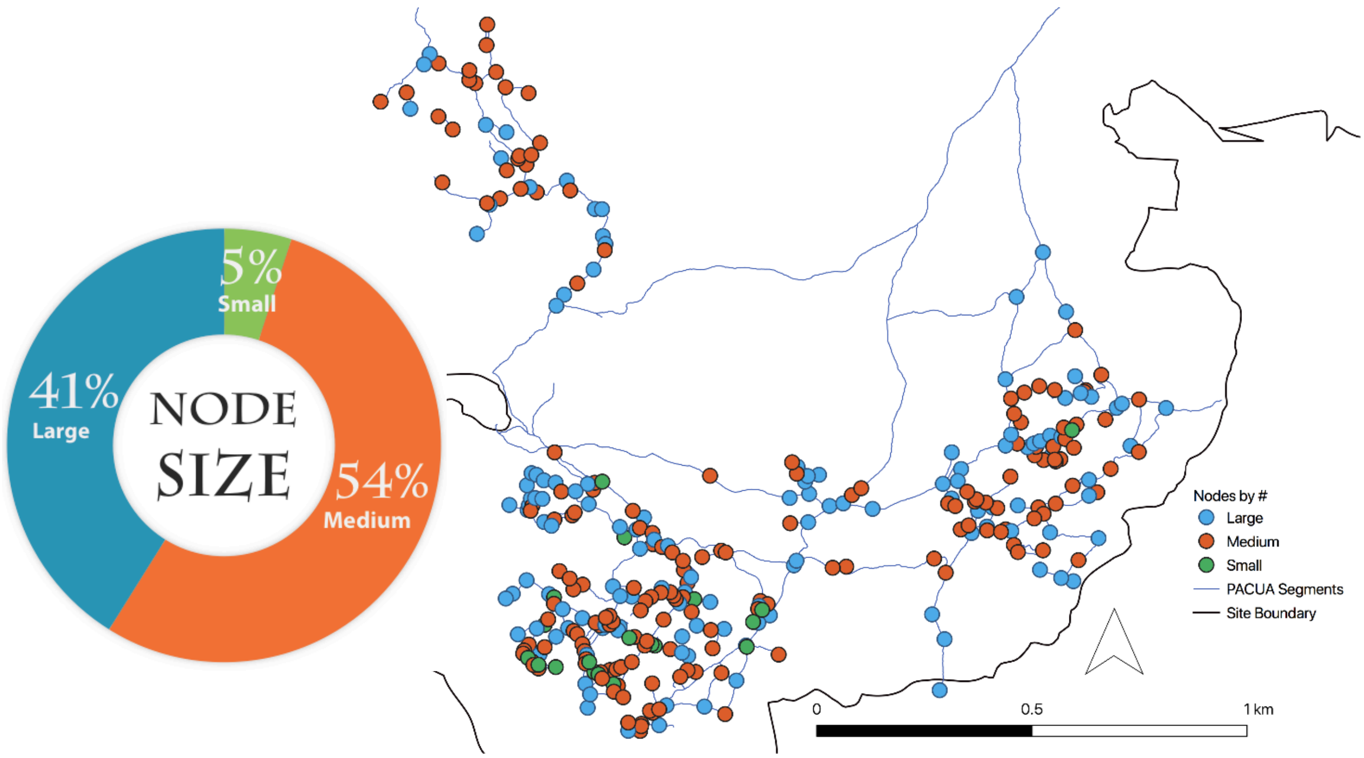


Figure 7.18. Proportions of nodes by area size and their location.

Surprisingly, small nodes are not the most common (only 5%). This could be because the mapping sample concentrated on roads outside *complejos*. Small nodes are more closely related to *pasillo*s (circulation inside complejos). Medium-sized nodes are, by contrast, the most commonly occurring types with *sendero* size segments. This represents the majority of what we found, whereas large nodes are associated with patios and plazas, which are areas for more than just the crossing of roads.[12] In sum, medium and large nodes, which probably have afforded much more interaction, are most common in the site.

[12] See interaction below.

Node shape

There are multiple types of nodes based on their shape. Most of these shapes are the result of the way segments intersect. However, some of the nodes may have been designed (e.g., patio and plaza nodes). Because the nodes are formed after changes in the segments, nodes could help explain how the network evolved or changed. For example, if a road is added to an existing road, then a new intersection is formed and, depending on its shape, could help identify which of the segments existed before. I grouped all unique forms into six categories, with three of them having subtypes.

1) Plaza-node

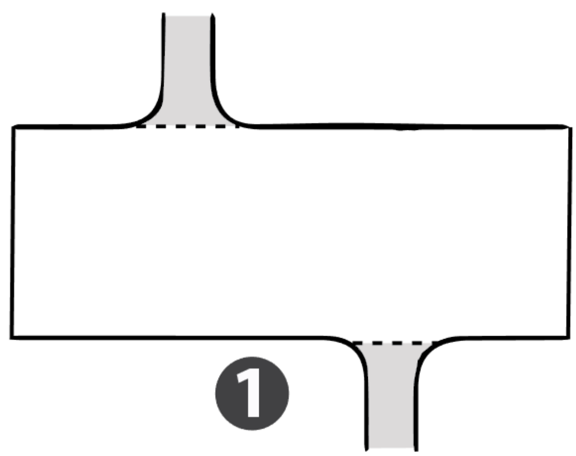


Figure 7.19. Plaza-node. It can connect more than two segments.

These nodes represent very large open or sunken areas like the plazas identified throughout the site. They might have hosted diverse cultural activities such as markets, religious celebrations, and other kinds of gatherings. Plaza-nodes can be the last point of a segment (dead-ends) or can connect to other segments.

2) Simple-node

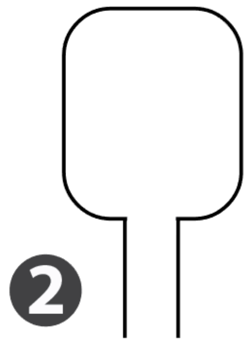
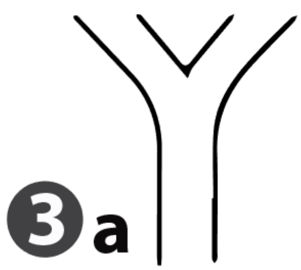


Figure 7.20. Simple-node (end-node). It connects only one segment. It could be a patio or entrance.

Simple-nodes connect to only one segment. They are similar to plaza nodes when they are large, like patios, but some can be entrances to *complejos*. Technically, an entrance would be a different node that also connects to internal *pasillo*s, but I have aggregated those within this type to keep the classification simpler.

3) Y-node



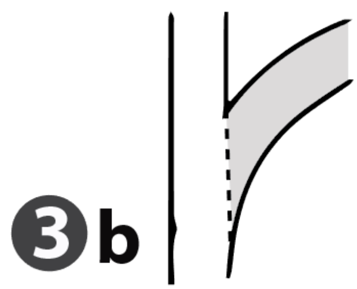


Figure 7.21. Y-nodes connect 3 segments and have an oblique shape.

Y-nodes connect three segments and their shape is oblique or irregular. There are two subtypes of Y-nodes: subtype 3a does not show any signs of hierarchy between the connecting segments. It could, for example, connect three different roads. The other, subtype 3b, has elements to suggest that one segment was added to an existing road. Some of these signs are blockages, steps, ramps, or a clear difference between segment types.

4) <u>X-node</u>

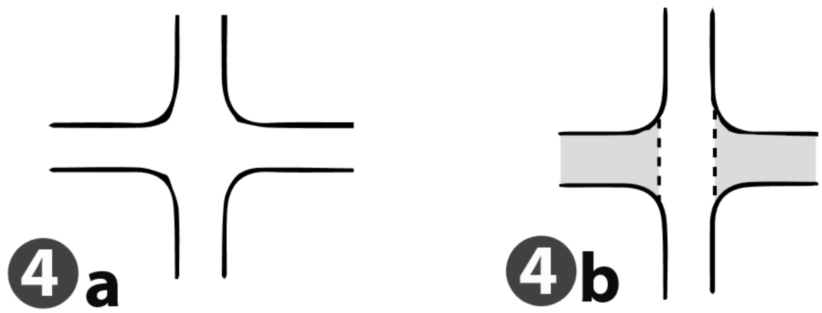


Figure 7.22. X-nodes connect 4 segments. Subtype a shows all segments of same class while b shows two or more segments of a different class.

X-nodes connect four segments and their shape can be orthogonal, although several examples were irregular. Similar to Y-nodes, there are two subtypes (4a and 4b) and X-nodes also depend on signs of segment hierarchy. Subtype 4a includes all segments of same class, while 4b shows two or more segments of a different class.

5) <u>T-node</u>

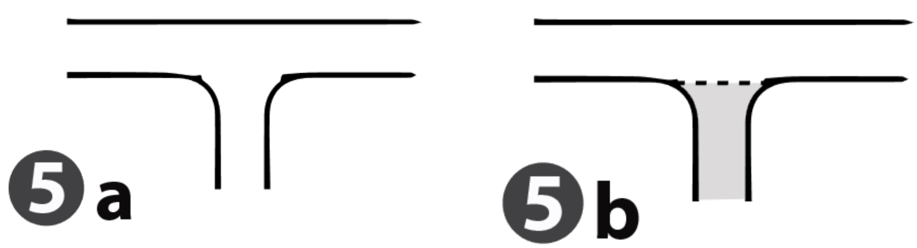


Figure 7.23. T-nodes connect three segments and have an orthogonal shape.

T-nodes connect three segments, similar to Y-nodes, but the difference is the clear orthogonal shape. This is an important attribute because T-nodes generally appear with straight and flat roads. This could be a good indication of planning. Again, there are two subtypes (5a and 5b), depending on signs of segment hierarchy.

6) <u>Multi-node</u>

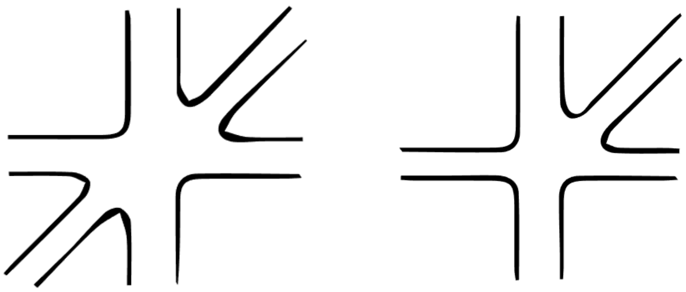


Figure 7.24. Multi-nodes connect more than four segments with various shapes.

The last type of nodes connects any number of segments over four. Naturally, there are many different shapes.

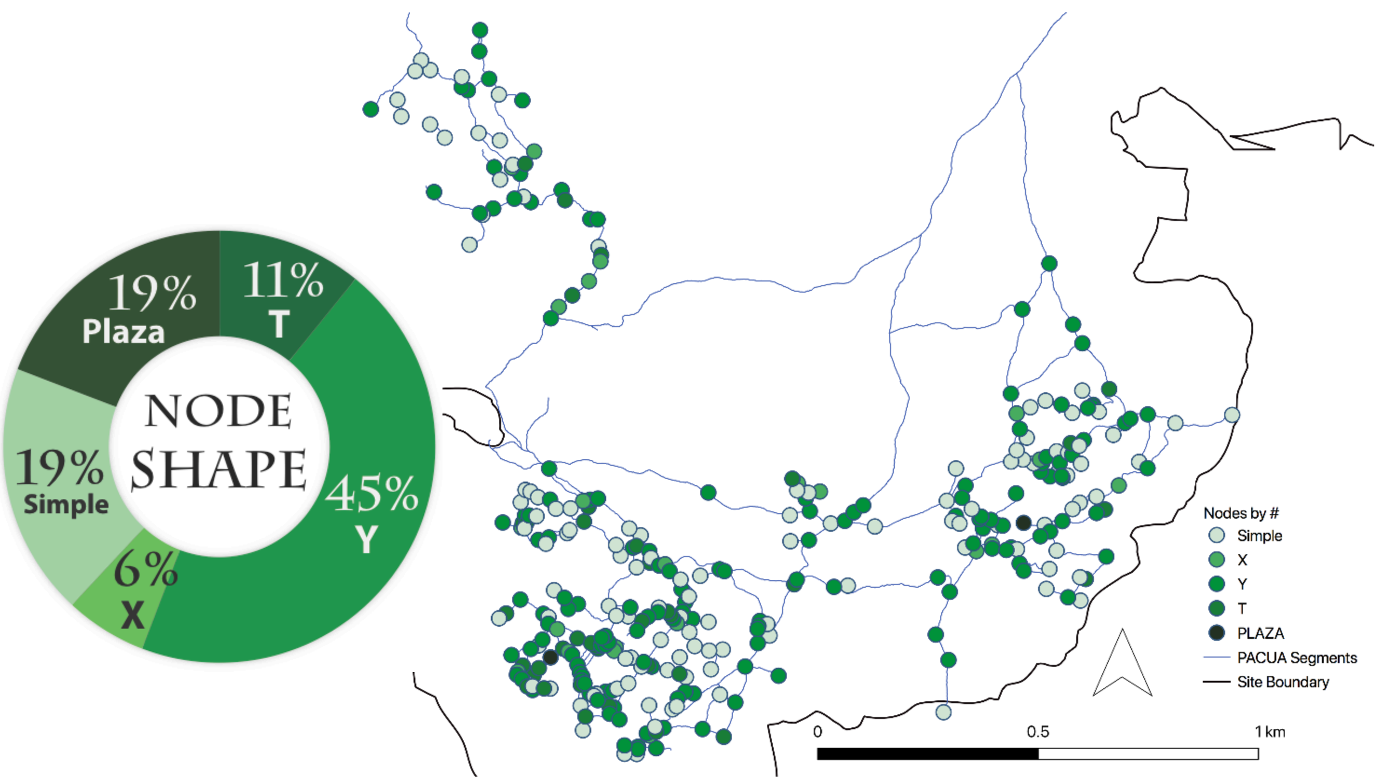


Figure 7.25. Proportions of nodes by area size and their location.

The most common node is the Y-node, constitute almost half of the total nodes sampled. If Y-nodes can be interpreted as roads that eventually had another road added (subtype 3b), this might suggest that the network was organically developed. Accordingly, the majority of the nodes might not have been planned or designed, but instead emerged as the needs of the inhabitants changed. By contrast, both T-nodes and X-nodes are generally related to planned roads, and together make up only a small part of this sample. In sum, the different types of nodes show the diversity of roads and the complexity of the network. While there is some evidence of road planning, it appears that the morphology of the network largely responded to the local needs of residents.

Node connectivity

Another way to classify nodes is based on how many segments they connect. This is useful to get a general sense of the connectivity of the network (Hillier, 2007). Moreover, it helps identify which nodes have more opportunities for route selection (Freiria et al., 2015). The type of connected segments and their direction are irrelevant in this classification.

I identified a total of five types of nodes for this classification, based on how many segments connect at the node.

1) 1-segment node. Also called an end-node, it connects only one segment.

2) 2-segment node. These are usually at patios or plazas, when the node is very large but is connecting two segments.

3) 3-segment node. This type is the most common.

4) 4-segments node. The most likely planned type of node.

5) Multi-node. Connects more than 4 segments.

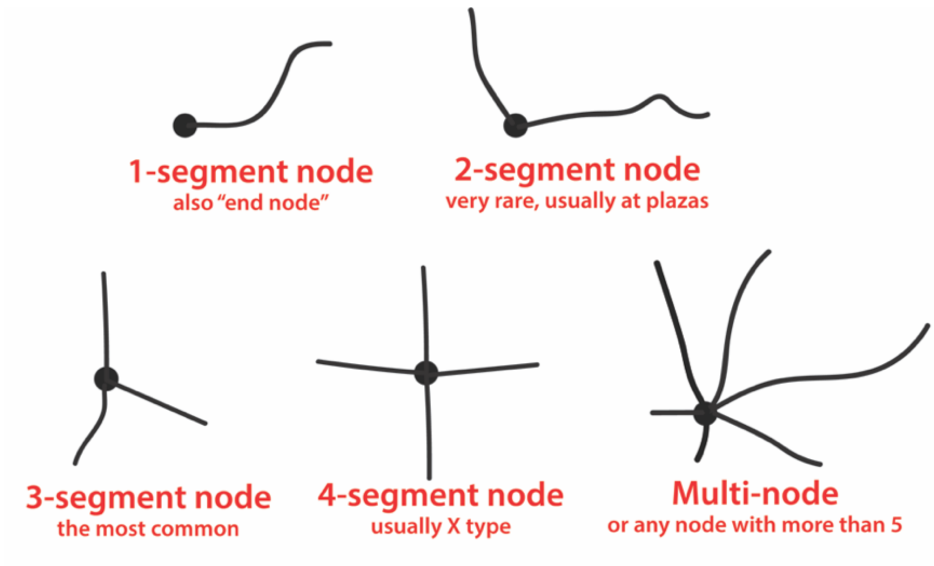


Figure 7.26. Examples of node types based on their connectivity.

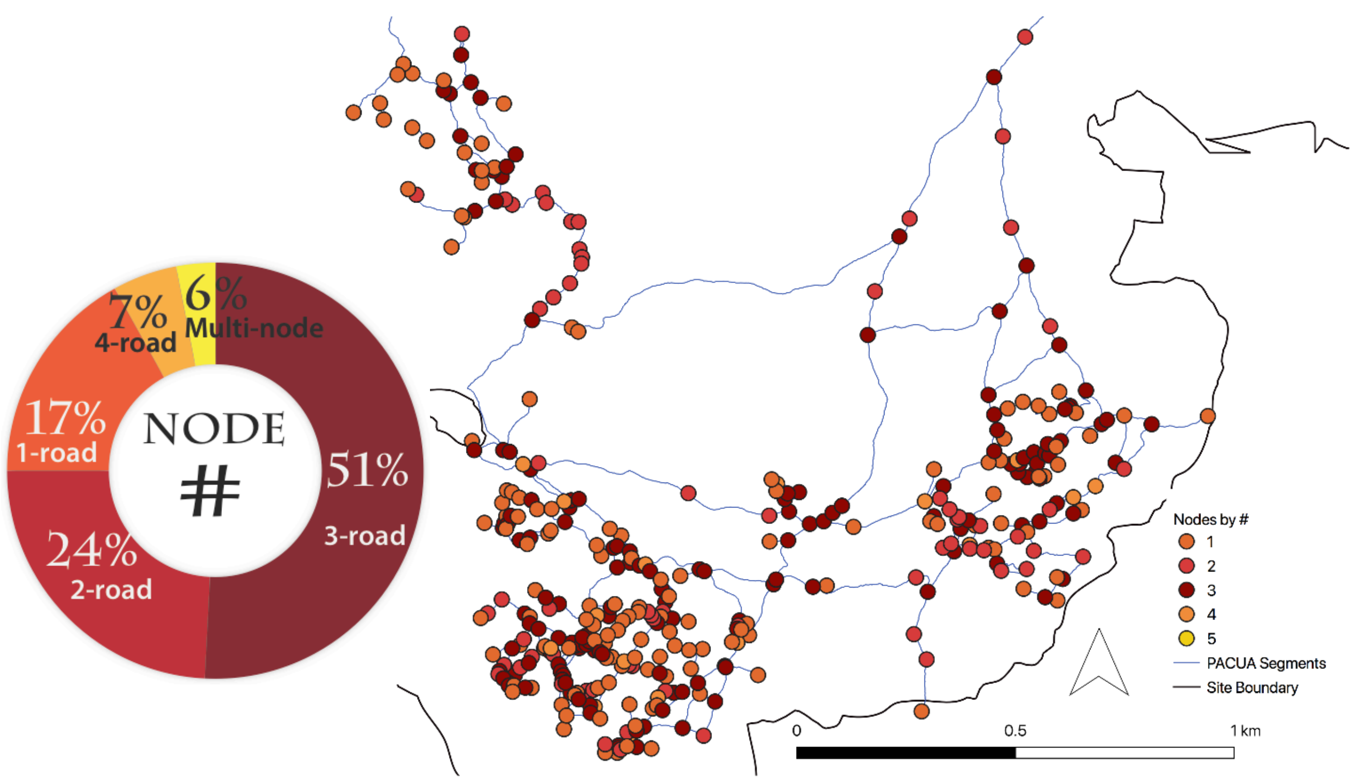


Figure 7.27. Proportions of nodes by number of segments they connect and their location.

Overall, finding many 3-segment nodes might indicate an organic development of the network and furthermore that points to the diversity and intricacy of the network. This is the same general conclusion of the typology by node shape. The sample also provided a very large number of 1-segment and 2-segment nodes. Specifically, the large number of 2-segment nodes, found where there might not be a need for a change of direction or connecting segments, leads to the hypothesis that the nodes themselves are important destinations.

Node topology

The last classification relates to the ease of observing a significant topological relationship between different segments at a node. That is, the possibility to identify overlap of segments that might suggest temporal ordering of roads. This hypothetical example uses an X-node subtype 4b: wherein, a road has existed at one location for quite some time. Then, eventually another road is built crossing over the first one. If the second uses a *banqueta* system but the original road had no architecture, then it might be easy to observe this topological relationship.

However, this is difficult observe in the field. The researcher must be acutely aware of the many attributes present and the ground must be highly visible for these observations to be possible. As demonstrated in the excavation of unit U1A02, it is possible to see this in profile. I grouped the total sample into two types: where it is possible to observe superposition of roads and where it is not. Doing so, I was able to identify 34 nodes where there is evidence of superposition on the surface.

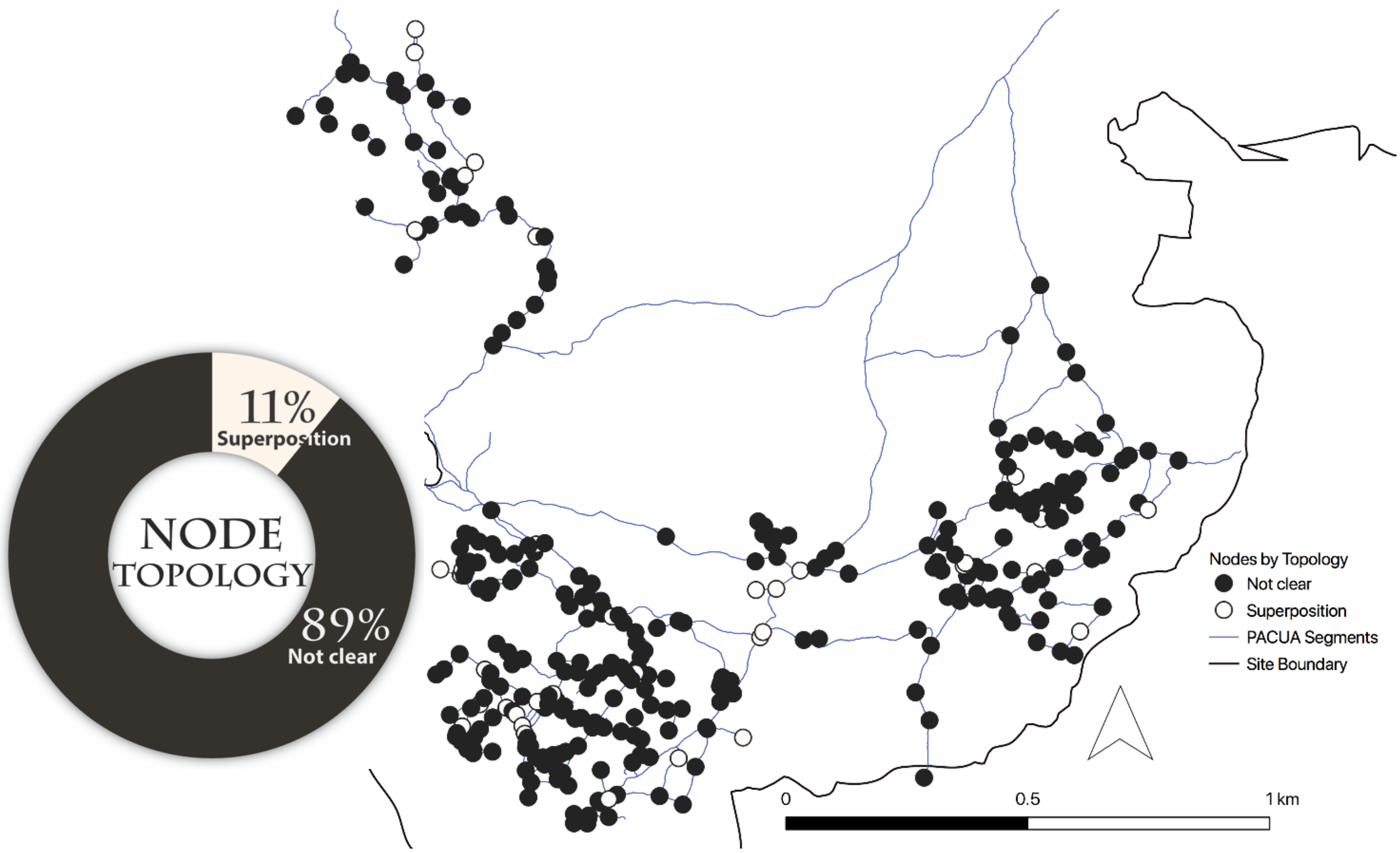


Figure 7.28. Proportions of nodes evidence of superposition and their location.

7.1.3 Summary of typology

Creating a typology for the nodes and segments of Angamuco is instrumental in beginning to understand patterns in the network, as well as recognizing how their attributes explain interaction, planning, and temporal sequence.

Based on their size, segments can be interpreted as private (*pasillo*s), community-used or semi-public (*senderos*), and public roads (*camino*s and *calzada*s). Of all of these, the most common type of road is the *sendero* (>70%), which is suitable for traveling alone or with one other person, and likely created and maintained by members in the immediate community (such as neighborhoods) based upon their simpler construction.

Residents at Angamuco were heavily engaged in the transformation of their landscape. Shape and slope are important attributes in identifying planning. According to the sample, roughly one-third of the roads provide definitive evidence of construction and planning. Construction styles were not counted during research. So, at this point, it is not possible to make sense of the most prevalent styles. What is known is that there is a wide variety of construction styles. This diversity, however, seems to be standardized, which might point to a society that engages in community, where types of roads that work given the topography, function or style are copied, or reused. The construction techniques also suggest different levels of engaging in community, from simple roads that required one person to build in only few hours (e.g., stacking rocks to create *banquetas*) to large and complex projects where hundreds of people and likely months' worth of labor were required for construction (e.g., large ramps).

Area size is an essential classification for nodes. Nearly all those surveyed (~95%) are large enough that they could host social interaction and gathering. These nodes not only function to distribute the traffic but as important locations to enhance daily interaction. In sum, the results from survey and mapping provided evidence of a diverse and standardized assemblage of roads (segments and nodes). This sample confirms that the road network is complex and resulted as a combination of direct engagement and planning, and less active modification of the natural topography.

7.2. Summary of general characteristics of the road network

Both the PACUA and DIGAR samples combined, produced a total of 12,834 km of walking surfaces in the network, comprised of 2,620 segments and 3,620 nodes (Figure 7.29). The combined work of applying several urban network analyses (UNA) permitted me to identify general characteristics of the network and outstanding segments and nodes. The network covers virtually all areas of the site and is very well integrated. This allows for almost all locations of the site to be reached using roads with multiple route options. Angamuco's road network is complex with thousands of diverse road options based on size, direction, and centrality. This complexity makes the network very versatile. Next, I present two general conclusions based on the urban network analysis: a) the identification of the main roads, and b) patterns of the network morphology.

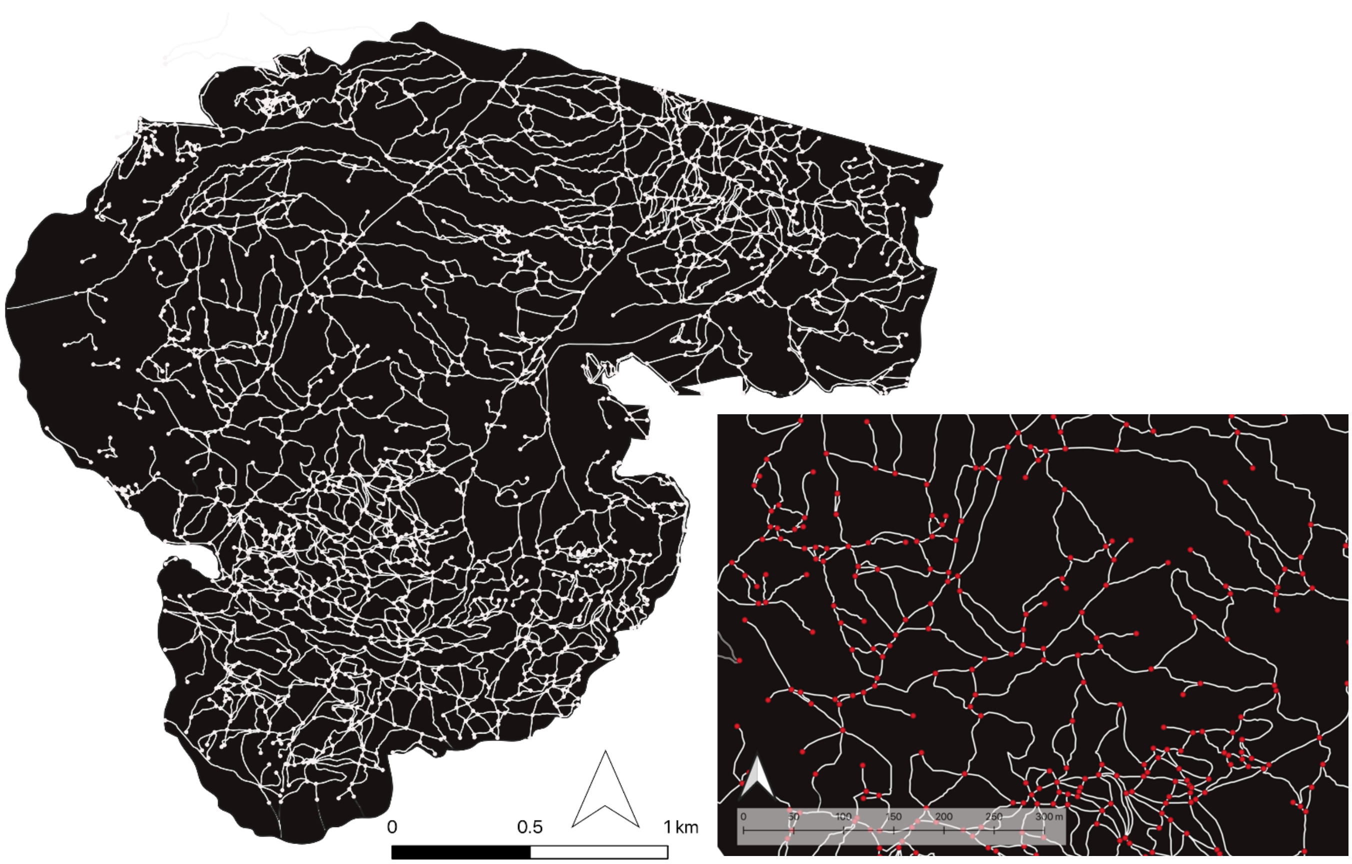


Figure 7.29. All segments and nodes (in white) of the site on the left, and detail on right.

7.2.1. Identification of main roads

Angamuco is a very large urban center with thousands of architectural features. It was expected that the site would have several roads that functioned as main arteries, directing traffic and connecting remote parts of the site. Before fieldwork started, and after three years of survey as part of the LORE-LPB project, several roads were identified and mapped (Fisher et al., 2011, 2019). Although these roads are clear on the surface and the DEM, they were never ground-verified. Only disconnected segments were mapped and no other measurements or attributes were collected besides their general shape and location.

In this research, UNA helped identify the main arteries, and allowed for the classification of roads into secondary and tertiary roads based on network-centrality indices. I propose that Angamuco had a four-tier system of roads (Figure 7.30):

1) <u>Primary roads</u>

These roads were planned, built, and maintained by the governing structure (state). Primary roads are generally *calzada*s or *camino*s. They are generally flat, straight, exposed, and easy to traverse. Their segments between nodes are longer in average (~30 m), and they connect to all entrances to Angamuco.

Two primary roads run parallel through the center of the site in a N-S direction, with several others perpendicular, and a last one following the escarpment in the lower part of the site. The total number of segments that count as primary roads is 238, or 9% (red segments in figure 7.30).

2) Secondary roads

Secondary roads complement the main roads and have very similar characteristics, although they seem to be slightly narrower (*camino*s) and extend in a radial shape throughout the entire lower Angamuco area to the south. The total number of segments that count as secondary roads is 291, or 11% (orange segments in figure 7.30).

3) Tertiary roads:

These roads are smaller, all of them are *camino*s with curves and slopes. Tertiary roads appear to be the most important roads within neighborhoods or districts and are likely modified from the landscape by the community. They are not direct routes. They are usually curved, include a slope, and are not too exposed. The total number of segments that count as tertiary roads is 825, or 32% (green segments in figure 7.30).

4) Common roads:

Finally, all other roads, totaling 1,266 segments or 48% of the network, are *senderos* and range from easy to difficult to traverse. All these roads most likely emerged as households created new spaces for living and needed to connect to the rest of the network. These roads are sinuous and many of them concealed. Perhaps they were surveilled if not controlled by the nearby residents. In any case, while some construction was required, most of them follow the natural topography. These roads are the best indication of how Angamuco residents adapted to the landscape and settled organically (gray segments in figure 7.30).

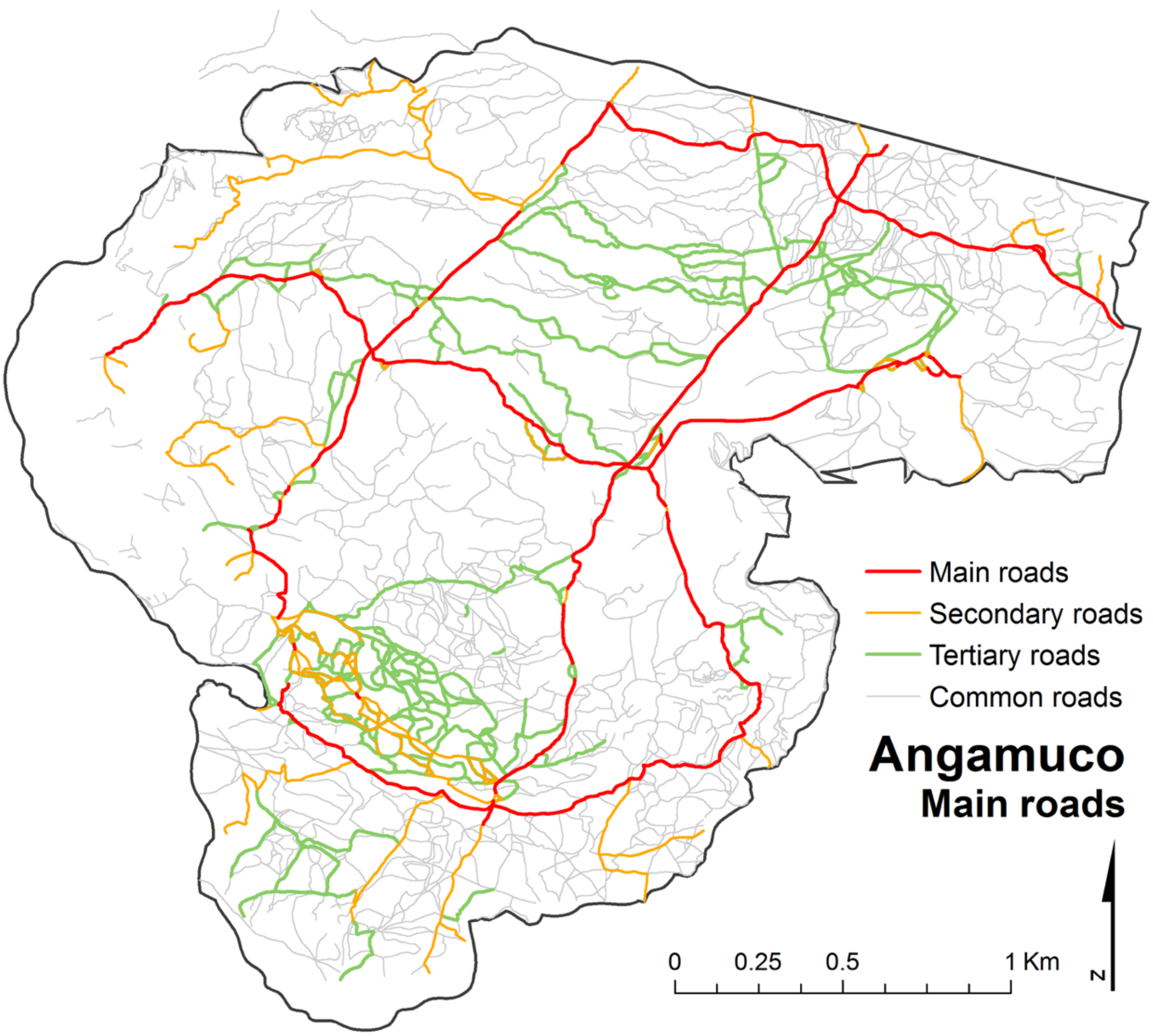


Figure 7.30. Map of the four-tier system of roads.

7.2.2. Patterns of the network

UNA also helped me understand the spatial patterns of roads at the site. Cluster and closeness analysis were instrumental to identifying two different patterns of road distribution: *dense* and *sparse* network patterns.

A dense network pattern is characterized by a high density of segments and nodes within an area. Topography seems to be a factor where dense network patterns are located. Dense networks are composed mostly of *senderos* and not necessarily located near entrances but aligned with or centered by a main road.

I identified two areas of dense network patterns in the site: the areas described before as *NoE* (~ 0.5 km^2) (Figure 7.31) and *SoC* (~ 0.65 km^2) (Figure 7.32). Both of these areas are located on upper Angamuco, and not directly associated to Late Postclassic architecture or surface material (based on the results from LORE-LPB work). Area NoE was not as thoroughly mapped as SoC.

I suggest that these two areas might be able to shed light on the chronological development of the city. Both areas were likely populated around the same time, before the Middle Postclassic, in a period when the Upper Angamuco was settled. This does not mean that these two areas were occupied before the rest of upper Angamuco, but that the city was probably more centralized until then. A denser road network might mean that there is more cohesion among households and/or that resources (natural and cultural) were more shared. If this is true, then it is possible that the un-centralized urban layout of Angamuco was developed during the Early and Middle Postclassic.

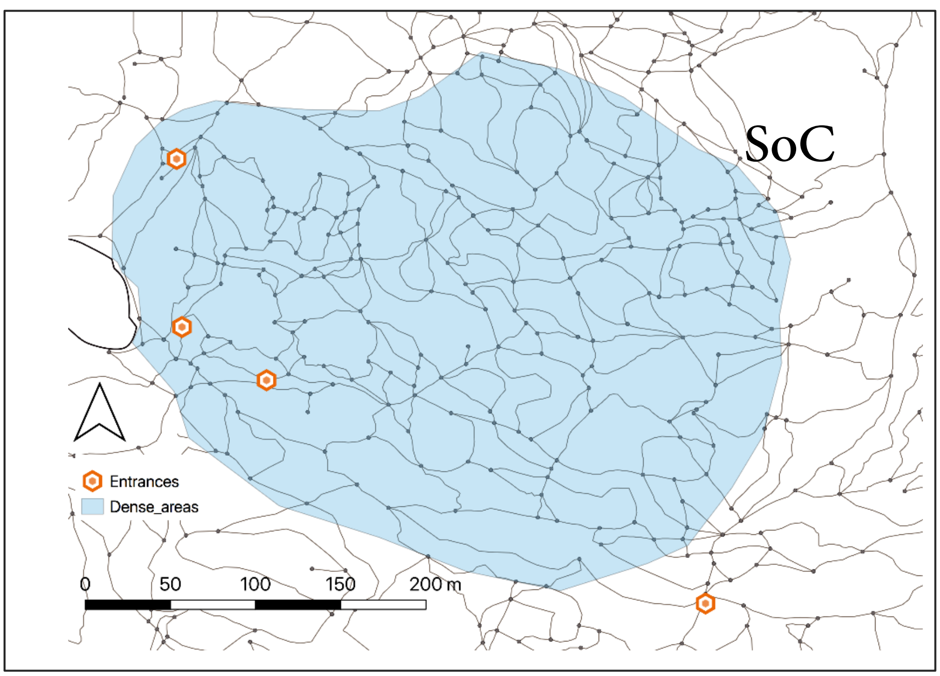


Figure 7.31. Example of dense network pattern. SoC area.

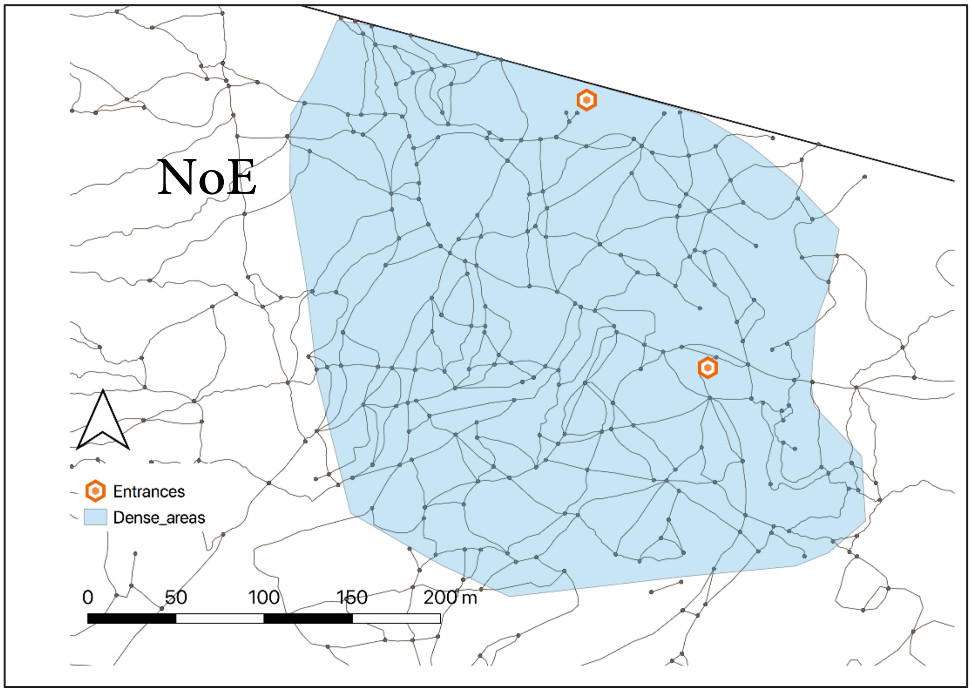


Figure 7.32. Examples of dense network pattern. NoE area.

Conversely, a sparse network *pattern* has a large diversity of road types and allows connection of extended areas, resources, and locations (the non-blue areas in Figure 7.33). I see the rest of the network (excepting NoE and SoC) as a sparse pattern. This pattern of road distribution is more functional, with a skeleton of main and secondary roads, from which many other smaller roads extend to reach all areas of the site. It is this pattern that I believe is associated with the period of large transformations at Angamuco sometime around the year 1100 CE, during the Middle Postclassic, and the centuries leading up to the formation of the Empire. If this is true, the road network, as I observe it today, remained generally unchanged through the Empire and only modified slightly following the conquest in 1530 CE.

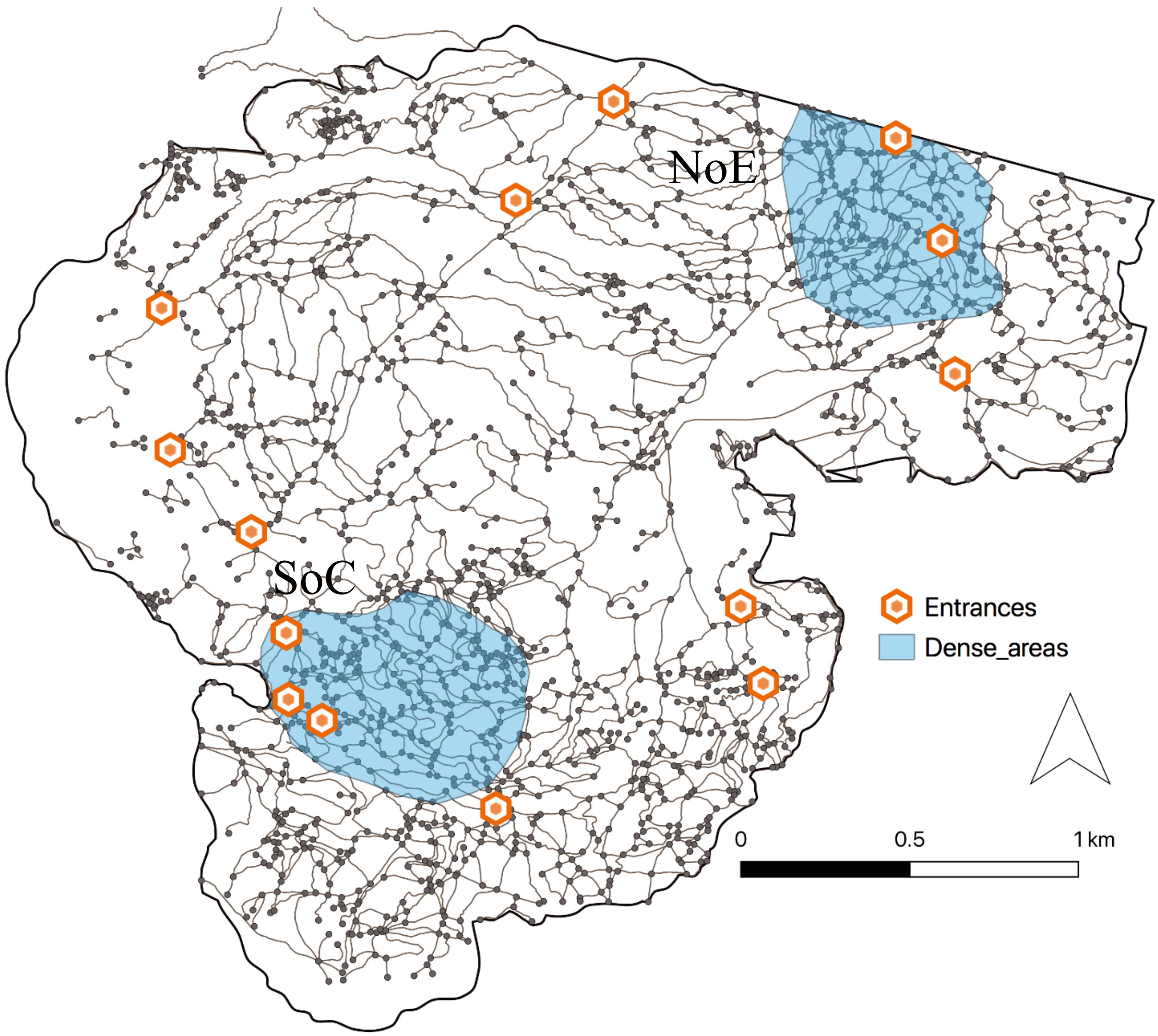


Figure 7.33. The two types of network patterns. Two blue dense networks, and the rest, sparce.

7.3. Urbanism: Social divisions of the site

Roads define social spaces by creating physical boundaries that affect the continuity of the built environment (Cutts et al., 2009). At the smallest scale of human interaction —individual scale— small roads like *pasillo*s can serve to connect and unite commonly used areas, like peoples' houses, creating an habitual space where its residents share some type of cultural affiliation or even identity (Arnauld et al., 2012; Kahn, 1996). By contrast, larger roads like *camino*s or *calzada*s, in fact, create voids in the landscape, demarking and shaping the space.

For Angamuco, Fisher, Urquhart, and the LORE-LPB project interpreted clusters of architectural features as socio-spatial units. The initial proposal suggested that these clusters occurred at three scales of organization: *Complejo* (the smallest, being a group of households), *Neighborhood* (that can extend to ~0.5 km^2), and *District* (groups of neighborhoods at larger scales) (Fisher and Leisz, 2013; Urquhart, 2015). While specifics on their configuration or the material components that form these clusters have never been described in detail, the proposal suggested that the residents inside each of these spatial units shared public spaces (e.g., plazas, public houses, etc.), familiar farming areas (e.g., patios, terraces), and other resources (e.g., wells, pyramids, water tanks). Moreover, the boundaries for these social clusters were implicitly defined through the combination of road segments, natural topography, and the built environment. Thus, Fisher (2011, 2013) and Urquhart (2015) used the presence of road-like features, more specifically their lengths, to produce a preliminary interpretation of the city layout composed of ~600 *complejos*[13] spread throughout the city.

This dissertation represents the first attempt to explore whether roads acted as explicit boundaries for such socio-spatial units.

In the following section, I explore three crucial components for the social configuration of the site. First, I explore the internal circulation and the configuration of two *complejos* chosen as examples. Then, I compare the idea of *complejos* and propose an alternative socio-spatial division of the site: the *city-blocks* approach. Finally, I discuss the entrances to the site and their role in the road network as public locations that influenced route selection.

[13] I have completed this work for other areas of the site to a total of 685 *complejos*

7.3.1. Circulation within *Complejos* (64 and 254)

Complejos are very diverse in size and configuration. The digital mapping of architecture over three years of full-coverage survey (Fisher et al, 2019a) provided basic shapes and dimensions of individual architectural features dispersed over 17% of the total area of the site.[14] From this data, it is possible to identify architectural features within *complejos* for as many as 283 out of 685 *complejos*. This is, however, not a complete picture because the roads that might have acted as outer boundaries of *complejos* and the *pasillo*s that supported circulation to the interior were never mapped before this project.

I mapped the internal roads or *pasillos* of six *complejos* in four areas of the site (Figure 7.34).[15] The results support the initial idea of the diversity of *complejo* configuration (Table 7.4).

COMPLEJO ID	AREA	# OF INTERNAL PASILLOS	# OF ARCHITECTURAL FEATURES
19	I	15	19
21	I	9	5
7	AD	14	37
20	I	11	11
254	H	15	27
64	FG	14	13

Table 7.4. Total counts of *pasillo*s and architectural features of surveyed *complejos* in 2016

[14] See chapter six

[15] These *complejos* were selected because the vegetation was less dense and visibility of buildings and internal *pasillos* was clearer.

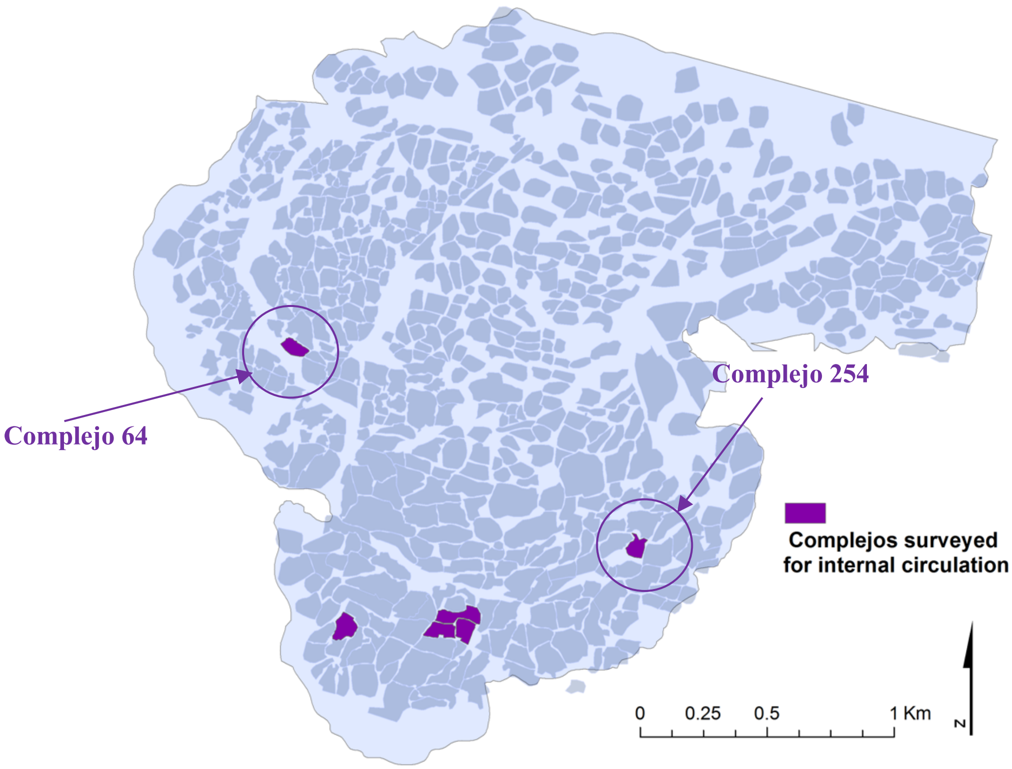


Figure 7.34. *Complejos* that were mapped for internal circulation (in purple).

There are several differences between the nodes and segments within *complejos*, as opposed to nodes and segments associated with the main network of Angamuco. For example, the general network roads are well defined either through their architecture or through their surrounding topography. As a result, their crossings stand out in some cases, because they were built to integrate roads (as in plaza nodes). This creates an explicit space for movement and walking. While there are many opportunities to create countless different routes, pedestrian traffic is guided by these roads, their confined walking surfaces, and their explicit direction. However, within the *complejos* —and once access is gained to a *complejo* through an entrance— circulation is less structured. The segments inside *complejos* (*pasillos*) do not have confined walking surfaces (e.g., *banquetas*, ramps, etc.). Instead, they are created by the spaces between other architectural features like rooms, buildings, mounds, terraces, etc. (functioning similarly to a hall inside a building). Thus, both the *pasillos* and nodes are not very explicit. Circulation inside *complejos* might at first appear open and unrestricted. However, access to buildings might actually be limited and structured.

***Complejo* 64**

In the example of *complejo* 64, located in Area G on the east side of the site (Figure 7.35), there are at least 10 rooms and few other semi-public areas that include patios, a large plaza, and a well. The *complejo* is delimited by sharp topographic features like the escarpment to the south and hills to the north. There are two formal access points to the *complejo*. One is from the south through the escarpment. Although, this is a very narrow *pasillo* (not a formal road) that connects to small terraces and was most likely only used by the residents of the *complejo*. The other is at the northeast side, through a formal entrance to the *complejo* that also creates a node for three *sendero* segments.

Circulation through the *complejo* is directed by the internal network of *pasillos*, meaning that certain locations need to be visited in order to access any other area of the site. For example, in order to access the plaza in the south or the area of rooms in the west, one must pass by two patios (or large rooms), near the entrance, and then through a cluster of rooms and patios by a well. Fewer combinations for new routes are possible within the *complejo* compared to the general network of the site. Some locations are more secluded, for example, the two rooms on the north side at the center, but many others are visited virtually all the time by all residents of the *complejo*. This creates a more intimate and continuous interaction of the residents of *complejo* 64 as they go about their daily activities. Two other interesting examples involve access to the well and to the plaza. The well was most likely a very important feature and it is located at the center of the *complejo* (or the *complejo* was laid out outwards from the well). The well is surrounded by a wall that creates a unique secluded room with only one access point, from which every person must enter. To access the well, there is a patio that acts like an antechamber with three access points. The well is a highly surveilled feature. It would be hard for people to get to the well without being noticed by the residents of the nearby rooms and patios. Contrastingly, the large plaza on the south has two access points. One of them, on the west side, does not have any rooms nearby and is less controlled, whereas the east access point is flanked by a series of open spaces (patios). The plaza (a public area that could have served as a religious gathering place, market, or area for children and others to interact), has less controlled access, which is more inviting for social interaction.

These two examples show how the circulation network offers differential interaction possibilities and access modes.

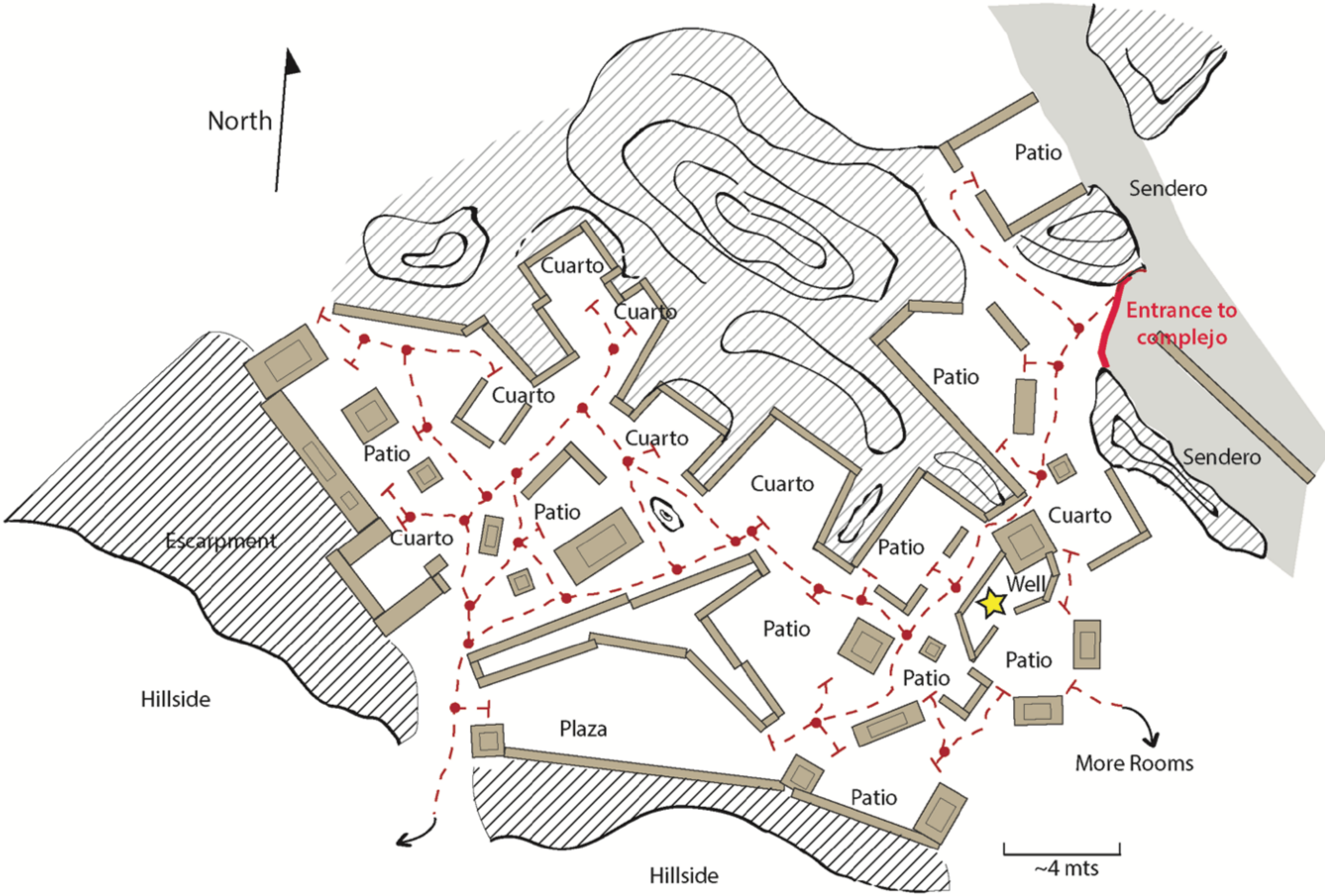


Figure 7.35. Plan (not to scale) of west section of *complejo* 64 showing architecture, and internal circulation. Located at I19SE, Tile 39 in Area G.

***Complejo* 254**

Complejo 254, located in area H on the west side of the site, shows further examples of internal circulation within a very different configuration (Figure 7.36). Again, main roads (*senderos* in Figure 7.36) and topography (escarpment to the south and hill to the north) define the outer boundaries of the *complejo*. However, access and circulation inside seem to be more structured than in the example of *complejo* 64. The spatial distribution of buildings confines movement much more. For example, there is only one entrance to the *complejo*, directly surveilled by the first set of rooms that also act as a vestibule. All residents of this *complejo* must pass through this vestibule to access any other part of the *complejo*. They also need to pass through it to get to the plaza on the west side. Access is generally more restricted, either because there are fewer options of routes, or because, in addition to narrow *pasillos*, pedestrians must also use stairs to access different levels (e.g., plaza to the west on a bottom level or the big staircase to access the *palacio* grounds).

Similar to *complejo* 64, the wells (in this case two) are located at the center. Interestingly, the one to the east is protected by an artificial stone wall that directs access through one location, contrasted with the one on the west located on an elevated natural platform without a clear restraining border. In practice, the latter well can be accessed from all directions once a >1 m platform step has been ascended. The difference in access to these adjacent wells is a unique feature to this *complejo*.

More research is needed on the interior of *complejos*, but no other *complejo* with more than one well has been discovered so far. It is possible that the two wells correspond to different periods. A second interpretation is that each well was used by different groups of people, either from different social or cultural classes. Human-made modifications of the space and the circulation infrastructure within the *complejo* could be a guide to explore how the wells were used. At the very least, the difference in access also provide different opportunities for interaction. For example, the west well can be visited by the most people and the open nature of the platform might invite people to hang around and socialize. It is also easy to see who is extracting water from a distance (e.g., from the entrance), without walking directly to the well. By contrast, the east well is very restricted. Only by entering the well grounds can a person see if the well is being used by others. The confined area of this well is big enough to accommodate over eight people and creates a very intimate space for them. However, it is considerably smaller than the west well. These two simple examples show how circulation within the *complejo* has the potential to enforce interaction and socialization.

Several other areas of the *complejo* are only accessible after passing by rooms and patios and thus, are very secluded (i.e., NE and SE patios). The clearest example of secluded areas is the *palacio* grounds located at the flatted top of a hill to the north of the *complejo*. In order to access to this area, residents must walk by a large and wide hall (that may have been used as a plaza or terrace) and climb through a set of informal stairs. The entire area is full of elite rooms and a large *palacio*, similar to that observed in El Palacio of Area A during LORE-LPB excavations in 2014. The entrance to the *palacio* grounds is highly restricted and circulation is completely directed. There is only one way to get to the *palacio* (as well as the patio behind it), which means that every single room is visited before accessing the most sacred location. These two areas (the general area and *palacio* grounds) explain the urban complexity of this site at the smallest scale.

In sum, architecture alone can be used to understand how people expressed social difference but understanding access and movement between these features also explains how the residents interacted while performing daily activities.

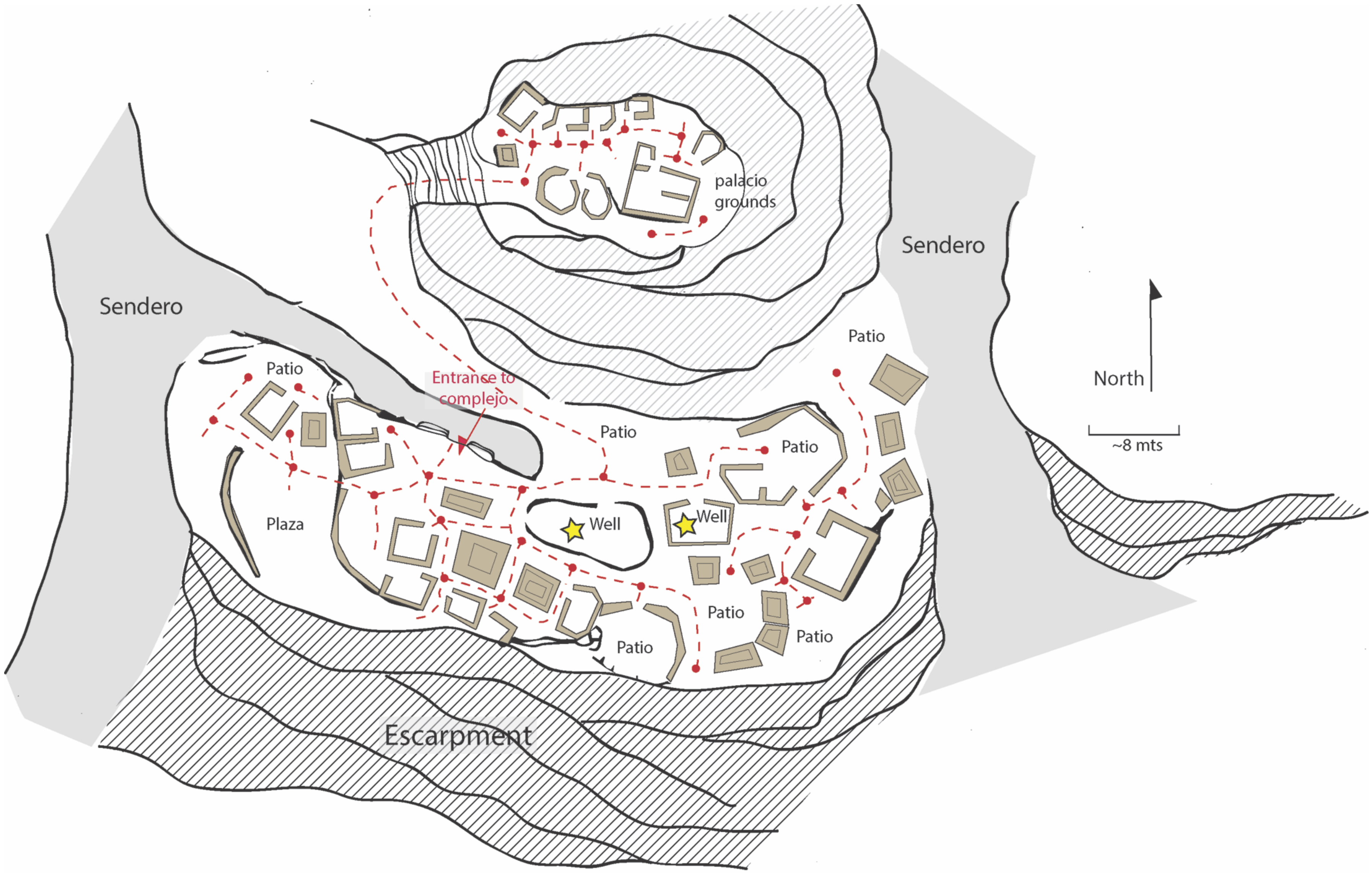


Figure 7.36. Plan of *complejo* 254 showing architecture, and internal circulation. Located at J18SW, Tile 88 in Area H. This plan is not to scale.

7.3.2. City blocks vs *Complejos*

Angamuco was a large urban center that probably hosted several thousand people at a given time. It has also been noted that there is not one unique ceremonial center, single water source, or shared farming area for all residents (Bush, 2012; Urquhart, 2015). That, in addition to the *complejo* system, suggest that the city did not seem to have been organized in a centralized manner. While a governing state might have influenced many aspects of life in the city, it is likely that residents self-organized spatially and socially.

If each unique *complejo* represents the living area of a social group, extended family, or community, then those areas would have to be delimited somehow. Fisher proposed that those boundaries were explicit and were established by a combination of roads and topography (Fisher et al., 2012). However, for some regions of the site, boundaries between *complejos* are not very clear. Examples of these boundaries are: extended natural features like ridges, terrace zones, or areas without architecture. Hence, delimiting these boundaries is an essential aspect for understanding the number and diversity of the social groups that may have constituted the *complejos*.

I have observed at least three kinds of boundaries:

1. <u>Natural (unmodified).</u> For example, ridges, hill slopes, valleys, and the escarpment.
2. <u>Modified.</u> When the natural topographic is partially modified. For example, a flattened top of a ridge, or some roads.
3. <u>Artificial.</u> Completely created by humans. For example, platforms, walls, and other roads.

Good examples of natural boundaries are the escarpment in both aforementioned *complejos* 64 and 254. In both cases, the escarpment, with a 30 m drop, creates a steep and treacherous limit to the south. Only few small *pasillos* connect to narrow terraces along the slope that were most likely accessed by residents of such *complejos*, not for public access. This escarpment provides an explicit physical limit but also defensive visual advantage points.

By contrast, *complejo* 13 (Figure 7.37) is a good example of a modified topography boundary. The entire *complejo* is located at the top of a large ridge in area A. In order to make space for rooms, patios, plazas and other spaces, its residents flattened the top of the ridge, creating a plateau (similar to the *palacio* grounds in *complejo* 254). The east and west boundaries of the *complejo* are a natural slope for the ridge, except they only function as boundaries after *complejo* 13 residents directly acted on creating a living surface (plateau) through engineering and collaborative work (Figure 7.37).

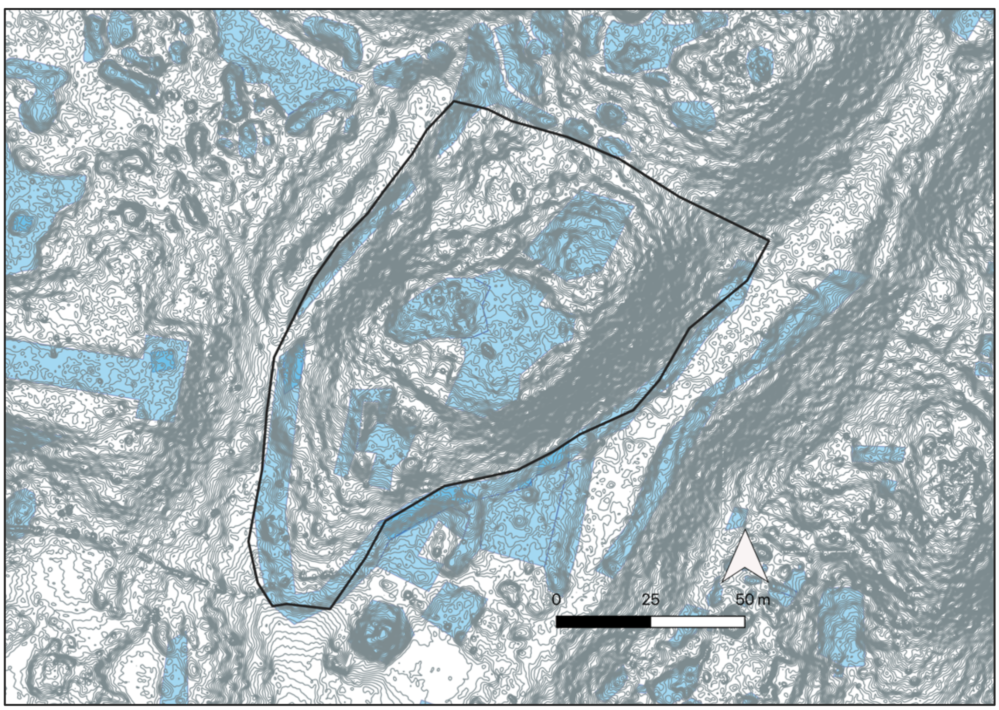


Figure 7.37. *Complejo* 13 (black line perimeter) built on the flatted top of a ridge. Gray lines represent contour lines of 50 cm and blue polygons are some architectural features mapped by LORE-LPB.

Finally, *complejo* 7 contains the semi-public building —ED 5130— excavated during LORE-LPB season 2013 (Fisher et al., 2014). It shows a completely artificial boundary. This *complejo* was built on top of a 1–2 m high platform that elevates all the buildings from the roads that surround it (Figure 7.38). The platform creates an explicit division between the *complejo* and the roads that lead to other features and *complejos*.

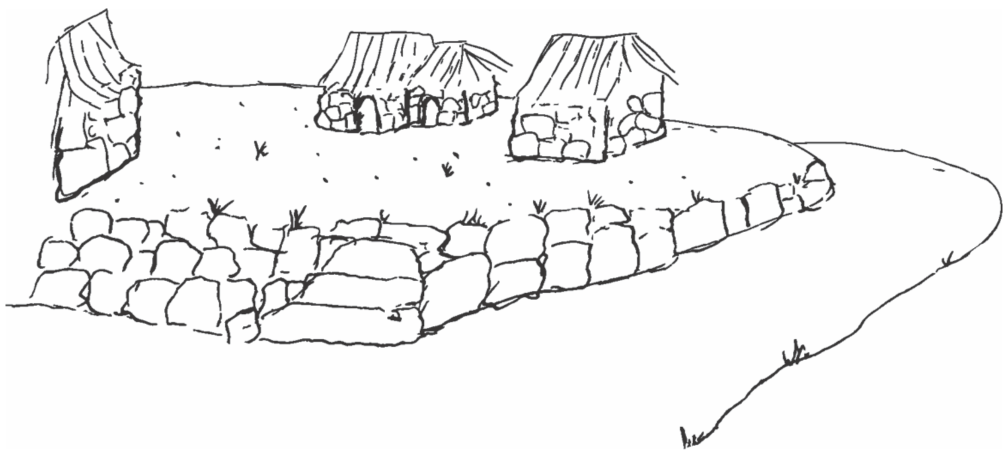


Figure 7.38. Sketch of *complejo* 7 built on top of a 1 m tall artificial platform.

In all these examples, roads run around the boundaries of the *complejos*, either emphasizing the platform, or helping navigate at the base of ridges and hills. Thus, while roads might not be planned as a fundamental element of *complejo* spatial delimitation, they do serve to highlight and identify the physical boundaries of such socio-spatial clusters.

I propose that in order to better understand the limits of a *complejo*, we extend the *complejo* grounds toward the closest road. For example, instead of defining the end of a *complejo* half-way through a hillside, we include the entire hillside as part of that *complejo* until the next road. It is very possible that natural topographic features were shared with residents of neighboring *complejos* and thus, those areas are not necessarily controlled by the closest *complejo*. However, assigning arbitrary limits to the *complejos* provides more uncertainty to the socio-spatial division of the site. Furthermore, all *complejos* are explicitly connected to the road network though formal *complejo* entrances that are located somewhere on the *complejo* boundary (see Figures 7.35 and 7.36). While roads of the network create a perimeter for the *complejo*, not every point of this perimeter appears to be used to access the roads. Even if the residents created shortcuts or jumped from the platform to the roads, making the perimeter permeable, the presence of such entrances suggests that there was an intended differentiation between the inter-*complejo* space and the outside space that is clearly defined by roads which are specifically crossed through at particular entrance points.

For all these reasons, I believe that the extraction of the complete road network from this research represents a new way of conceiving the *complejo* boundaries, on in which the roads play a crucial role in defining boundaries.

In Figure 7.39, I compare the two alternatives of defining *complejos*. The image on the left represents *complejo* 64 following a combination of roads and topography as observed by Fisher and Urquhart (2015). By incorporating the topography as part of the *complejo* and using the roads as perimeter, the same *complejo* changes its shape (right side of Figure 7.39).

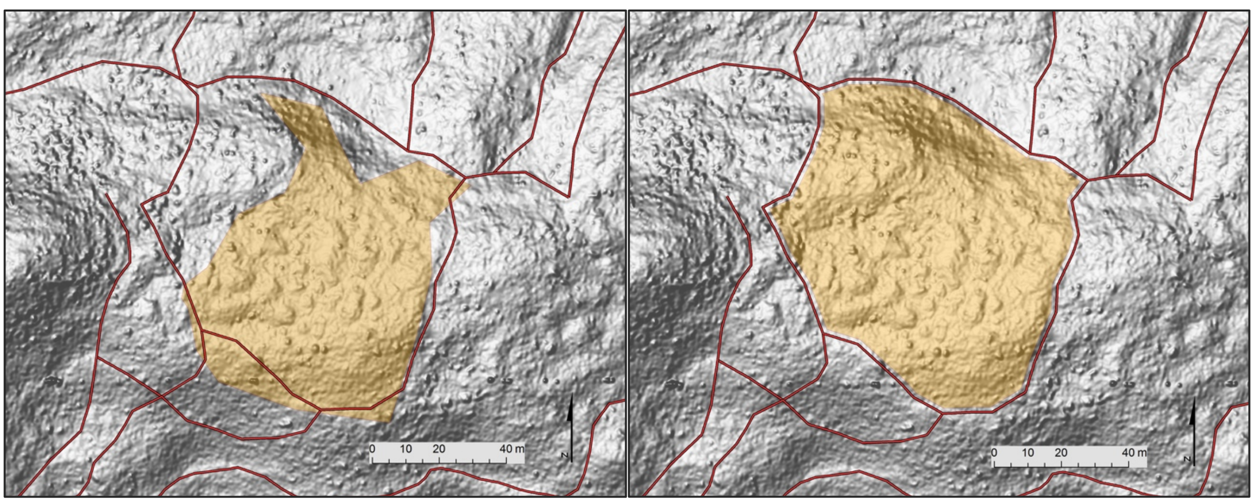


Figure 7.39. Comparison of *complejo* 64 (left) and city-block 64 (right) with surrounding roads

This new shape is much more similar to a city-block in a modern setting. The sizes of city blocks (or grid blocks), have been used to explore efficiency of navigation, planning, importance of symbolic spaces, and other benefits of city-living in contemporary urban centers (Gell, 1985;

Lynch, 1984). Several studies in urbanism have used the size of city blocks as a predictor for walkability (high levels of pedestrian activity) with inconclusive results that usually suggest that small city blocks generate more diversity and complexity in the urban scenery (Boer et al., 2007). While these studies are based on modern settings where there is an alternative mode of transportation (vehicular) to walking, I argue that concepts like walkability are valid for pedestrian-only cities. A particularly fascinating study from Sevtsuk et al. (2016), used the road network to explore how grid blocks affect the collective perspective[16] of walkability in a city.[17] They concluded that more than city block size, other factors such as number and size of plots within a block and the width of the roads (number of pedestrians it supports side by side) are more significant predictors of walkability. Their conclusion is that more access points into a city-block (e. g., number of plots in a city-block, connectivity to the network), the more walkable that city is.

I find this approach relevant for Angamuco, since the road network becomes a fundamental element to access each *complejo* and to connect it to all others. Angamuco *complejos* do not necessarily function as modern city-blocks because they are not composed of entirely unfamiliar households. *Complejos'* explicit boundaries and shared entrances suggest that all *complejo* residents shared some sense of social relationship. Residents of a *complejo* might be more like "extended relatives" than "friendly neighbors" as it occurs in modern city-blocks. Ultimately, all complejos are directly connected to each other by two means: a) entrances to complejos that lead to: b) the road network.

[16] As opposed to an individual perspective or whether one resident finds a particular city-block walkable or not.
[17] On modern cities with orthogonal grids

In sum, I call city-blocks to more explicit and spatially-defined *complejos*. Their internal architectural and social configuration is the same, however, their outer boundaries are completely defined by roads in the network.

In order to explore if such idea as city-blocks can be observed at Angamuco, I created a new map of Angamuco by assigning a standard 4 m width to all roads in the network and converting all the spaces surrounded by roads to polygons ("city-blocks"). By dividing the site in this way, I identified a total of 743 city-blocks. Since roads are naturally less preserved on the peripheries of the site due to modern urbanization and agriculture, the "city-blocks" for those areas are correspondingly distorted. So, excluding the periphery city-blocks (orange and red in Figure 7.41), the mean area size is 5,484 m^2, compared to 4,743 m^2 for *complejos* (Table 7.5). A comparison of the socio-spatial division of the site using the *complejo* and the city-block models is presented below, in Figures 7.40 and 7.41.

	TOTAL COUNT	AVERAGE AREA SIZE	SMALLEST	LARGEST	UNITS DIRECTLY CONNECTED TO THE NETWORK
Complejos	685	4,743 m2	441 m2	30,302 m2	533
City-blocks	749	5,484 m2	300 m2	85,015 m2	749

Table 7.5. Comparison of *complejos* and city-blocks

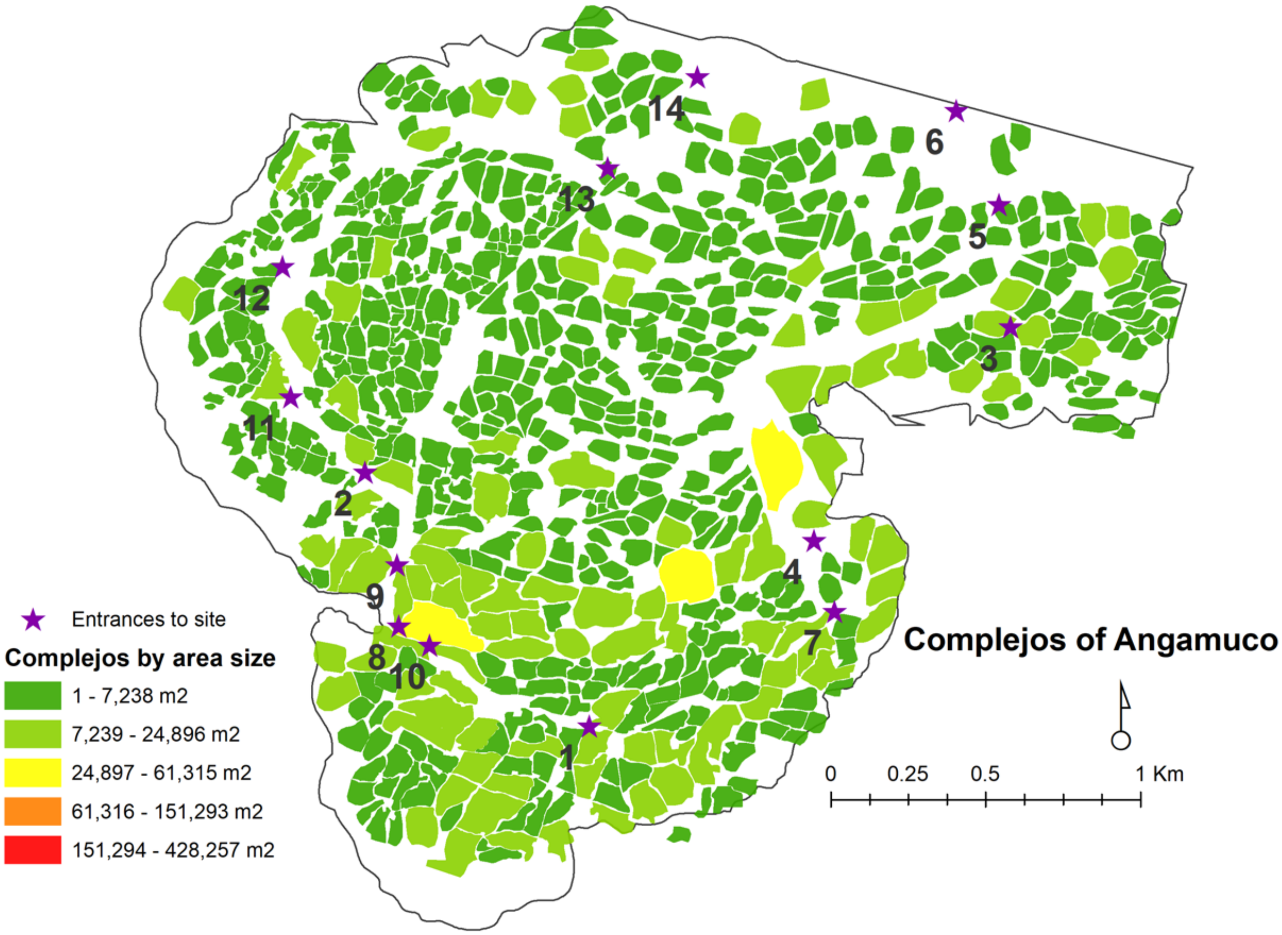


Figure 7.40. C*omplejo* model of Angamuco.

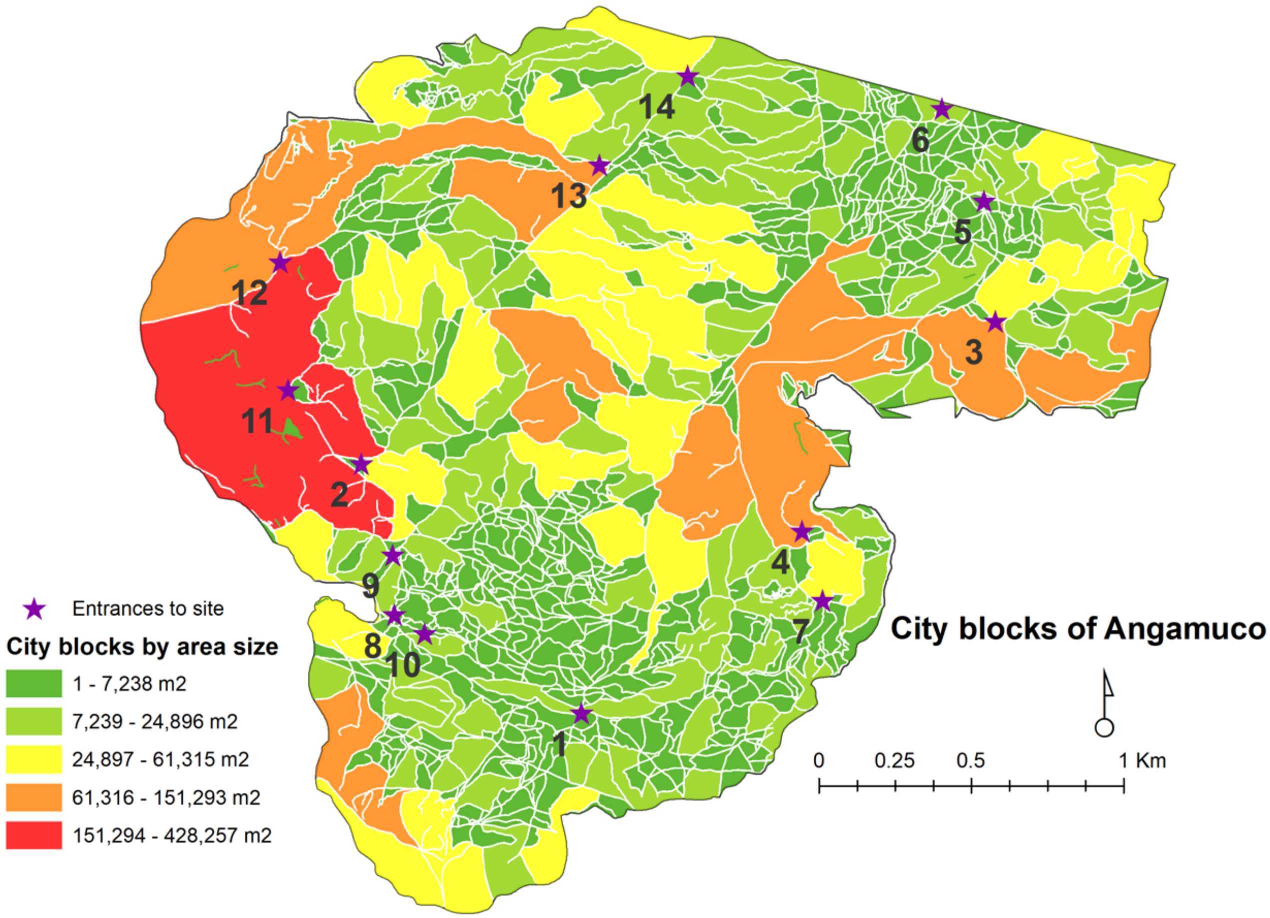


Figure 7.41. City-block model of Angamuco.

In conclusion, I believe that the explicit demarcation of *complejos* and their shared resources, including entrances that connect them to the network, serve to create, reinforce, and maintain unique socio-spatial communities in Angamuco. Since they are fundamentally connected to the network, I propose that *complejos* be explored and defined using roads to identify *complejo* perimeters. Much more work needs to be done on this, especially for areas where roads are hard to identify, like in the peripheries of the site. Nonetheless, I hope that a city-block approach helps explore social configuration and community formation at Angamuco.

7.3.3. Entrances (Upper and Lower Angamuco zones)

The geomorphological characteristics of the land, the fluctuation of the lake basin, and other political and environmental events in the region[18] necessarily influenced the settlement of inhabitants in all areas of the Angamuco, particularly the lower and upper zones, over at least 1,300 years. Most likely, there was one gradual urbanization process from the upper to the lower zone sometime during the Epiclassic period (~650 CE). But once Lower Angamuco was settled for housing and other activities, both areas continued being inhabited until the conquest.

As I have mentioned before, the distinction between Upper and Lower Angamuco zones is clearly defined by an escarpment that surrounds the southern part of the site, reaching up to 62 meters at its highest point, but with an average height of 38 m. This escarpment creates relatively steep slopes with an average of m=2.57 that makes transit difficult. In addition to forming a natural barrier for flood-prone areas before the Epiclassic period, it could also have been exploited as an element for defense and even, to culturally distinguish its inhabitants from lower areas (a geopolitical boundary of the settlement). It could also have been used as arable areas from terraces at some points. The escarpment is clearly a central feature for the urban development of the site. It is critical to understand its role in the road network. There are small roads that cross through the escarpment, but these connect directly to *complejos* (see example in Figure 7.35). These smaller roads were probably only used by residents of such *complejos* to access terraces or as shortcuts and are not likely formal points of access between the two zones.

Perhaps the most important characteristic of formal entry points, is that they allow restricted access to water reservoirs, located at the bottom of the escarpment, and a way into the surrounding valleys, arable lands, and neighboring cities. Residents of Upper Angamuco would be

[18] See chapter three

better protected from outsiders but also would be more restricted in access to water reservoirs and other resources outside the site. All the traffic was channeled through these entry points, forcing people to negotiate access, but it is also possible that the *complejos* neighboring these entry points had much more daily interaction, were more diverse, or served as sentinels to the state or the community-at-large in some regard.

The following criteria was used to identify these access points (that I call "entrances"):

1) located at the top of the escarpment,

2) located at continuous *camino*s or *calzada*s (>3 m wide), and

3) not connected to *complejos*.

Based on these points, I identified 14 entrances that would have allowed inhabitants to traverse between Lower and Upper Angamuco zones. Eight of these locations were field-verified during fieldwork and the rest were found during the digital extraction of roads[19].

None of the field-verified entrances are associated with architectural features. That is, they do not seem to be guarded, surveilled, or controlled by the state. Nonetheless, the construction style of the roads in which they are located confirms that many people were involved in their planning, building, and maintenance.[20]

In general, there are surprisingly few formal or semi-formal access points through the escarpment. They are all composed of gradual or steep ramps, two of them paved with cobblestones on the surface (Entrances 1 and 2). Excavation in Entrance 3 revealed other construction styles at different periods[21]) These same entrances have walls up to 2 m high and 1.5 m wide. For example, Entrance 1 is located at the end of segment S2I009, at the center of the site

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[19] See chapter four

[20] See descriptions of senderos in units U1H01, U1H02, U1I03, and U1F01 in chapter five and below in section 7.4.

[21] See unit U1H01 in chapter five

(Figure 7.44). This segment climbs a slope of 25 m/60 m and a total height of 2,122 masl (or 26 m above ground) through a paved ramp with a single switchback in its middle part (Figure 7.42).[22]

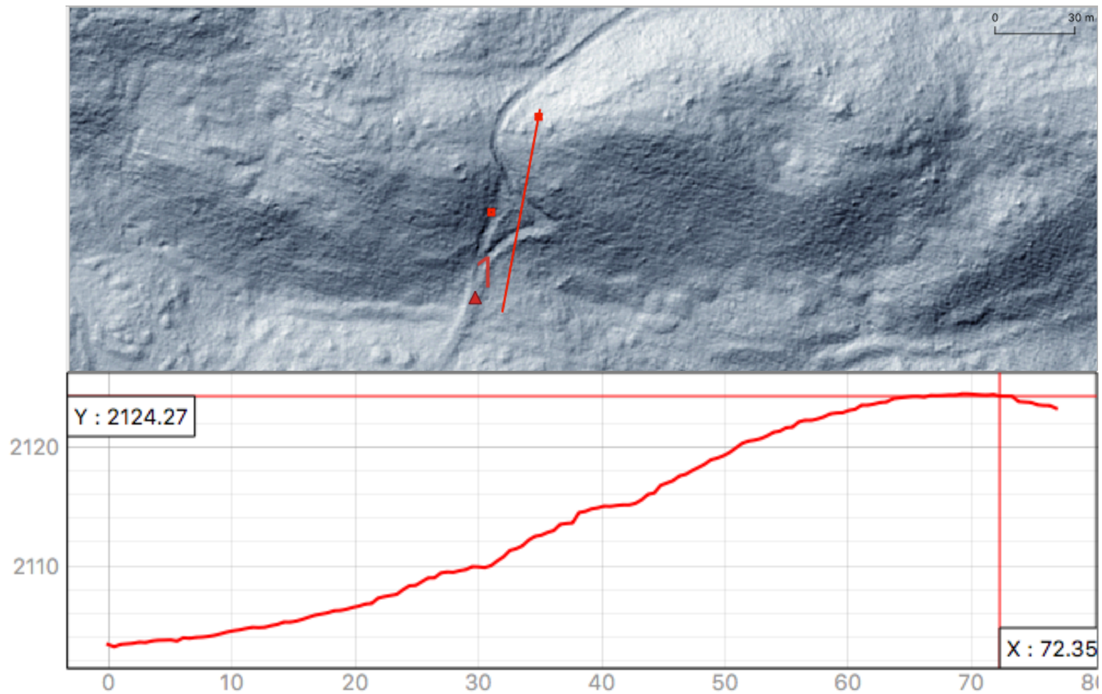


Figure 7.42. Example of escarpment profile. Red line is a cross section of the escarpment by Entrance 1 (red triangle). Below the map, a profile in meters above sea level.

22 See discussion in section 7.4

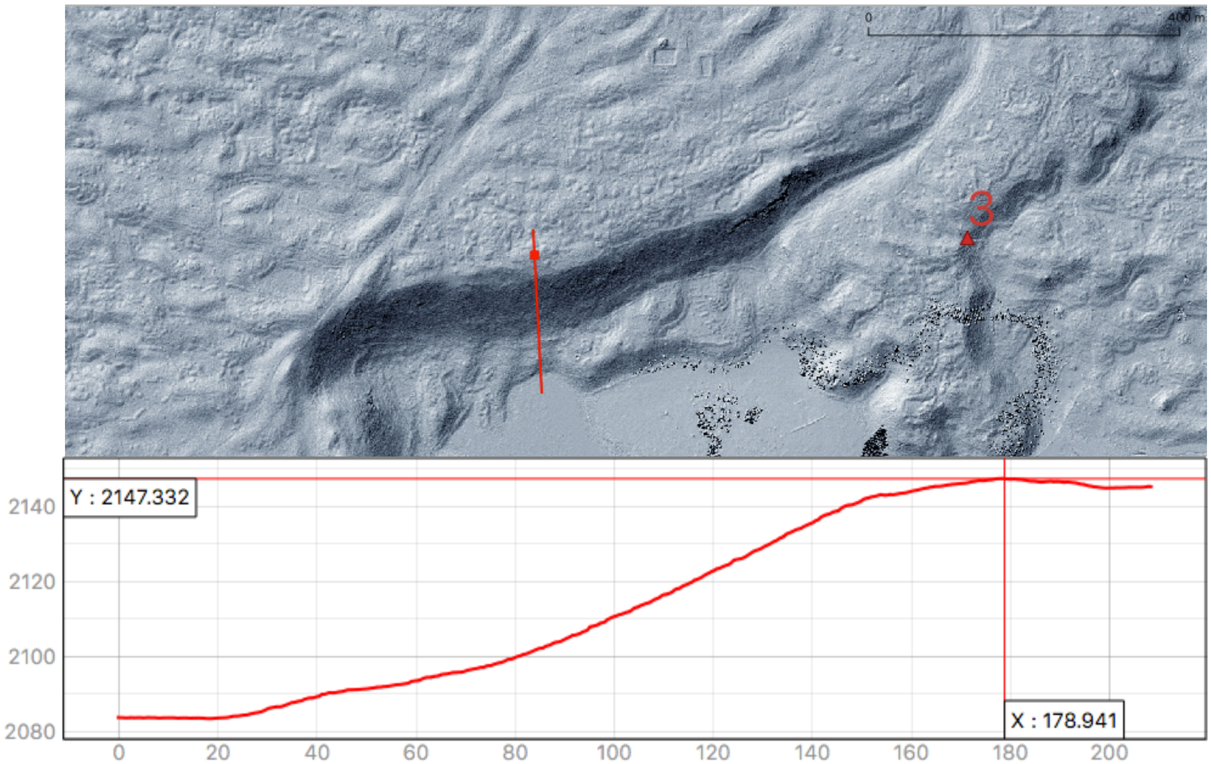


Figure 7.43. Example of highest point in escarpment near Entrance 3. Red line is a cross section of the escarpment. Below the map, a profile in meters above sea level.

All entrances were studied during the urban network analysis in chapter six, and their importance was corroborated by their connection to the main and second tier roads, and similar high *Gravity* values.

While it is still important to check for chronological information about these entrances (e.g., to confirm the Angamuco occupation model discussed in chapter five), it is now clear that in fact, residents from Upper and Lower Angamuco zones traversed and interacted between those zones, and that this interaction was formalized through monumental construction projects.

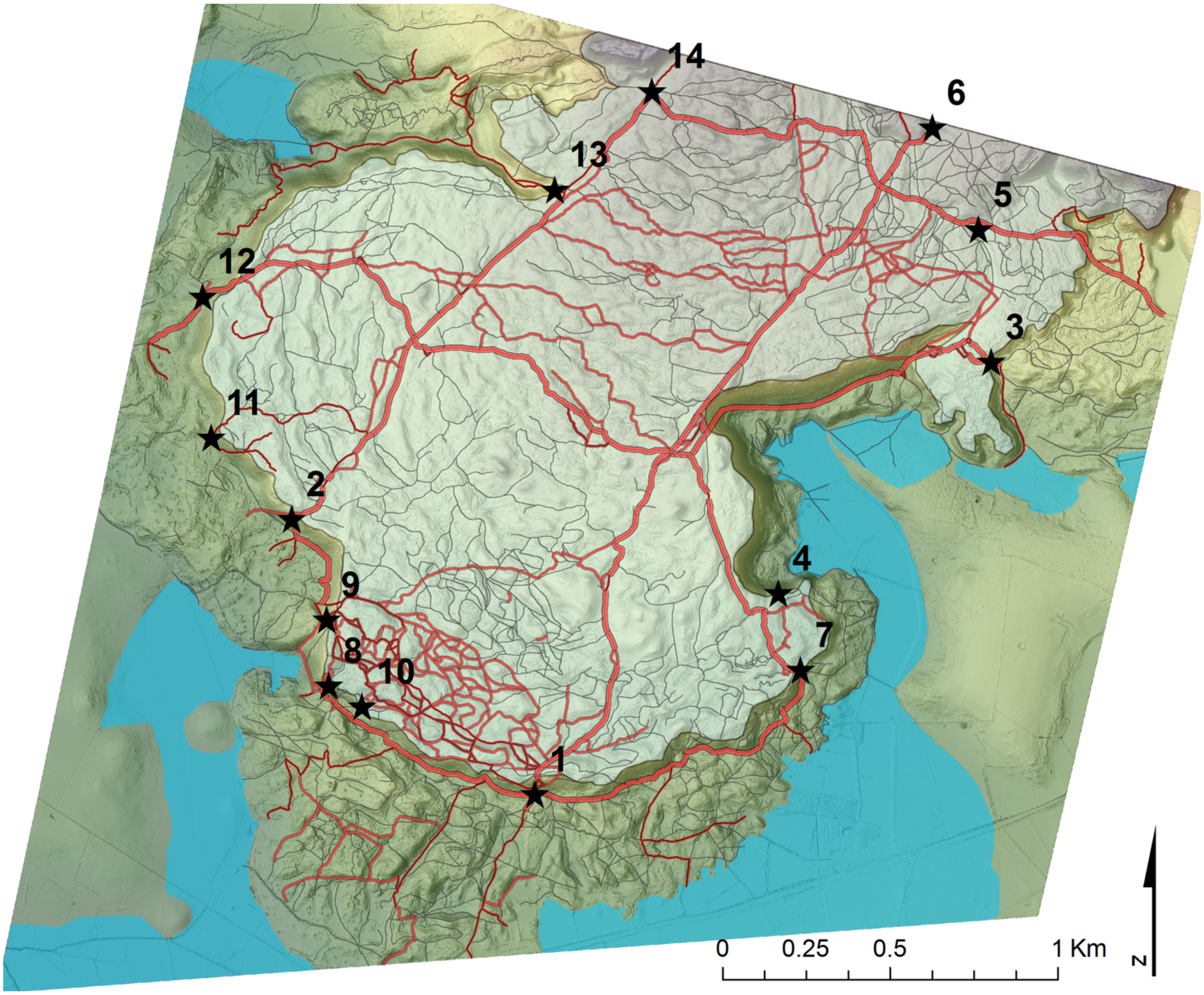


Figure 7.44. Map of Angamuco showing all entrances as black stars, main roads in red and the remaining roads as gray lines. The Upper Angamuco zone is represented in light blue and water reservoirs during the middle to Postclassic periods are in sky blue.

7.4. Transformation of the landscape

I mentioned earlier how this research demonstrates that the inhabitants of Angamuco were directly involved in the transformation of the natural landscape. Research done at the site by LORE-LPB showed how landscape alterations were not only projects carried out by individuals and their families, but by large numbers of people. (i.e., excavations in 2013 and 2014 revealed that a semi-public house was built on top of a 50 m^2 artificial platform, the Plaza complex called El Palacio on top of another 250 m^2 artificial platform, and the Grand Plaza over an artificial platform of 500 m^2 and 2 m deep). Additional upcoming master's theses also explore water management and pyramid construction that add to these observations (Friedl, 2019, Harris, 2018, Simpson 2019). The construction of roads, either through the modification of natural topography or as new constructions, provide additional evidence of this process.

In the next section, I will focus on several examples from excavation and survey that reveal how these landscape modifications were used to improve and/or inhibit transit. While these two are contrasting motivations and should be analyzed in their own chronological and spatial contexts, both show that Angamuco residents succeeded in taking ownership of landscape. This was accomplished by extracting and transporting construction materials for these projects. In so doing, they changed the purpose and transit flow for specific reasons during short and rapid transformation periods, rather than over the course of long, slow episodes of movement patterns.

7.4.1 Modifications of landscape to enhance movement

The first two examples of landscape modification that enhanced transit have been presented and described in detail in chapter five (units U1A01 and U1I03).

Modification during the Middle Postclassic (~1100 CE) by U1A01

Segment S1A059 is flanked lengthwise by terrace hills associated with contemporaneous *complejos* built on the top. The road ends at a "sunken" plaza (node N1A051) that was probably built during Early to Middle Postclassic (Figure 7.45). At that point, the plaza worked as an end-node. On the north wall of this patio a change in elevation separates an entire new higher area that leads to more *complejos* and other resources. It is unknown if those *complejos* were also contemporaneous to the road, but at some point, in the Middle Postclassic, a small ramp (~2 m wide) was built to serve to access the higher *complejos*.

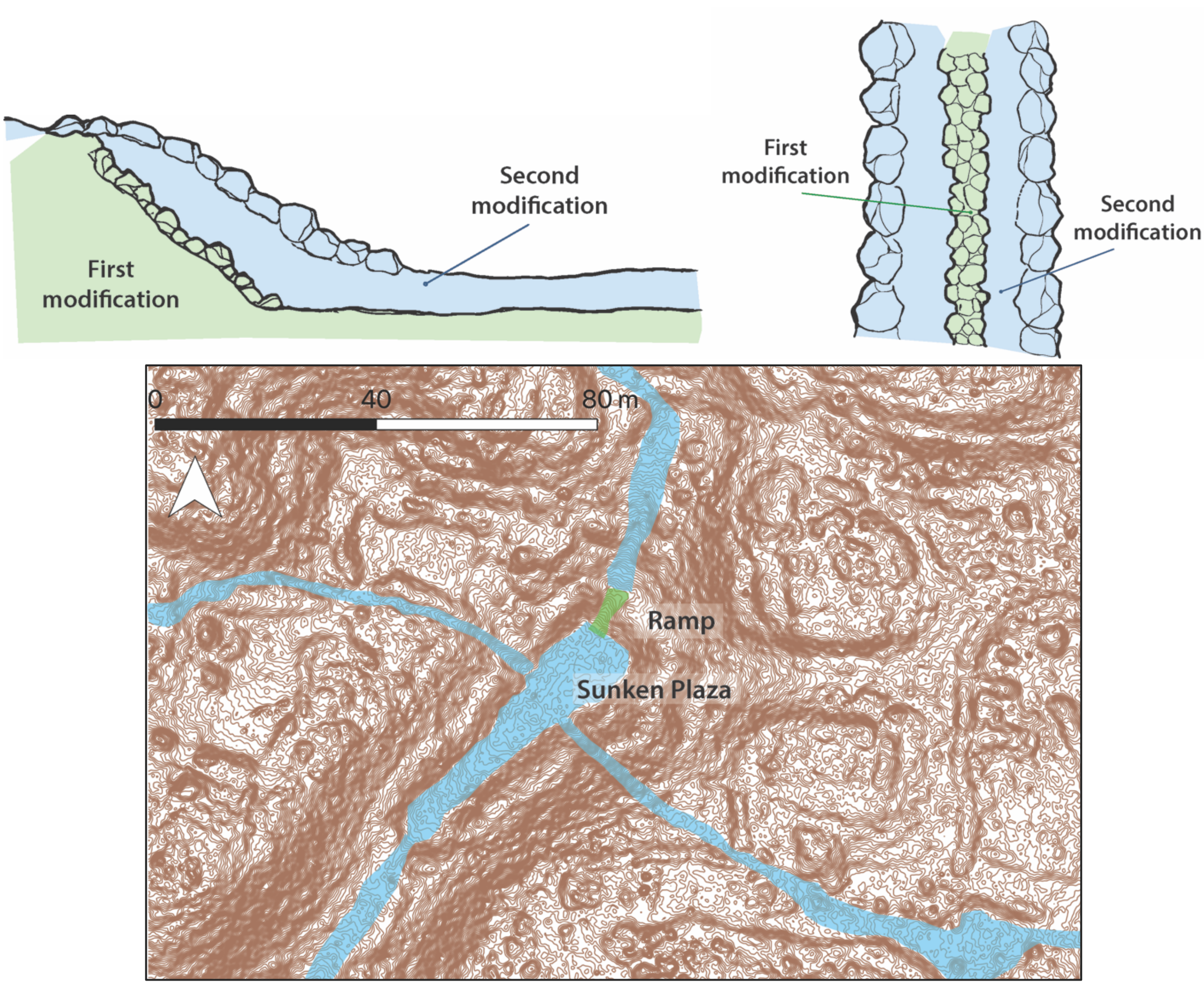


Figure 7.45. Sketch of segment S1A059 and sunken plaza. Left: profile of the two modifications at the ramp. Right: plan view of same ramp.

Excavation revealed that the ramp was not sufficiently large enough to serve the high amount of transit that would connect road S1059 to the higher *complejos* through the "sunken" plaza by the late Middle Postclassic. A larger construction project that would have involved several individuals then modified both the patio and the ramp. The ramp was extended to ~2 m wide, fully paved and with a sort of balustrade on both sides. The plaza was filled approximately another 40 cm (possibly to flatten the surface), and a second ramp was built on the west side to connect another area of *complejos*. All these modifications might have happened over a span of ~100 years, which is swift considering the long inhabitation of the site. These modifications are consistent with many other transformations of the site by the Middle Postclassic, a period when the entire site witnessed a large growth in population, partly from migration from the central Mexican basin.[23]

Similar landscape transformations occurred around the same time in other parts of the site. For example, units U1I01 and U1I02 in Area I, where we found evidence of covering old rooms to create new open spaces and new roads, and digging up new areas to create sunken patios, ramps, and other roads (see descriptions in chapter five).

These examples show how the changing needs of the settlement and subsequent spatial reorganization affected the movement infrastructure and how roads were modified as a response to these changes.

[23] During this time, there was intense volcanic activity in El Metate, about 50 km West of Angamuco (Chevrel et al., 2016). A non-tested hypothesis by Fisher, Cohen and Solinis-Casparius suggest that they influenced the migration and expansion of Angamuco as a result of unrested volcanoes.

Modification during the Late Postclassic (after 1530 CE) by U1I03

Unit U1I03 is a unique example for the site. As described in chapter five, the unit is located on segment S2I008, a major road that connects both Upper and Lower Angamuco by Entrance 1. This road (*calzada*) is over 5 m wide, generally straight, and flat all the way to the northernmost part of the site. From the south, the *calzada* intersects another important road (a second tier, "sunken" road formed by segments S2I003 and S2I006) as it reaches the base of the escarpment. At this point it turns into a large ramp with a switchback to climb the almost 40 m towards Upper Angamuco (Figure 7.46).

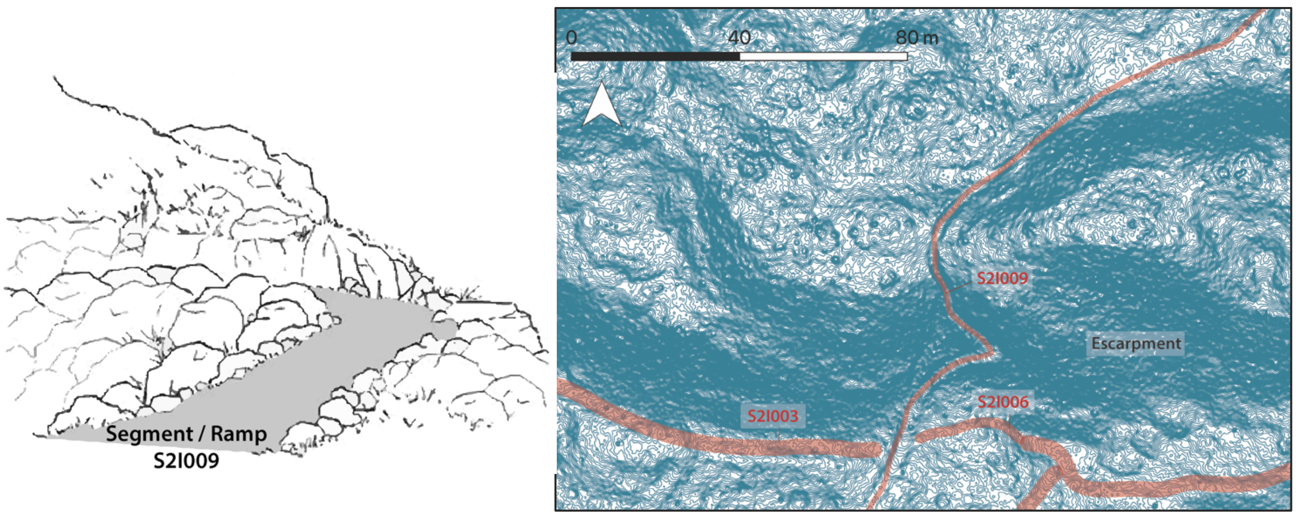


Figure 7.46. Sketch of the switchback in the middle of the ramp

Several modifications can be observed at this *calzada* and occurred most likely because of its prime location and role in the network. The first set of modifications are related to crossing a sunken road and probably occurred around the Middle Postclassic period. Excavation revealed that the *calzada* existed as a low platform (~50 cm high) above the width of the sunken road S2I003, which created a sort of bridge to connect the *calzada* to the escarpment. It is possible that before the construction of this platform, which functioned as an elevated road, both roads intersected without much architecture to define them. By building this platform, the residents distinguished *calzada* S2I008 from the sunken road, probably with the intention of signaling its importance and creating a hierarchy between both roads. At this time, access roads that stem out of (or connect) the *calzada* were included as well.

Perhaps the most important modifications occurred at the very end of the Late Postclassic or Early Colonial times, a few decades after the conquest of the Purépecha Empire. At this time, the *calzada* was completely redesigned. The platform was dug out and on top of its foundation, two large (~1 m wide) stone walls were erected on both sides of the *calzada*. The inside was then filled and covered with a very compacted sediment to function as the walking surface. Overall, the *calzada* width was expanded several meters to the east, a project that also included modifying the access roads. Finally, as the *calzada* became closer to the escarpment, the surface was paved and became a ramp. No excavation was performed at the ramp itself, but the architecture and dimensions are very similar between the *calzada* and the ramp (a wide railing wall on the east edge and paved with cobblestone). I believe that the construction of the ramp is contemporaneous to the last modifications of the *calzada*.

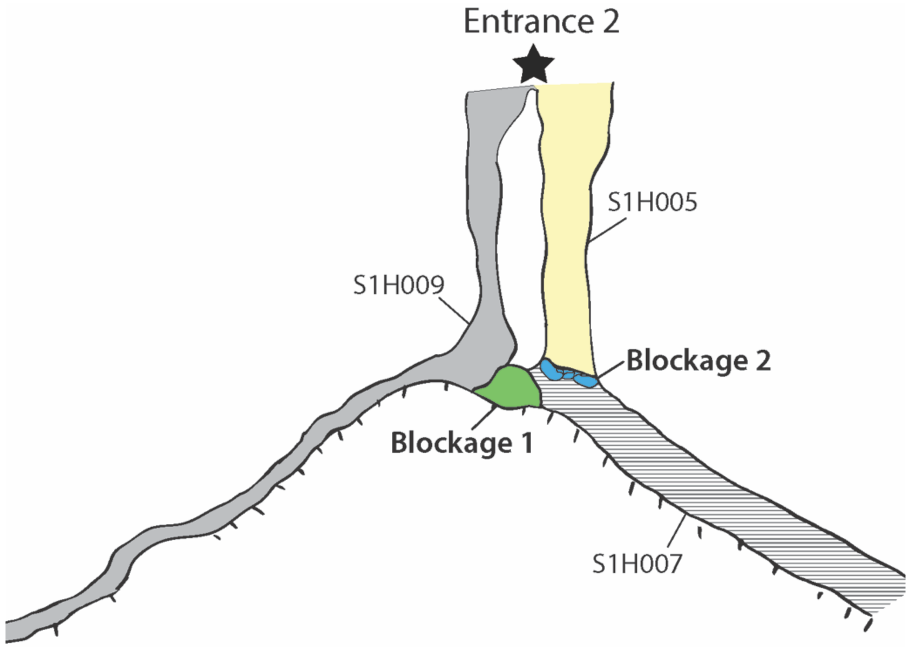
It is not surprising that this road had such massive transformation (from ~3 m to ~8 m wide and from ~1 m to ~3 m high) considering the changes in the economic and cultural life of its inhabitants after the conquest. I believe this road was modified not only to serve a substantially larger amount of traffic, but to serve a different kind of traveler, one that made used of newly introduced horses and carts. After the modifications were made, horse powered carts were only able to traverse through some of the major roads and not through the entire site. This would prove that the site's settlement changed again as it slowly became abandoned while some major roads continued being used to cross the site.

7.4.2 Modifications to inhibit movement

This research also revealed massive modifications of the landscape that inhibited the movement through the site. The clearest example is the series of changes at the roads and ramps that lead to Entrance 2 on the west side of the city.

This area was excavated through units U1H01 and U1H02. Both units were placed at the middle points of the ramps, which provided evidence for the construction style. The construction of these ramps was very simple in comparison to the large transformation —blockage— of both roads closer to the actual Entrance 2 on the top of the escarpment that was investigated through survey.

Both roads S1H009 and S1H007 begin somewhere on the west side of the site in Lower Angamuco and run along the lower base of the escarpment in facing directions. At about 150 m before they meet, both slightly bend towards the east as they cut the escarpment in the shape of one-direction ramps with a slope of m=2.33 going up towards Entrance 2, about 50 m high (Figure 7.48). At the top of the ridge, road/ramp S1H009 continues roughly straight for ~40 m into Entrance 2, while road/ramp S1H007 turns about 90 degrees at the top of the ridge, to then run parallel to road S1H009 and also meets Entrance 2 after ~50 m (Figure 7.47).



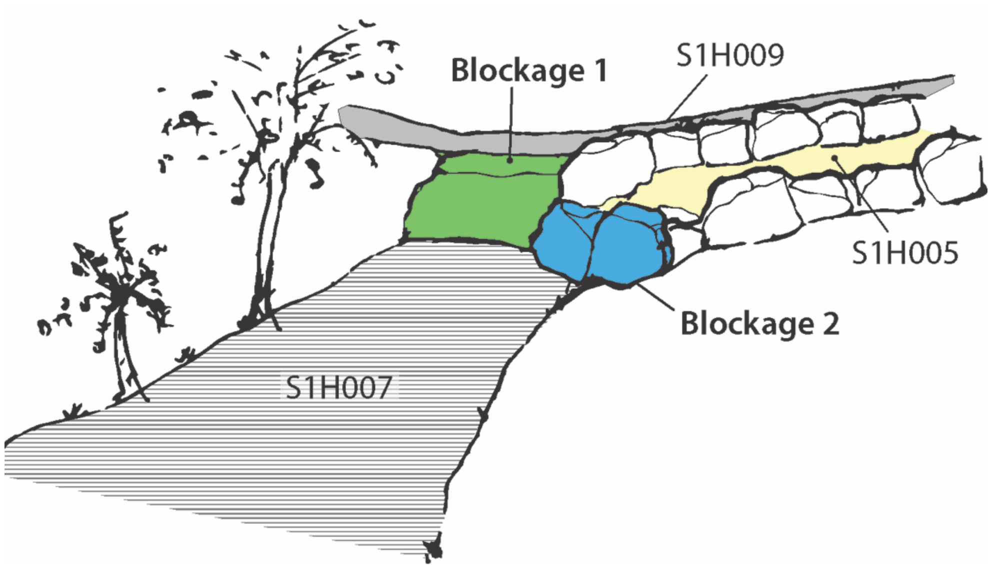


Figure 7.47. Sketch of blockages by Entrance 2

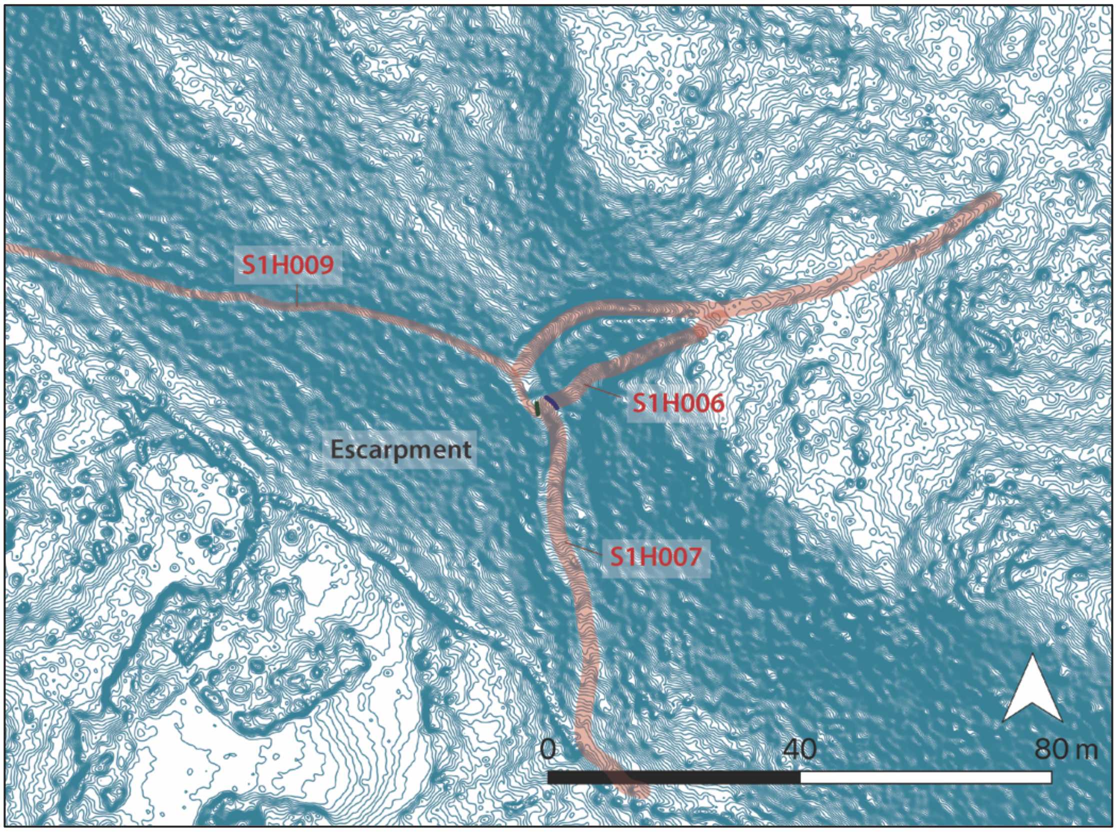


Figure 7.48. General view of S1H009

Road S1H009 and S1H007 have very different construction styles which might suggest that they were used and modified at different periods and for different purposes. Road S1H009 was used continuously throughout the lifetime of Angamuco. As described in chapter five, this road was composed of a paved walking surface, *banquetas*, and a retention wall along the face of the slope. This road was not uniform, since it became wider at sections of the ramp that fit another retention wall for the upper face of the slope. The road is straight overall, but with a few minor curves and a total distance of 160 m across the escarpment. All these characteristics point to similar construction traditions to what was used for other roads and buildings at the site during the Early to Late Postclassic periods. I propose that road S1H009 was the main access to Upper Angamuco through Entrance 2.

By contrast, road S1H007 is about 2 m wider (in total 6 m wide), 60 m shorter, and with a steeper slope. It also has a retention wall for the lower side of the slope but there are no indications of the existence of a similar wall to control the erosion of the slope above the road. The road was reinforced with a layer of rocks that were then covered with packed soil. The walking surface was a combination of compact sediment with medium-size rocks as pavement in some parts. Once the road reaches the top of the escarpment and after the 90-degree turn, it becomes a type of "sunken" road delimited by two large walls (~2 m tall and ~2.5 wide) built out of large rocks. The walking surfaces of the two sections (exposed and sunken) are very different, with the sunken section being very rough with irregular steps, breaks, and in a noticeably worse state of conservation.

The following two blockages are essential for interpreting the usage of road S1H007. First, the 90-degree turn appears to be modified as a later addition with the purpose of blocking this road from connecting to road S1H009 (Blockage 1 in Figure 7.47). It is possible that both roads connected at this point but for some reason at a later period the roads were kept separated. I suggest that at the time this blockage was built, the sunken section was created to extend road S1H007 as a separate passage until further into Upper Angamuco. Second, coming down from the north at the end of the sunken section of the road, there is a second intentional blockage made from large boulders (Blockage 2 in Figure 7.47). These boulders break with the continuum of the sunken section, and more importantly, create a very tall step not practical for pedestrians to cross. This second blockage is a clear division of both sections and could be the reason for the abandonment of the sunken section. I propose that road S1H009 only underwent functional and aesthetic modifications, but its use was not altered by the residents of Angamuco. On the other hand, road S1H007, which might have been smaller before the Postclassic period, underwent three periods of modifications by the Late Postclassic period:

1) The first was a width expansion and involved straightening and flattening the ramp; the construction of the sunken section; and the building of the 90-degree turn blockage.

2) At a later period, the sunken section was canceled by the modification of the junction with the open section that included large boulders to inhibit transit.

3) The 90-degree turn blockage was subsequently modified to create a step and allow pedestrian walking from road S1H007 to road S1H009.

It is hard to suggest the motivations for these changes. Clearly, the dimensions of road S1H007 could mean that carts and horses were introduced. Perhaps these changes occurred after the conquest. More research and dating would help answer these questions. Unfortunately, no ceramic materials were recovered at this road. It is possible that Entrance 2 became a more desirable route out of the site since it faces the last capital of the Purépecha Empire (Tzintzuntzan) directly to the west, or that modifications helped control access as a means of defense during the empire. Whatever the motivations were, roads clearly sustained massive transformations that would have involved dozens of residents for their construction and required the collaboration of the community-at-large for their maintenance.

Figure 7.49. Several views of the two blockages at S1H007. Green: Blockage 1. Blue: Blockage 2. Red: S1H007. White: S1H009. Top: views from SE and SW of blockage 2. Middle: General views from the south (on S1H007) showing both blockages. Bottom: Views from the north towards S1H007 on the left, and S1H009 on the left.

Figure 7.50. General view from the south on S1H007 showing both blockages

In sum, roads and crossroads are unique features that help identify socio-spatial organization and human landscape adaptation, similar to what the analysis of architecture can provide. However, I believe that the study of roads and how they changed is more powerful since most roads (other than *pasillos*) have an inherent public usage and are mechanisms for interaction and social construction.[24]

[24] See section 7.5 below

7.5. Social interaction afforded by movement

This research was designed to explore how the road network played a role in developing and reinforcing social relationships by means of interaction.

Sociologists, geographers, and urban planners have the longest tradition of studying human interaction and socialization at road networks (e.g., de Certeau, 1988; Gehl, 1987a; Hillier et al., 1993; Lynch, 1984). Though, most of these analyses rely heavily on ethnographic research (Wolfinger, 1995) and modeling pedestrian behavior (Kadali and Vedagiri, 2013). These studies have generally concentrated on two aspects of human interaction: route choice and road crossing.

An important aspect for understanding pedestrian socialization and interaction that remains unexplored in archaeology is the potential for micro interactions at road crossings as afforded by the physical and material characteristics of these locations.

I propose that there are two factors that influence the interaction: the iterations of face-to-face exchanges (number of times a person faces another person), and the duration of the interaction. These two factors occur at different intensities, making it difficult to quantify without the use of modeling tools, which were not used for this research. However, here, I propose that to study interaction in daily movement can be somewhat addressed by attending to the spatial characteristics of the places where those interactions occur. Below, I present a discussion on two spaces for interaction within the road network. First, the roads themselves as spaces for linear and passing-by interaction and second, the nodes as places for open and (temporary) fixed interaction.

7.5.1 Interaction at roads (segments)

I have described throughout my dissertation that roads are linear spaces where several social activities can occur. Ignoring religious activities, such as pilgrimages and processions, and economic activities, like trade and exchange, I will focus on the action of walking for the sole purpose of moving to and from destinations. The material and spatial characteristics of the road network provide clues to understanding how people walked and how they would have encountered others. A few of the questions for which I sought answers were: "How many people could walk together?" "What spatial qualities make a route faster?" "What are the chances of running into someone else on a meandering route?" and "What are the chances of getting lost?"

This research has proved that the road network of Angamuco is explicit, clear, and recognizable. It is complex in terms of the many options available for traveling to destinations. Yet, all the roads are distinguishable and likely accessible to everyone. Roads are public (except the *pasillo*s inside *complejos*). For example, *banquetas* clearly define where is allowable to walk over, and ramps and stairs also signal what other segments are available to use.

Since roads are not coded or ambiguous, people would spend less time trying to decipher how to get to places or understanding the network, and more time engaging with the other elements in their travel, like the landscape, signs, and other pedestrians (as suggested by Hillier and Hanson, 1984; Lynch, 1960). Thus, the material and spatial characteristics of the road network are a fundamental factor for people having more time available for interacting.

Naturally, these interactions would not have been agreeable at all times. Interactions, in general, can respond to existing tensions, factions, and conflicts among pedestrians (Mehta, 2013a). However, I am not attempting to qualify the interactions here, but simply identify the opportunities for them to occur while walking on the network. Additionally, I am not differentiating between the diverse ages, mobility conditions, or gender of pedestrians. In all, including these considerations, I modified the street interaction types developed by Jan Gehl (1987), and propose two types of pedestrian *linear interaction* at road segments (Table 7.6):

1) People walk among others

1a. People that travel together for most of their trip, usually acquaintances. This interaction can be predictable if the members of the group know each other.

1b. People are joined by others sometime along their trip.

In both cases, the time spent on the interaction is prolonged, which turns the travel into a shared experience that would solidify and reinforce the relationships between the members of the group.

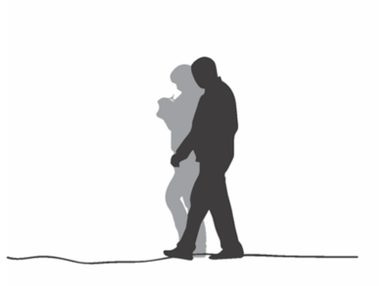
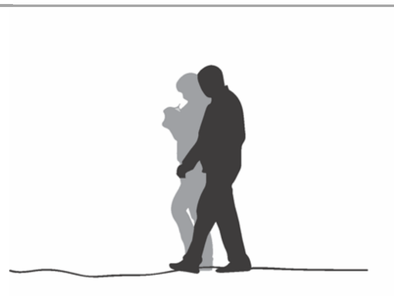
2) Encountering people passing-by

2a. People walking on the opposite direction. This encounter is momentary and unexpected. There is not enough time to engage in conversation. However, there is enough to identify the other pedestrian(s) provided there is good lighting, both people are looking, etc.

2b. Passing static individuals. These could be people standing by the road (resting, loitering, chatting with others, etc.) or standing at a location by the road (e.g., terrace, outside a house, etc.). This is very similar to people walking on the opposite direction, but it is a slightly longer interaction since only the pedestrian is moving, so there is more time to engage with a static person.

2c. Passing or being passed by someone else going in the same direction at different speed. This interaction is longer. However, chances for eye contact are low, perhaps only at the exact time of passing. Sometimes during the walk, it is possible to engage in a quick conversation or have enough time to identify the pedestrian you are passing by.

In all these cases the interaction time is different, from very brief (i.e., 2a) to slightly longer (i.e., 2b and 2c). Yet in all cases, this type of interaction is brief enough that engagement is kept to a minimum and may only involve identifying the other pedestrian. These types of brief encounters become important when they become repetitive over time (months and years).

DIRECTION	SUBTYPE	EXAMPLE	DURATION	SOCIALIZATION
Linear (road)	1a		Long	Enduring
Linear (road)	1b		Long	Enduring
Linear (road)	2a		Brief	Fleeting
Linear (road)	2b		Brief	Fleeting

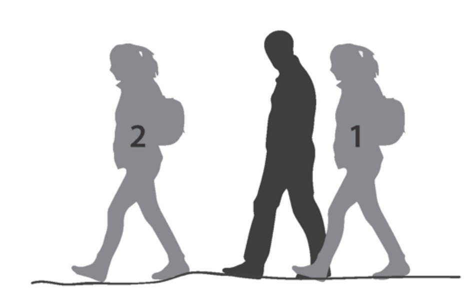
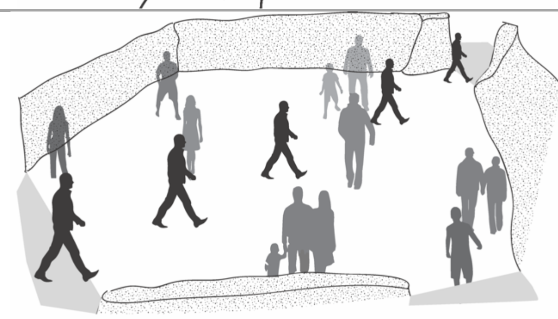
DIRECTION	SUBTYPE	EXAMPLE	DURATION	SOCIALIZATION
Linear (road)	2c		Short	Passive
Open (node)	3a		Brief	Fleeting
Open (node)	3b		Brief to short	Passive
Open (node)	3c		Brief	Fleeting

Table 7.6. Illustration of the different types of linear and open interactions at Angamuco.

The physical qualities of the roads would have definitely conditioned the type of linear interactions. For example:

a. Since *senderos* (1-3 m wide roads) are more common at Angamuco (~70%), I suggest that people traveled alone more often than in groups. Thus, most of the linear interaction was of type 2 (encountering people passing by), that is, momentary.
b. There are fewer examples of *calzada*s/*camino*s (>3 m wide roads) that afforded people to walk together in groups or to temporarily stop beside a road (~22 %). These wide roads might have also hosted specific cultural activities like provisional markets or religious pilgrimages. These wider roads are also the most direct and flat, which would have attracted many users and become the main areas for longer and most linear interactions. However, these roads do not connect to all parts of the site. Everyone would have used several narrow roads for most of their routes.
c. Virtually all roads in Angamuco provide chances for type 2b interaction. All roads pass directly by public places, *complejos*, or terraces. There is no evidence that *complejos* were enclosed (e.g., fence) at the site. Thus, people at their houses would have seen pedestrians on the nearest road. Additionally, given the high density of housing structures, the probability of running into other individuals standing at these locations was likely very high.
d. In Angamuco, 238 of the segments have the physical conditions for type 1 of interaction (wide and straight: main roads). Another 1,116 have the potential to provide that level of interaction (second and third tiers).
e. I suspect that *pasillo*s or roads within *complejos* are the best places for linear interaction because the chances of running into someone you have seen before are greater, due to the

decreased diversity of people and a shorter and more constrained road network. Unfortunately, that analysis was not part of this research. Further research on quantifying these kinds of interactions and models to predict their occurrences will help identify whether major roads or *pasillo*s are more significant for linear interactions.

7.5.2 Nodes as areas of interaction

Nodes are very different spaces for socialization because of the kinds of interactions their spatial characteristics allow. I have described how there are at least eight types and subtypes of nodes according to their shape, and several more according to their size. These physical characteristics necessarily influenced the number of pedestrians that can meet at the same time at such locations, and as a result, the likelihood and nature of those interactions.

Contrary to segments where the direction of movement created linear interactions, nodes have the potential to accommodate larger numbers of people coming from multiple directions, and for extended periods of time, in a more “open” interaction.

Sociologists have explored pedestrian behavior at street crossings, which illustrate the kind of brief but direct interactions that can occur between strangers. For example, how behavior changes when there is more than one person waiting for the light at a street crossing, and how other factors affect those interactions (e.g., time of the day, waiting time, assessment of danger, etc.), resulting in people’s decisions about how to navigate (e.g., willing to wait longer time at the lights if they are accompanied) (Hamed, 2001), or creating a sense of brief alliance while waiting for the light even without any verbal interaction (Wolfinger, 1995).

A useful model for the modes of interactions at nodes is provided by the work of Jerry Moore (2004) at prehispanic Andean plazas. Formal plazas are more culturally defined spatial locations than nodes. However, many nodes (~40%) in Angamuco share similar spatial characteristics and even functioned as plazas. Both might have hosted diverse public interactions (e.g., sacred, non-religious, commercial exchanges, games, leisure time, or just crossing) that are evoked, constructed, and provided because of the actual physical properties of such spaces. In other words, certain kinds of interactions can only occur in open spaces.

In addition to hosting open interaction, nodes (whatever shape they have) are the active element of the network. It is at road intersections that people engage with the network because it requires pedestrians to make decisions about their route selection and to examine their choices. Additionally, intersections are generally the spaces where the landscape becomes more visible (for example, convex spaces in Space Syntax Hillier & Hanson, 1984). For example, even pedestrians that know their route might still take some time at an intersection to double-check before deciding to turn or continue on their direction. Many others might do this by necessity if they are not familiar with the location or route. These actions inevitably add a few seconds to the trip and elevate the chances of running into another individual. Furthermore, since larger nodes are essentially public plazas or patios, pedestrians traversing these open spaces have more time to engage with other pedestrians who are crossing or stationed. As a result of all this, nodes are the locations that help pedestrians engage with the network, create routes, and evaluate the landscape.

Thus, I propose three types of *open interaction* at nodes based on their occurrence and duration. Some of them are very similar to those that occur at linear interactions. The types of interactions are:

<u>3) Encountering people crossing-by.</u>

3a. <u>Crossing others at small intersections</u>. This encounter is short but intimate since the interaction is face-to-face. There is enough time to identify the other pedestrians. If the encounter is at the same time, it requires negotiating the space (e.g., letting the others pass or rushing to cut through first). While negotiating movement, certain social norms might be at play, like social class, language, gender, etc.

3b. Crossing others at large intersections. This encounter is longer but less intimate. Crossing a large node (e.g., plaza) requires *entering* and *remaining in* the same confined space for some time. This means that whatever meaning that public space has, it is shared with others. For a minute, certain social norms need to be adopted, similar to the way we behave differently once we enter a church or even a pedestrian traffic light crossing in a modern city. Since a node can be large, the interaction is not always intimate or in close range.

3c. Crossing static individuals. This encounter is the same as passing by static individuals on roads. Pedestrians might encounter people performing a range of static activities at the node. The exchange is short and requires both to engage actively.

In all these cases, the interaction time is different, from brief and indirect (e.g., 3b and 3c) to slightly longer and more intimate (3a). Again, nodes contribute to repetitive interactions and socialization in the long term.

Figure 7.51. Artistic interpretation of a casual interaction at a node in Angamuco.
Drawing by Jennifer Purnell.

The physical characteristics of the nodes at Angamuco might have indeed conditioned open interactions. For example:

a. About 20% of the nodes in Angamuco are patios or plazas, providing great chances for people to experiment type 3b interactions.
b. More than 60% of the nodes are small enough that the interactions would be face-to-face or type 3a.
c. Only 15% of the nodes are simple or dead-end, making the chances of running into any other pedestrian very high.

d. I identified 22 nodes connecting more than four segments. All of these are small to medium nodes. These locations are important focal points for face-to-face interaction. These are also all located on the upper Angamuco zone.

7.5.2 Socialization

I have discussed how the physical characteristics of segments and nodes allowed chances for interaction and affected the duration of these interactions. A useful approach to understanding how these interactions actually influenced socialization is the typology of pedestrian behavior developed by Vikas Metha (2013). In his ethnographic study of contemporary streets, he developed the following system of three sociability behaviors occurring at streets.

1. *Passive sociability* refers to non-direct and non-verbal contact between people in a shared space. This generally occurs between strangers and familiar strangers who are not uncomfortable with the presence of others and might occasionally engage non-verbally with others. The best examples of this behavior would be the individuals who are standing by, resting, relaxing, or even performing their own activities in solitude (e.g., farming, watering, fixing a wall, etc.) but nearby or exposed to passing pedestrians like the "static individuals" in a type 2b linear interaction.
2. *Fleeting sociability* is a direct, verbal, but short-term and low-intensity, contact between two or more pedestrians. These brief, fleeting interactions help humanize the moment for the people engaged in the interaction. Despite these short-term, low-intensity contacts representing weak and unauthentic ties, they are the possible beginnings of deeper and more enduring social connections between people (Gehl, 1987b; 1989).

3. *Enduring sociability* includes intimate relationships (close friends or partners) and affiliations (regular meetings of a group of friends or acquaintances), both meaningful associations among people.

Socialization at Angamuco could be explained from any combination of these three types of socialization processes. In Table 7.6 above, I propose which of these occur depending on the types of linear or open interactions afforded by the spatial characteristics of the road network.

A final and important factor in whether these socialization mechanisms are triggered, are the iterations of such encounters. Jacobs (1961) argues that through repeated short-term contacts people grow to trust their neighbors who may otherwise be strangers. Similarly, Berger and Luckmann (1966) suggests that the re-visitation of landscapes and repeated encounter between the same people creates a stronger sense of community. Because the road network at Angamuco is functional and explicit, there were many opportunities for people to repeatedly encounter the same pedestrians over their daily activities.

7.6. Brief summary of results and interpretations

In this chapter I presented different examples of roads and intersections at different scale of analysis —from individual segments to the global road network. These selected examples aimed at discussing evidence of the degree of people's engaging in the modification and use of their landscape. In sum, I argue that it is possible to distinguish between more local processes of road construction and modification, such as circulation inside *complejos*, and more global processes of creating the road network, such as the major arteries of the site. These processes combined suggest some evidence of planning at individual roads, but a broad pattern of a non-centralized planning of the urban layout of the city.

CHAPTER EIGHT: Conclusions and future work

The role of road networks in the social definition and integration of Angamuco

Through this dissertation I have argued that the study of urban road networks provides unique datasets that have the potential to help us explore questions on spatial and social configurations of ancient cities. Moreover, certain cultural activities (e.g., processions, ritual closure of areas, etc.), and certain modes of social interaction (e.g., recurring visiting of spaces) are unique phenomena that occur at the spaces created by roads; thus, they can only be understood if the investigation is centered on road networks.

The goal of this research has been to explore methods and approaches to precisely investigate the road network for the site of Angamuco in the Lake Patzcuaro Basin. In the previous seven chapters I described the different lines of evidence that guided this study —which includes study of road construction techniques, layout of urban architecture, analysis of ceramic deposits at roads, radiocarbon determination, and the configuration of the complete road network — and the various ways this can be interpreted.

Through this work I have been able to better understand how the city of Angamuco emerged, developed, was inhabited, and experienced by its residents, and the roles that roads played during all of these processes. I was able to identify patterns of pedestrian traffic, discussed evidence of urban planning at state and community scales, suggested alternatives for settlement sequences, and confirmed an important moment (1100 CE) in the history of Angamuco when a massive transformation of the landscape took place prior to the formation of the Purépecha Empire.

In this final section, I present a general summary of the major contributions and interpretations discussed in chapters 4, 5, 6 and 7 with an emphasis on the complexity of the Angamuco road network.

I group these general conclusions into two main sections:

1) Contributions to the historical and cultural development of Angamuco, as well as to the general understanding of urbanism in the LPB area; and,
2) Contributions to methods for archaeological investigation of ancient road networks.

An important point of this discussion are the limitations and challenges encountered during data collection, data standardization, and analyses. This chapter concludes with an examination of the future directions and research themes that can stem from this work.

8.1. Conclusions

8.1.1 Contributions to the understanding of Angamuco's urban development

The assessment of Angamuco as a complex, large, and dynamic urban settlement established (at least partially) several centuries before the Purépecha Empire, has helped demonstrate how its road network was a fundamental socio-spatial element. At a very simple level, the absence of a strong centralized political government facilitated movement across the city formalizing roads of various construction styles, shapes, and extensions. Other elements were also part of this infrastructure including ramps, walls, stairs, and the intersections that were incorporated to enhance or limit accessibility. This resulting road network continually changed and played an important role in configurating the settlement both spatially and socially.

The research presented here was designed to investigate the material evidence that would explain if the emergence of the Purépecha Empire influenced the configuration of the road network and, consequently, the social organization of the city. Ultimately, this dissertation was not able to fully demonstrate empirically the association between the road network and the social order of Angamuco. However, several findings in both, the temporality and construction styles of roads have set the basis for future research on this topic. Moreover, exploratory analysis on the usage and function of the network provide a good framework for new proposals on social organization and interaction.

These two sets of conclusions (descriptive and interpretative) are presented in context of how they augment the diachronic cultural history of this site, initiated by the LORE-LPB project and expanded thereafter by individual research from MA theses and PhD dissertations in less than ten years of investigation. In general, none of this dissertation's outcomes contradicts the previously proposed interpretations about the development and characteristics of the site and the region, what is more, it makes important contributions that reinforce three main findings: the decentralized urban layout of the city, the seemingly low impact that the emergence of the Purépecha Empire had in the socio-spatial configuration of the city, and the identification of the most significant moment of urban and population growth (~1100 CE). Additionally, this research proposes that the site continued being heavily transformed after the European conquest and demonstrates that the road network was a complex and dynamic movement infrastructure.

Descriptive conclusions about the road network

Ultimately, the unique landscape, topography, and the particular historical development of Angamuco influenced the diversity of roads and intersections. The combination of fieldwork (excavation and survey) and computational analysis provided several specific results that illustrate this conclusion. Here, I present the most relevant descriptive conclusions of the road network.

1. There is an identifiable road hierarchy at Angamuco.

I propose that a road-hierarchy can be identified through two methods:

a) *Based on network characteristics*.[1] I used a combination of *Betweenness* and *Redundancy* indices measurements in Urban Network Analysis to create a four-tier hierarchy. In total, I identified 238 segments for main roads; 291 for second tier class; 825 for third tier class; and 1,266 for remaining common roads.

b) *Based on road width*.[2] I concluded that width of roads is an indication of the total number of pedestrians that can traverse the road along each other at the same time. Segment width might be a more significant measurement than segment length, or segment shape, to classify roads because there is a natural break between classes. Those classes also correspond roughly to road width classification for modern pedestrian streets. Further, the variation between width classes is lower (0.59 CV[3]) than that observed for lengths of roads (0.84 CV). The width was only observed in the 419 road-segment sample collected in the field (out of potentially 2,620, or the 16%), so it will need to be expanded and revised with a bigger sample. Based on this measure, it is possible to group roads into four categories: pasillos, senderos, caminos, and calzadas.

Either of these two classification approaches (because of network characteristics or width) provide a classification system based on potential traffic, similar to the ways pedestrian and motorized roads function in modern cities (e.g., Louf & Barthelemy, 2014; Shrestha, 2011) and, more importantly, they correspond to initial observations of the most relevant routes of the city.

[1] See section 6.2.4 in chapter six
[2] See section 7.1.1 in chapter seven
[3] Coefficient of variation

2. <u>There is an arterial framework of the network.</u>

While the complete road network is composed of 2,620 segments thorough the site, I have identified an arterial framework of 1,354 segments.[4] The segments together form a basic structure of:

a) Two parallel central roads that run NE-SW;

b) Two perpendicular roads that run E-W on the upper Angamuco zone;

c) One semi-circular road that surrounds the natural escarpment for 1/3 of the site on the lower Angamuco zone; and,

d) Four radial roads that stem outwards from the escarpment on the Lower Angamuco zone.

3. <u>There are at least two patterns of the urban layout based on road network configuration.</u>

At first glance, besides the underlying arterial framework, the network as a whole appears to be well structured and homogeneous. However, the various urban network analyses I presented in this dissertation show that at closer inspection, the location, shape, and connectivity of segments and nodes reveal a more diversified network.

One of these characteristics is the spatial patterning within the network. Network pattern can be described as the clustering of segments/nodes with a similar structure, placement, and arrangement. I have observed at least two distinct patterns:

a) *Dense network pattern* observed in two locations of the site named SoC and NoE;[5] and,

b) *Sparse network pattern* observed in the remaining of the site.

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[4] See figure 7.30 in 368 p.

[5] See section 7.2.2. in chapter seven

4. Roads are not passive structures or byproducts.

Perhaps one of the most relevant findings of this research is the evidence of massive construction associated with roads that is not evident on the surface. The following three examples show evidence of active engagement in the construction of roads at Angamuco:

a) *All the excavated segments showed evidence of construction, modification, and/or maintenance*. In Angamuco, the LORE-LPB project has noted standardized construction techniques for various architectural features (e.g., double rock-alignment walls) and has been suggested that such constructions in residential settings could have been built with relatively little effort, time, and manpower. For example, two people could set up a 5 m long house-wall with a height of 1.5 m in half a day (Fisher et al., 2014).

Similarly, I observed several standardized construction styles for roads (e.g., banquetas, ramps). These construction styles were also simple and unsophisticated. However, since the dimensions of a road or a ramp are significantly larger than a house, the total construction project for a road was actually a massive undertaking that required that, somehow, several individuals get organized and coordinated.

b) *Roads were structures that endured or were in use over many centuries*. Excavations in unit U1A01 and U1I01 for example, show evidence that these roads were modified and maintained over a long time. Other examples like the surrounding infrastructure of retention walls and walking surface of unit U1H01 also show that the placement and shaping of roads was planned.

It is possible that smaller roads like those within complejos lacked banquetas or complex constructions, and that the basic shape or foundation for large roads were actually natural features in the topography, however, the evidence of construction, modification, flattening, straightening, and risen of roads indicate that road creation required active engagement and planning.

5. Most massive road transformations happened around 1000–1100 CE.

Another contribution of this dissertation are new dates towards the occupation history of the site. To this date, the chronology of Angamuco is still in development and it is based on a combination of different lines of evidence including C14, association of architecture, ceramic, metal, and other artifacts (Fisher et al, 2019b). The occupation model for Angamuco was summarized in chapter five. In short, it has been proposed that there were at least three important moments of massive urbanization. The results of the ceramic analysis, the stratigraphic sequences, and the C14 dates from this dissertation revealed that indeed one of this urbanization moments occurred during the Middle Postclassic period (~1100 CE), few centuries before the formation of the Purépecha Empire. The construction of ramps and roads in the lower Angamuco zone, and the associated architectural features occurred in a time span of 100–200 years during this period. For example, the road S1A059, its ramp, the sunken patio adjacent to and the elevated plaza that connects to it in area I, all might have been built during ~1000–1200 CE.

Since several of the excavated roads dating to this period are associated to the arterial road framework, I propose that the basis for Angamuco's road network, and therefore, the urban layout, was already in place by this time period. Moreover, this two-century period coincides with extreme volcanic activity east of the site (see Haskell and Stamaghwski, Maghgoub, et al., 2017; Ramírez-Uribe, 2017; Terán Guerrero, 2017). It is very likely that these geologic events influenced massive migration to the LPB and particularly to malpaís sites such as Angamuco (as has been also suggested by Arnauld and Faugére-Kalfon, 1998; Pereira, et al., 2013 for other malpaís sites in the region). This last idea needs to be tested with more absolute dates from other areas of the site, but a rapid urbanization and expansion of the site could be an indication of such events.

Interpretative conclusions about the road network

6. Both, segments and nodes are spaces that allow different types of recurrent interactions.

I propose that the road network at Angamuco, except for the *pasillos* inside *complejos*, worked as an extended public space (or the sum of many public spaces) that enhanced interaction between residents of all social classes. The actual mechanism that afforded interactions was daily movement through the city, and the network formalized and guided most of this movement (similar to Kazerani & Winter, 2009).

Various daily religious and economic activities like water-gathering, trading, visiting religious temples, or exiting the city towards neighboring areas exposed residents to other individuals through recurrent, and brief exchanges. These encounters can be classified in enduring, fleeting, and passive, depending on the length of the interaction and the total number of residents at a given encounter.[6] The nature of movement guided by the shape of segments (linear) and nodes (open) afforded different types of socialization (fleeting, passive, and enduring). In sum, the physical characteristics of each class of nodes and segments allowed different types of potential interactions. Ultimately, daily movement through the city over time helped established a dynamic social network.

7. Nodes are areas for meaningful interactions.

Similar to the previous point, I propose that nodes —particularly medium and large size nodes— are spaces for more meaningful interactions. They are also spaces with the potential to host more people at the same time and for an extended period of time compared to segments. However, nodes are different than other public spaces (e.g., plazas, patios) because they are not

[6] See discussion in section 7.5 of chapter seven.

structures created with specific functional purposes or have social/ethnic attribution. In contrast, nodes are multi-use spaces, likely to be more egalitarian, less restricted, and with a constant flow of visitors.

8. Complejos or household-blocks are socio-spatial units.

Complejos or city-blocks explicitly defined by roads seem to be the most important socio-spatial units in the layout of Angamuco.

The socio-spatial configuration of Angamuco is an area that still needs more investigation. Nevertheless, this dissertation has provided arguments to better describe the urban layout of the whole site.

The urban road network also helped define the boundaries of socio-spatial areas that include land for farming and housing architecture. These socio-spatial units align with previous ideas of household complex and decentralized spatial organization. A total of 685 of these units, called complejos, were identified.

Moreover, the morphological and functional characteristics of the urban road network are seemingly different than the internal circulation network of these clusters. Further work on the patterning and style of the architecture and material deposits, in addition to internal roads within these clusters will help understand the internal socio-spatial structure and use of resources.

9. Differentiated accessibility can suggest elite vs commoners, or temporality.

The road network in its entirety is well integrated. Most areas are well connected to the network. However, some UNA analyses (e.g., accessibility, gravity) revealed that some complejos were remarkably less connected.[7] There are at least two possible interpretations:

a) These areas (generally *complejos*) are purposely less accessible to keep social classes separated. In order to signal elite-only areas, roads were built in such ways that directed traffic only through selected routes. In other words, a common pedestrian would have fewer options to access to such *complejo*. Excavations at the site in 2013, and 2014 (Cohen, 2016) have demonstrated that however the governing class ruled Angamuco, there were at least two distinct social classes (elite and commoners). There is an identifiable archaeological assemblage that distinguishes the elite class (at least for the Postclassic period) but also, it has been demonstrated that certain socio-spatial areas (*complejos*) were mostly inhabited by elite groups. However, these *complejos* are not clustered, but distributed throughout the city, neighboring other *complejos* primarily inhabited by commoners. I argue that accessibility might have been a method to identify social division.

b) These areas were established/settled at different time periods. That is, their placement in the landscape corresponds to later connectivity needs than those for which the existent network was designed. In other words, there is a different "logic" or pattern of road network for each time period, and these patterns are evident when calculating accessibility for the entire network. This interpretation is harder to demonstrate since several lines of investigation should be first explored, like using architecture or ceramics to determine chronologies for two neighboring but less connected *complejos*.

[7] See section 6.1.3. in chapter six.

8.1.2. Contributions to the study of roads in Archaeology

Throughout this dissertation I have made reference of a select number of studies where ancient roads have been the center of the investigation. Many of these have introduced innovative approaches like space syntax (e.g., Branting, 2004; Kaiser, 2011; Laurence, 2006) that are not yet fully part of the standard archaeological toolkit. A lesser amount of case studies has been explicit about the methods and techniques they used in the field for mapping and/or excavating ancient roads (e.g., Keller, 2006).

Additionally, the diversity of ancient road networks and urban layouts thorough the world and particularly in Mesoamerica adds to the challenge to form a body or work that helps standardize or guide further archaeological research on road networks. For example, characterization of road diversity (e.g., road typologies or categories) are sparse in the archaeological literature.

This study has been designed for the unique landscape and historic characteristics of Angamuco, but it is my hope that the methods, approaches, workflows, and techniques developed here serve as an example of future research centered in urban roads. Particularly, I have made an attempt to include exploratory spatial analysis that have become fundamental in urban studies of modern cities. Survey and application of approaches outside the archaeological spectrum might bring new directions and questions to archaeological urban landscapes.

Two particularities of this research made the comprehensive study of the global urban road network possible: a) A good resolution DEM derived from lidar scanning, and b) An outstanding good conservation state of architecture that included roads. Other sites in Mesoamerica (e.g., Chunchucmil, Cantona, Palenque, El Prieto) have the potential for similar research and it is my expectation that some elements of this dissertation serve for future work in such sites.

8.1.3. Shortcoming and limitations of this research

Given the limited work done at Angamuco to this date, carried out only through less than 10 years of research by one project, there is still very little understanding of the culture history, chronology, archaeological assemblage, and urban development. Furthermore, this is the first time the road network has been systematically examined, and, to the best of my knowledge, the only study of urban road networks in western Mexico.

Additionally, the PACUA dataset has its own limitations, primarily, its small size due to time and staff constraints during fieldwork. Another problem is that the sample of the network is not well-confined. A road network, by nature, is expansive, and our fieldwork mapping was generally very inclusive. In other words, we followed segments and nodes to whichever direction they were expanding. This meant that at some points during fieldwork, we deliberately stopped mapping segments even if the network continued. We always terminated our survey at nodes, but they were not always end-nodes. Graphically, the outer nodes on the PACUA dataset resemble simple-nodes. While the PACUA database might look like a small and limited network, it should be treated as a section with unclear limits.

Even with those limitations, the PACUA sample covers an area of about 14% of the site (824,472 m^2 or a little less than 1 km^2) and includes a wide range of segments, nodes, and construction styles. I believe it is a very good representative sample of the diversity of the roads and the road infrastructure at Angamuco, which was an essential goal of this dissertation.

In order to date construction events and explain the functioning of urban roads, it is fundamental to refine the occupation model of the site, and a comprehensive knowledge of the ceramic and architectural diversity. The lack of these two aspects limited the interpretation of this work. At times, this also provided a more open framework to explore features of the network more freely. Dedicating great amount of resources to basic contextual research like ceramic traditions restricted my investigation and slowed down my progress. Another constraint was the need for methods specifically applicable for collecting data on movement, or how to study roads archaeologically. Overall, the biggest challenge of this dissertation was developing workflows to clean and standardize all the data. Figuring out how to collect, code, and explore the data required thoughtful planning and keeping the research goals clear.

Finally, the road network is the quintessential representation of a palimpsest. In chapter six, I described the three main assumptions that were necessary to convey this research. Without such premises —all roads are made by humans, all roads are prehispanic, the network is contemporaneous— I would have been very difficult to move forward in the exploration of roads.

8.2. Future directions of research

This analysis of the Angamuco road network only represents a small part of a larger investigation using traditional archaeological approaches directly on roads, and concepts of centrality and Space Syntax onto the global network. There are many useful analytical scopes and methodologies in fields like urbanism, transportation systems, landscape studies, and others available to archaeologists with the potential to generate new directions, questions, and interpretations.

Within the context of Angamuco and the LPB, this study has provided the foundation from which future work can be developed. I highlight the role of remote sensing and GIS as mechanisms to identify and evaluate road networks and create spatial datasets. As a result of this initial research, we can now establish the potential that road networks have in understanding historical, social, and spatial development of ancient urban centers. Particularly, I identify the following new directions for future research:

a) The recent acquisition of new lidar scanning for the northern part of Angamuco might suggest that the dimensions of the city triplicate. It would be important to compare road network patterns and confirm if major arteries expand towards those areas.

b) Explore more suitable methods for extracting and identifying roads. I used a combination of image analyses working on products derived from a DEM. It is very likely that other approaches like working directly with the lidar point cloud (e.g., comparing point densities (Beck, 2014)), or surface modeling (e.g., breaklines in TIN models (Linyu et al., 2012) can provide more accurate and faster results).

c) Exploring human movement behavior and interaction in the network through Agent Base Modeling (ABM). Tools like ABM can help identify segments and nodes more likely to afford interaction, what locations are more attractable, other traffic patterns comparable with the already suggested road hierarchy, etc. (e.g., Ausloos et al., 2014).

8.3 Final thoughts

Through the systematic examination of the archaeological and spatial information for the urban road network of Angamuco, this dissertation has demonstrated an important relationship between the urban configuration and the complexity of the network. The urban network analysis approach has provided an evaluation of the creation, use, and significance of the diverse network of roads, as well as identified the nodes as fundamental locations to understand movement and interaction. The excavation and survey have demonstrated that roads are architectural structures that require planning and organization. The composition and functionality of the network has reinforced the ideas of a decentralized government for the centuries previous to the formation of the Purépecha Empire. Finally, the absolute and relative dates indicate that Angamuco witnessed a moment of massive transformation of the landscape and population growth during the Middle Postclassic period.

This research privileged the material evidence associated to daily urban movement. The focus of this work were the physical and spatial qualities of the roads, and their role in the configuration of the city. However, the interpretations offered here intend to complement our understanding of the life of the people that inhabited the site of Angamuco.

A city is an assemblage of places charged with meanings, experiences, and power. The road network is the structure where individuals share these ideas and develop relationships. An archaeological approximation to the road infrastructure as it has suggested here, has the potential to help us understand how people created their communities and urban lives.

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Thank you for reading

APPENDIX A: Photos of ceramics

Find this appendix within the electronic supplemental media that contain:

1. Representative sample of ceramic and lithic fragments from excavation
2. Please contact author for access to all photographs

APPENDIX B: 3D models of excavation units

Find this appendix within the electronic supplemental media that contain:

1. 3D PDFs of each end of excavation unit

APPENDIX C: Cataloguing protocols

This appendix contains:

1. Field forms for mapping segments and nodes
2. Pre-sorting material matrix
3. Attribute analysis matrix

PACUA 2016

ROAD SEGMENT FORM

ID CODE

Initials: ______ Date: ______

GNSS # ______ Tablet # ______ Camera # ______

Provenience

Quad ______ Tile ______ Area ______

Class: ☐ >3m Camino ☐ Sendero ☐ <1 m Pasillo

Width (m): Start ______ Other ______

Type of start/end End ______ Middle or narrowest point

☐ entrance ☐ node ☐ plaza ☐ patio ☐ wall ☐ dead end ☐ other

Shape: ☐ Straight ☐ Curved ☐ Sinuos **Slope:** irregular flat slope

Architecture/Construction

☐ Banqueta ☐ Stairs ☐ Sunken ☐ Ramp (up/down)

☐ Building ☐ Blockages ☐ Raised ☐ Retention wall

☐ Well ☐ Paved ☐ Wall ☐ Other

Experiential:

☐ Can you **see** next node/decision making?

Effort/Slope easy / moderate / difficult

Photos of:

☐ Start ☐ End ☐ Side ☐ Node ☐ Architecture

Files: ______

FS collection:

☐ Ceramics ☐ Lithics ☐ Other

FS Number: ______

Notes:

______

______

______

______

PACUA 2016

NODE FORM

ID CODE

Initials: ______ Date: ______

GNSS # ______ Tablet # ______ Time ______ Camera # ______

Provenience

Quad ______ Tile ______ Area ______

Class: ○ 1-road ○ 2-road ○ 3-road ○ >3-road

Type:
Choose one

○ K-Node ○ T-Node ○ Y-Node

○ Simple ○ X-Node ○ Other

Conditional:
For simple nodes

○ Entrance ○ Plaza node ○ Other

Size:
Area

Ⓢ $<50cm^2$ Ⓜ 1-3 m^2 Ⓛ >3 m^2

Visible evidence of **superposition** Yes or No ○

Architecture/Construction

○ Banqueta ○ Stairs ○ Other ○ Ramp (↑ / ↓)

○ Sunken ○ Blockages ○ Raised ○ Retention wall

○ Building ○ Paved ○ Well

Photos of:

○ Start ○ End ○ Side ○ Node ○ Architecture

Files: ______

FS collection:

○ Lithics ○ Other

FS Number: ______ ○ Ceramics

Notes:

______

______

______

______

PACUA PRE-SORTING CERAMIC ANALYSIS CHEAT SHEET

	ID	InternalNo	Count	Weight	SherdType	SherdTypeCode #	Class	ClassCode#	Comments	RecordDate	Marked
Description	FS number	Code including type/class	Total amount of pieces per class	Weight per class in grs with up to 1 decimal	Sherd type or part of the object	Code #	Class of sherd	Code #	Any special comments on the collection like polychrome, complete figurine, etc.	Date of Pre-sorting	How is marked in the sherd (same code for all sherds of same class and type). Drop the first digits of the FS
Example	FS0005	PA.C.FS0005.1.2	12	67.5	Body	1	Undecorated	2	Very small cylindrical piece-possible minature	6/6/16	5.1.2
Codes	FS+Number	Project two digit code+C (for ceramic)+FS Number+Code per Type+Code per class			Sherd type/part descriptor.	Body = 1 Element = 2 (Inlcudes rim, soport, handle, base) Special = 3 (Pipe, spoon, figurine) Indeterminate = 4 (not clear) Other = 5 (anything else not in this list)	Class descriptor.	Decorated = 1 (paint, slip, appliqué) Undecorated = 2 Other = 3 (Anything that does not fit in previous categories)			

PACUA Attribute Analysis Database Description of codes

* The below example is a fake analysis just to show the process

In all cases, double zero corresponds to N/A or if it cannot be determided

	Basic Identification							
	Bag FS	**InternalNo**	**Area**	**Field collection**	**Unit**	**Level**	**Feature**	**Analytical Entity**
Description	FS number	Code giving during pre-sorting including type/class/individual piece number	Area of Unit of excavation	Surface or Excavation	Unit of excavation or road	Level of excavation	If belongs to an archaeological feature	Object being coded (similar to Sherd Type in Pre-sorting analysis)
Example	FS0005	PA.C.FS0005.1.2.1	F	E	U1F01	02	F01	07
Codes	FS+Number	Project two digit code+C (for ceramic)+FS Number+Code per type + code per class + individual piece number		E = Excavation, S = Survey, O (letter) = found out of context		0, 1, 2, 3… *Zero level corresponds to cleaning excavation unit wich could be taken as survey		00 – cannot be determined 01 – whole vessel; rim + body + base; 50% or more complete 02 – incomplete vessel; rim + body + base supports; less than 50% complete 03 – rim and body 04 – body and base with or without supports; no rim 05 – rim 06 – body 07 – base 08 – appendage; support with no substantial base fragment attached, handle, spout 09 – neck 10 – figurine; anthropomorphic or zoomorphic; whole or partial 11 – pipe; whole or partial 12 – circular sherd 13 – spindle whorl 14 – spoon

	Vessel Form						
	Lip Attributes (lip = the upper edge or margin of the rim or mouth of the vessel)				**Rim Attributes** (rim = area between the change of orientation of the lip and the side or neck of the vessel. Where no change of orientation is present, a vessel is defined as having a direct or straight rim.)		
Class	**Tapering/Thickening**	**Symmetry**	**Flaring**	**Lip thickness**	**Maximum orifice diameter**	**Rim thickness at body**	**Rim form**
Class of the piece				measured with calipers across the upper surface of the lip (mm)	measurement of mouth of the vessel at the uppermost edge of vessel walls (mm)	measurement of the vessel wall at the articulation point of the rim and the upper body using caliphers (mm).	
01	00	00	00	00	00	00	00
00 – cannot be determined 01 – Decorated (paint, slip, appliqué) 02 – Undecorated 03 – Other (Anything that does not fit in previous categories)	00 – not applicable 01 – tapered 02 – thickened 03 – constant	00 – not applicable 01 – flat 02 – round 03 – round with flattened top	00 – not applicable 01 – exterior 02 – interior	00 – not applicable	00 – not applicable		00 – not applicable 01 – convex: insloping rim that curves inward 02 – direct/straight: does not exhibit change in orientation from body 03 – outsloping: rim that curves out from body

Vessel Form					
Neck	**Body Attributes** (portion of the vessel between the orifice and body that includes the maximum diameter of the vessel or the region of greatest			**Base:** underside of vessel	
Neck	**Body form**	**Wall thickness**	**Vessel height**	**Base form**	**Base thickness**
neck = restriction of the orifice of the vessel, beginning above the point of maximum diameter of the body		measurement at the thickest point of sherd (mm)	measurement of maximum height of vessel if 50% or more complete (mm)		measurement as closely as possible to center of base (mm)
00	02	10	00	04	14
00 – not applicable 01 – curved 02 – curved, inverted 03 – curved, everted 04 – straight, inverted 05 – straight, everted	00 – not applicable 01 – incurved (probably closed) 02 – outcurved (probably open)			00 – not applicable 01 – annular 02 – flat 03 – convex 04 – rounded	

					Vessel Form
Appendages	**Figurines**	**Pipes:** Specific attributes were recorded if available.			
Appendages	**Figurines**	**Portion**	**Pipe type**	**Pipe decoration**	**Vessel Type**
type of support, handle, or spout	anthropomorphic and zoomorphic miniature sculptures				
00	00	00	00	00	02
00 – Not applicable 01 – Support, fragment, unknown form 02 – Support, hollow ball (Hueco pelota) 03 – Support, hollow cone (Hueco cónico) 04 – Support, hollow cylinder (Hueco cilíndrico) 05 – Support, hollow mammiform (Hueco mamiforme) 06 – Support, hollow spider (Hueco araña) 07 – Support, slab trapezoidal/ with or without serrated edges (trapezoidal) 08 – Support, miniature solid (Sólido miniatura) 09 – Support, solid ball (Sólido botón) 10 – Support, solid cone (Sólido cónico) 11 – Support, solid cylinder (Sólido cilíndrico) 12 – Handle, lug (asa oreja) 13 – Handle, strap – diagnostic Tariacuri phase 14 – Handle, solid 15 – Handle, spoon 16 – Handle, support 17 – Spout (vertedera) 18 – Handle, circular (square LPC spouted vessel)	00 – not applicable 01 – head 02 –arm 03 –leg 04 – body 05 – foot 06 – other (expand in notes)	00 – not applicable 01 – bowl 02 – stem 03 – parts of bowl, stem, supports, etc. 05 – complete	00 – not applicable 01 – circular opening 02 – oval opening 03 – square opening 04 – X opening	00 – not applicable 01 – no decoration 02 – one twist 03 – two twists 04 – incisions, dots 05 – incisions, lines 06 – pinched	00 – not applicable 01 – Bottle 02 – Bowl 03 – Grater 04 – Incense burner 05 –Jar 06 – Plate 07 – Sieve 08 – Spouted vessel 09 – Miniature

Vessel Type	Attributes of Technology			
Vessel Type 2	**Paste**	**Paste Color**	**Finish**	**Slip**
If possible, sherds were classified more specifically within each morphological type	Overall characterization of paste	Based on Munsell	The process that occurs after the pottery vessel has attained its final shape and after any irregularities have been eliminated.	
02	02	10R=3	01	7.5YR=8
00 – not applicable 01 – Bowl, composite silhouette 02 – Bowl, convex wall 03 – Bowl, everted rim 04 – Bowl, incurved rim 05 – Bowl, large shouldered (see Prieto funerary bowl/covering) 06 – Bowl, outsloping wall 07 – Bowl, tripod 08 – Bowl, tripod yacata – polychrome and negative tripod 09 – Incense burner, brasero – applique circles or pellets, coarse 10 – Incense burner, sahumador – excision (may or may not have handle) 11 – Incense burner, tecomate style – incurved rim with two holes near top 12 – Jar, everted rim 13 – Jar, incurved rim 14 – Jar, incurved rim, tecomate 15 – Plate, convex wall 16 – Plate, flat base (comal) 17 – Sieve 18 – Spouted Vessel, shoe-shape (patoja) – may be decorated or unslipped 19 – Spouted Vessel, LPC polychrome gourd-like 20 – Spouted Vessel, square with spout, long neck, and small handle	00 – cannot be determined 01 – fine 02 – medium 03 – coarse	00 – not applicable OR – Munsell color (coded as follows: 7.5R=2, 10R=3, 2.5YR=4, 5YR=5, 7.5YR=6, 10YR=7, 2.5Y=8; i.e. 7.5YR 5/4 brown = 654)	00 – cannot be determined, due to erosion or breakage 01 – smoothing: smoothed with a soft tool such as cloth, leather, a bunch of grass, or a hand; performed when vessel was wet or re-wet. 02 – scraped: striations from scraping tool are present; performed when vessel was still wet or soft. 03 – burnished: surface was rubbed repeatedly with a smooth, hard object, such as a pebble, bone, horn, or seeds. Could show narrow parallel or criss-crossing linear facets, careless burnishing results in irregular and streaky luster; done when vessel was dry. 04 – polished: surface was rubbed with a smooth, hard object; luster is uniform; performed on dry surface. 05 – roughened: surface is less unsmoothed through striating, combing, stamping, impressing; may improve grip and heat transfer. 06 - No finish (simple)	00 – cannot be determined 01 – no slip OR – single slip color (Munsell code)

				Decorative Attributes		
Slip color	**Secondary Slip**	**Granulometry 1**	**Granulometry 2**	**Substractive**	**Displacement / Joining**	**Paint class**
Munsell color description		Other characterictics of the paste	Other characterictics of the paste	An implement was used to remove clay from the formed vessel. Most subtractive decoration is executed when the clay is plastic or leather-hard; some may be done when the clay is dry, and some after firing.	process by which embellishments are cut from or impressed into the surface; joining involves attaching pieces of clay.	
strong brown	00	01	02	00	00	01
	00 – cannot be determined OR – slip color (Munsell code)	00 - Cannot be determined 01 - Homogenous 02 - Heterogenous	00 - cannot be determined 01 - Porous 02 - Very compact 03 - Compact	00 – not applicable 01 – incising: A tool is applied to the surface of the vessel and cuts it with pressure. 02 – combing: A form of incising using a multi-pronged tool. 03 – fretwork: The vessel is pierced to make the decoration.	00 – not applicable 01 – impressing: stamping or paddling techniques in which an impression is left by applying a tool of some kind (e.g. fingernails, fingers, molds, seals). 02 – appliqué: shaped pieces of clay are bonded to the surface using pressure (e.g. conical spikes; bumps). Functional elements such as handles and spouts are not types of appliqué. 03 – modeling: pieces of clay are added to an existed form, and are shaped to produce a three-dimensional design.	00 – not applicable 01 – simple, 1 color 02 – simple, 2 colors 04 – simple, 3 colors 05 – negative: use of a resist to define a design in a reduced firing environment 06 – negative + 1 color 07 – negative + 2 colors or more 08 – other (expand in notes)

					Chronology		Type
Paint Color	**Paint color description**	**Paint Color 2**	**Paint Color 3**	**Motifs**	**Main Phase**	**Occupation Period**	**Type**
Color of paint	Color of paint description	Color of paint	Color of paint	note the number associated with motif picture in motif catalog	Proposed main phase	Associated to occupation period	Angamuco Type (according to Cohen/Pollard)
7.5R=2	Brown	00	00	00	PR	05	RO
00 – cannot be determined OR – paint color (Munsell code)		00 – cannot be determined OR – paint color (Munsell code)	00 – cannot be determined OR – paint color (Munsell code)	00 – not applicable 01 – motif 1 catalog number (e.g. 01-11) 02 – motif 2 catalog number 03 – motif 3 catalog number 04 – other (e.g. panel on a complete vessel; expand in notes)	PR = Pre-purepecha Empire E = Post-Purepecha Empire C = Colonial	00–cannot be determined **01–Preclasico Tardio** **02–Preclasico Terminal** **03–Clasico Temprano** **04–Clasico Medio** **05–Epiclasico** **06–Posclasico Temprano** 07–Posclasico Medio 08–Posclasico Tardio	P – Polychrome FR – Fine Red DR – Dull Red WR – White on Red PB – Pale Brown FRG – Fine Reddish Gray DRG – Dark Red on Gray RO – Red on Orange BNP – Biochrome POB – Polished Black IA – Incised Aplique RPB – Red on Pale Brown

Other		
Comments	**Date Analysis**	**Initials**
Any special comments on the piece. place to put unique attributes, particulars about artifact location and associated artifacts.	Date of Analysis: MM/DD/YY	
	6/10/16	

APPENDIX D: Detailed stratigraphy of units

Unit U1A01

The strata in Unit U1A01 were found in the following order:

I. Stratum I was a very thin (<5 cm) layer of sediment with rich organic components, the most recent deposit and most likely absent in ancient times.

II. Directly below, stratum II was only observed in the north side of the unit (and clear in the north wall profile). This semi-compacted stratum is a mix of silt and small rocks. I believe that it is the edge of the ramp's pavement and the top of the road.

III. Stratum III, directly below, extends across the unit under the *banqueta* walls. It is clear in the profile that the base of the *banquetas* rests at the end of stratum II (or the top of stratum III). The *banquetas* were most likely constructed at the same time that stratum II was deposited, which served to both fill and cover the walls of the *banquetas*, leaving the top exposed, and as pavement for the ramp. Since stratum II is not observable on the south wall but the *banquetas* extend to the south past the unit, it is very likely that this pavement was marking the difference between the ramp and the plaza node. No sediment was found at the base or around the foundations of the wall, which is safe to assume means that the *banquetas* were not built to serve as balustrades but were purposely partially covered with the pavement. This sediment likely represents the occupational surface before the construction of the ramp. Strata II and III contained a moderate density of artifacts. The earlier ramp/road is located about 40 cm below the surface inside stratum III.

IV. Beneath this layer, stratum IV is a larger deposit of yellowish-brown clay that extends to ~1 m below the surface with almost no cultural deposits.

V. To the east of the unit, we placed a 1 m x 1 m test sub-unit where we found stratum V, containing a large amount of fill composed of yellowish-brown compact clay sediment with few rocks and high artifact density. This stratum continues for at least one meter (~1 to ~2 m below surface), but we were not able to find the bottom in the time allotted. A large stone *laja* was found at the bottom of the unit that appears to be associated with another feature to the south of the unit. We did not excavate this, as it would have required opening the adjacent unit to the south. *Lajas* are very important and have been observed in Urichu (Pollard & Cahue, 1999) and Angamuco (Cohen, 2016; Fisher et al., 2016) as architectural components, generally found as walls or tops for stone cases of offerings and burials.

Unit U1A02

The first layer corresponds to a very thin (< 3 cm) of compacted silt. This layer was not collected separately but was observed in the profile. Most likely this is the result of sediment compaction from a high level of pedestrian traffic, as opposed to a planned construction technique. Interestingly, both S1A013 and S1A017 show the same layer, although, as I discuss below, the roads might not have been contemporaneous. It is possible that the earlier road (S1A017) was reused later and thus created the same residue of pedestrian traffic.

The strata in Unit U1A02 were found in the following order:

I. Stratum I represents the natural sediment deposits since abandonment. It was observed to the west of S1A013 and between S1A013 and S1A017. This stratum was about 10 cm deep.

II. Directly below, stratum II is a semi-compact silt and was present in all areas of the unit outside the roads. This stratum showed a low amount of materials suggesting it is the remains of the natural deposits.

III. Stratum III was only found inside S1A013. It is very similar to stratum II but with slightly more artifacts. It is possible that the natural layer (stratum II) was dug out to build up the foundations of the road and that it was eventually reused to fill the ditch for the road.

IV. Stratum IV is a compact strong-brown clay and is very similar to what has been observed as deep and sterile natural deposits throughout the site (Cohen, 2016; Fisher et al., 2014; 2016). This layer was found at the bottom of S1A013 with no artifacts.

V. Stratum V, similar to stratum I, is a dark silt and most likely a recent natural deposit but was only found at the east end of the unit outside S1A017. Stratum V was excavated at a later date, but is most likely contemporaneous to stratum I.

VI. Stratum VI can be described as loose silt mixed with gravel and ceramic materials. This deposit was found inside the walls of the eastern *banqueta*, a typical construction technique.

VII. Stratum VII is another version of fill but established part of the platform created for S1A017. Finally, an intrusion or blockage was found next to the outer side of the eastern *banqueta* for S1A013. This deposit is described as the fill of an intentional blockage or adjustment in the meeting point of both roads and was excavated as feature A-02. A radiocarbon sample was taken from this stratum.

Unit U1F01

The strata in Unit U1F01 were found in the following order:

I. Stratum I is very similar to the other top recent soils full of organic materials observed in the site. Despite being a road of likely high traffic, this top layer (~10 cm deep) was not very compacted. This stratum contained no cultural materials.

II. Stratum II is a semi-compact silt with small to medium size rocks throughout the unit. This same stratum becomes more compacted and harder as it reveals larger stones midway through the deposit (IIb). This accumulation of rocks could be considered an unsophisticated surface for walking, but the rocks are not consistent enough to be classified as pavement. Very few ceramic materials were found within this stratum.

III. Finally, stratum III is a lighter sterile yellowish-brown clay that indicates the end of the unit. There are many large boulders within the sediment. This stratum has been observed at other areas of the site as a natural sterile layer and occurring at around the same depth (1–1.5 m below the surface).

Unit U1F02

The strata in Unit U1F02 were found in the following order:

I. The first stratum is very similar to the humus layer of U1F01, with a high presence of organic matter, a very dark brown color, and a semi-compact texture of only few cm deep.

II. Directly below, stratum II is a slightly darker and loser silt. Within this stratum (levels 3 and 4 at 30–40 cm below surface) there was a uniform layer of medium size stones (IIb) that could either be a walking surface or an unsophisticated pavement.

III. Below this possible pavement, stratum III extended over 60 cm down and consists of a loose, dark yellowish-brown clay. Not many rocks were found within this layer, and only a small but consistent amount of lithic and ceramic materials is found across the entire layer.

IV. Stratum IV is about 60 cm deep, and a darker and more compact clay is observable in the western part of the unit. The unit was finished at this depth because of time constrains, but no materials were found in this last stratum. Radiocarbon samples were taken at few levels, although they were not tested, since they were found either at shallow levels or in areas with a high presence of roots.

Unit U1H01

I. The first stratum is a superficial layer of humus with a large presence of organic matter. When removing this stratum, a layer of small stones was observed. This element could be pavement that, together with the *banquetas*, created the walking surface for the road.

II. Directly below the alignment of small rocks there was a grayish semi-compact silt (stratum II) that was collected separately and most likely represents the fill used to create the pavement. There is a change of strata about 15 cm below the possible pavement.

III. Stratum III represents the event for the creation of the retention wall. This is a wall composed of two parallel alignments of large stones with a mixture of small stones and sediment inside, and the wall was registered as feature H-01. The sediment inside is different from the rest of the unit. Its texture is clay and is very dark brown in color. In its interior, a high density of ceramic fragments was identified.

IV. The last layer, stratum IV, is composed of silty-sandy sediment and was very homogeneous through the rest of the excavation. This layer did not show many cultural materials.

Unit U1H02

I. Stratum I is the typical organic layer and was only about 7 cm deep but homogeneously distributed.

II. Directly below is stratum II, a very dark brown semi-compact coarse sand mixed with silt and gravel. At the top of the layer there is a pavement-like layer of smaller rocks all around 10 cm in diameter. This is perhaps one of the better examples of pavement found in this project. This pavement is constituted with a layer of small rocks very well packed together with little sediment in between. It is very compact and hard to excavate with a trowel, and extends for about 10 cm. No material was found within the pavement layer. The rest of the stratum is constituted with a mix of gravel and sediment.

III. Gradually, the sediment became less compact and around 30 cm below the surface in the northwest corner, loose silt started to appear, marking stratum III. This sediment becomes softer and has no rocks as it gets deeper. The strata visibly follow the slope of the road, so any new changes in the stratigraphy appear first in the highest corner of the unit. No materials came from this stratum.

IV. Stratum IV is a very shallow layer (~5 cm) of semi-compact moist silt mixed with gravel, and acts as the cover for the final stratum.

V. Stratum V can be described as a fill layer of loosely fit medium size rocks with no sediment. The fill layer is so loose that the sediment from the level above would fall in to the voids created by the fill. No sediment was observed throughout this stratum, even after pulling out rocks as deep as 30–40 cm below stratum IV. The fill was a combination of large boulders and rocks, much of which could not be removed from the wall of the unit. This type of fill has been observed in areas D and F of the LORE-LPB excavations for the preparation of large platforms or plazas. No materials at all were found in this unit. Excavation stopped at 80 cm below surface given time constraints, but it appeared that the fill most likely continued.

Unit U1I01

I. Stratum I can be characterized as the natural organic post-Prehispanic deposit (dark reddish-brown silt) found at the base of the hill slope on the east side of the unit and on top of the sunken plaza/patio. This layer was only visible for less than 10 cm and extended only about a meter away from the hill on the east side, and as deep as 30 cm outside the road (sunken plaza/patio). It is very likely that this is the washout of the hill sediment on the east side.

II. Stratum II in contrast is very compact silt, is lighter in color than stratum I, and is present in the west side of the unit (on the road). This layer did not show many cultural materials and was deeper closer to the retention wall. Not much (if any) post-Colonial humus accumulated on top of this strata and its compact texture did not leave much room for larger vegetation to grow. Instead, it was covered by grass and as a result was also covered with abundant grass roots.

III. Stratum III is considered the fill for the ramp and is composed of a mix of silt and small rocks. It is also very compacted, like stratum II, but slightly darker in color. Other larger rocks are occasionally present. This layer extends about 40 cm deep in some areas and is notably deeper by the retention wall on the west side of the unit, although this layer was also found under stratum I outside the road on the sunken plaza/patio. Found at the same level, but outside the ramp, stratum IIIb (*talud*) is only slightly darker and looser than stratum III. It may be another post-Colonial natural deposit.

IV. Stratum IV was found directly below the fill (stratum III) and without a clear transition. This is a loose yellowish-brown clay, the same as what has been observed as the natural and sterile layer in areas A, C, and D by LORE-LPB (Fisher et al., 2016, 2014) and areas AD and FG by this research. On the south wall of the unit, it is clear how this layer expands across the road and into the sunken plaza.

V. Lastly, stratum V was found directly below features I-03 and I-04. Stratum V is composed of semi-compact sand deposited as part of the construction for the retention wall.

Unit U1I02

The very top layer of the unit around its center presented a very similar sediment as that observed in unit U1A02: a semi-compact fine and thin (<5 cm) grayish silt with no gravel or materials. This layer was lined by a simple alignment of medium rocks (*banqueta*) on the surface. It is possible that this is the result of high traffic compaction of the sediment. This establishes a second example of this kind of layer in this research, suggesting it may be possible to identify walking surfaces at other roads, or that both U1I020 and U1A013 are contemporaneous roads.

I. Stratum I is a layer of highly organic materials (humus) and is dark and moist with many roots and insect burrows. It was observed through the unit as the top layer that extended between 10–20 cm deep. Directly below the road surface, stratum Ib is very similar to stratum I, only slightly grayer in color and perhaps finer. I suspect it is a different stratum since it was found directly below the road, but it can easily be confused with humus or stratum I. By the southwest of the unit, stratum IV was on top of stratum I and continued all the way to the surface. This stratum is most likely a pavement for a staircase made of many small irregular rocks mixed with loose sediment. This pavement was only observed on an area of ~30 cm^2 between the southern *banqueta* and the slope (Figure 5.45).

II. Stratum II was found in most of the unit, particularly clearer by the western side. It is a dark brown silt and probably the natural deposits had been disturbed by the different construction events. This stratum was found in between structures. Stratum IIb is the same as II, however it was found inside a room in one of the structures and had large contents of ceramic fragments and carbon, which were collected separately.

III. Stratum III is the last natural deposit in the unit and, similar to other units, it is a yellowish-red clay with no materials and many rocks.

V. Stratum V was found as part of the fill for an earlier room within the northeast area of the unit. This stratum is characterized by a dark silt with a high presence of ceramics and is very similar to the deposits observed inside structures excavated by LORE-LPB in 2013 (Cohen, 2016; Fisher et al., 2014).

Finally, feature I-02 is actually the corner of a wall for an earlier structure, and is possibly a room. Together with stratum V, feature I-02 represents an earlier habitation period. A large amount of materials was recovered from inside the boundaries of the wall. Similarly, feature I-01 and its fill, stratum VI, also represent an earlier wall built before this area was cleared and reused as a road, but helped define the retention wall for the slope. A large amount of ceramic materials and the biggest density of lithics was recovered from this feature. None of these features were fully exposed. The total depth of the unit did not exceed 100 cm below the surface.

Unit U1I03

I. As usual, the top layer of the unit is covered with a semi-compact dark brown silt (humus) full of organic material. This layer, or stratum I, was observed on the top of the road at the center of the unit, and was observed almost evenly across the unit, between the two edges of the raised road and stopping at the *banquetas* (Figures 5.49 to 5.52).

Ib. A very similar layer, stratum Ib, was observed at the bottom of the road at the two extremes of the unit. The difference is that stratum Ib is slightly looser and had clearly accumulated on top of and around rumble and post-depositional rocks for about 20–30 cm. Beneath the modern surface (stratum I), the top of the road contain a hard pavement that does not differ from lower sediment in terms of color, although a higher concentration of sand and gravel was observed. The main defining characteristic of the pavement is it very hard compaction.

II. The pavement, stratum II, is also unusually thick, and extends for approximately 10–15 cm.

III. Below the pavement, stratum III is a large fill deposit of brown sediment with scattered rocks (50–60 cm thick). This sediment forms the bulk of the modern elevated portion of the road and also forms a U-shape in profile. Colonial era sherds were found in this deposit between 40 cm and 60 cm below the surface.

VIII. Beneath this deposit, stratum VIII (40–60 cm thick) is composed of a mix of yellowish-brown sand and large rocks, and was either used as foundation for the road, or was the remains of an earlier road. Although this stratum was found at the end of the excavation (~40 cm deep) at 1.2 m below the surface, it has cultural materials and therefore is not a natural deposit. Each wall on each side serves to give structure to the raised platform to form the causeway. The west wall is very thick (>1 m) and faces the largest and quick drop-off against sunken road S2I003. It is formed by two rows of large stones with a rubble core consisting of small stones in dark sediment (stratum V). A deposit of semi-compact yellowish sediment is placed against the east wall (stratum IIIb), probably to help stabilize the fill for the *calzada* or for the wall itself.

VI. The east wall, excavated as feature I-07, consists only of large stones filled with a fine dark brown sand with medium rocks (stratum VI), and slopes down gradually to the east. Stratum VIII was found below the east wall (insert description of VIII here), and stratum X was found beneath the west wall, consisting of small loos stones with darkly colored sediment.

The stratigraphy for road S2I006 is slightly different. Located on the east section of the unit above the east wall, the walking surface for S2I006 (feature I-08 and stratum IV) is about 10 cm deep and is lined by two simple *banquetas* of medium rocks on the surface (one of them, to the west, was excavated as I-05). Both of these *banquetas* are 20–30 cm wide. Immediately below stratum IV, the walking surface for road S2I006, was a thin layer of small to medium rocks that could have been pavement for this road or the foundation for the walking surface. Below the pavement to the east, a layer of very dark brown silt lies between road S2I006 and the wall and was probably used as fill. It contains carbon (stratum VII) extends for 20–30 cm.

IX. Finally, stratum IX, a dark silty sand, might have been another fill to help structure the entire road project or the remains of an earlier road contemporaneous or slightly posterior to stratum VIII. This layer was found beneath the surface humus by the eastern end of the unit (beyond road S2I006) but also beneath strata VII and VI.

We did not reach the end of the road to a sterile deposit due to lack of time, so it is very possible that several more cultural layers from periods before stratum X are still intact and at the level of sunken road S2I003.

APPENDIX E: Codification of ceramic types

Codificación de tipos diagnósticos en la muestra de PACUA

	CATEGORÍA	ATRIBUTOS OBSERVADOS POR POLLARD/COHEN	ATRIBUTO	CÓDIGOS
Fine Reddish Gray Monócromo (FRG)	Formas	Jarras, vasijas miniaturas (con asa)	Entidad analítica	00-09
			Clase de pieza	00, 01
			Tipo de vasija	00, 05, 09
			Vasija tipo 2	00, 12-14, 21-23
	Pasta	Medio (2-5 mm diámetro) Café Núcleo gris/gris oscuro	Pasta	00, 02
			Granulometria 1	
			Granulometría 2	00, 01
	Acabado/engobe	Pulido Engobe: rojo y gris rojizo	Acabado:	00, 01, 03, 04
			Ubicación de engobe	00, 01
			Color de engobe	red, reddish gray
			Clase de pintura	00, 01
	Decoración	N/A	Sustractivo	0
			Engobe / articulación	0
			Descripción del color de pintura	red
			Motivos	0

	CATEGORÍA	ATRIBUTOS OBSERVADOS POR POLLARD/COHEN	ATRIBUTO	CÓDIGOS
Polished Black Monócromo (POB)	Formas	Cuenco, tarros y pipas	Entidad analítica	00-09, 11
			Clase de pieza	00, 01
			Tipo de vasija	00, 02, 05, 10
			Vasija tipo 2	00, 01-06, 12-14, 23
	Pasta	Fino (1-2 mm diámetro) Café	Pasta	1
			Granulometria 1	1
			Granulometría 2	2
	Acabado/engobe	Pulido Engobe: Gris muy oscuro Pintura: negro	Acabado:	00, 01, 03, 04
			Ubicación de engobe	00, 01
			Color de engobe	black, dark
			Clase de pintura	00, 01
	Decoración	N/A	Sustractivo	0
			Engobe / articulación	0
			Descripción del color de pintura	dark gray, black
			Motivos	0

	CATEGORÍA	ATRIBUTOS OBSERVADOS POR POLLARD/COHEN	ATRIBUTO	CÓDIGOS
Red on Pale Brown Bícromo (RPB)	Formas	Cuencos dese miniatura hasta grandes. Convexos Algunas jarras	Entidad analítica	00-09
			Clase de pieza	00, 01
			Tipo de vasija	00, 02, 05, 09
			Vasija tipo 2	00-06, 12-14, 23
	Pasta	Las inclusiones varían de gruesas a finas. Bayo a basalto-chamote a amarillo rojizo	Pasta	00-03
			Granulometria 1	2
			Granulometría 2	
	Acabado/engobe	Pulido Engobe primario: Café claro o pálido/grisáceo Engobe secundario: Café rojizo, rojo, rojo oscuro	Acabado:	00, 01, 03, 04
			Ubicación de engobe	00, 01
			Color de engobe	brown, gray
			Clase de pintura	01, 02
	Decoración	Achurado rojo, puntos, líneas paralelas, zig-zags, espirales e imágenes zoomorfas.	Sustractivo	0
			Engobe / articulación	0
			Descripción del color de pintura	red
			Motivos	00-03

	CATEGORÍA	ATRIBUTOS OBSERVADOS POR POLLARD/COHEN	ATRIBUTO	CÓDIGOS
Red on Orange Bícromo (RO)	Formas	Jarra pequeña, cuencos, recipientes vertedera (patoja)	Entidad analítica	00-09
			Clase de pieza	00, 01
			Tipo de vasija	00, 02, 05, 08
			Vasija tipo 2	00-07, 12-14, 18, 20
	Pasta	Inclusiones van desde gruesas a finas Rojo amarillento a café	Pasta	00-03
			Granulometria 1	
			Granulometría 2	
	Acabado/engobe	Pulido Engobe primario: rojo amarillento, amarillo rojizo Engobe secundario: Rojo	Acabado:	00, 01, 03, 04
			Ubicación de engobe	00, 01
			Color de engobe	yellowish red, reddish yellow
			Clase de pintura	01, 02
	Decoración	N/A	Sustractivo	0
			Engobe / articulación	0
			Descripción del color de pintura	red
			Motivos	0

	CATEGORÍA	ATRIBUTOS OBSERVADOS POR POLLARD/COHEN	ATRIBUTO	CÓDIGOS
Dark Red on Gray Bícromo (DRG)	Formas	Cuencos	Entidad analítica	00-07
			Clase de pieza	00, 01
			Tipo de vasija	00, 02
			Vasija tipo 2	00-07
	Pasta	El color sugiere horneado desigual Gris oscuro	Pasta	
			Granulometria 1	
			Granulometría 2	
	Acabado/engobe	Pulido Engobe primario: gris Engobe secundario: Rojo	Acabado:	00, 01, 03, 04
			Ubicación de engobe	00, 01
			Color de engobe	gray
			Clase de pintura	01, 02
	Decoración	Algunos diseños? No es muy claro	Sustractivo	0
			Engobe / articulación	0
			Descripción del color de pintura	red
			Motivos	01, 03

	CATEGORÍA	ATRIBUTOS OBSERVADOS POR POLLARD/COHEN	ATRIBUTO	CÓDIGOS
White on Red Bícromo (WR)	Formas	Cuenco, Botella	Entidad analítica	00-07
			Clase de pieza	00, 01
			Tipo de vasija	00, 01, 02
			Vasija tipo 2	00/06, 24
	Pasta	Fino (1-2 mm diámetro) Rojo amarillento a café	Pasta	01
			Granulometria 1	01
			Granulometría 2	02
	Acabado/engobe	Pulido Engobe: rojo	Acabado:	00, 01, 03, 04
			Ubicación de engobe	00, 01
			Color de engobe	rojo
			Clase de pintura	01, 02
	Decoración	Pintura: blanco Motivos epirales	Sustractivo	00
			Engobe / articulación	00
			Descripción del color de pintura	blanco
			Motivos	00-03

	CATEGORÍA	ATRIBUTOS OBSERVADOS POR POLLARD/COHEN	ATRIBUTO	CÓDIGOS
Bícromo Negativo/Positivo Bícromo (BNP)	Formas	Cuencos (incluidos trípodes)	Entidad analítica	00-08
			Clase de pieza	00, 01
			Tipo de vasija	00, 02
			Vasija tipo 2	00-07
	Pasta	Fino a medio Varios cafés	Pasta	01, 02
			Granulometria 1	1
			Granulometría 2	
	Acabado/engobe	Pulido Negativo o positivo Engobe: Rojo oscuro a café rojizo	Acabado:	00, 01, 03, 04
			Ubicación de engobe	1
			Color de engobe	red to reddish brown, black
			Clase de pintura	01, 02, 05, 06
	Decoración	Banda de borde rojo, rayas verticales blancas sobre negro, posible diseño de coyote	Sustractivo	0
			Engobe / articulación	0
			Descripción del color de pintura	red, white
			Motivos	00-03

	CATEGORÍA	ATRIBUTOS OBSERVADOS POR POLLARD/COHEN	ATRIBUTO	CÓDIGOS
Polícromo (P)	Formas	Botella, cuencos, jarra, vasijas vertederas, trípode en miniatura	Entidad analítica	00-09
			Clase de pieza	1
			Tipo de vasija	
			Vasija tipo 2	01, 02, 05, 08, 09
	Pasta	Fino a medio Rojo amarillento a café	Pasta	01-08, 12-14, 19-21
			Granulometria 1	01, 02
			Granulometría 2	1
	Acabado/engobe	Pulido Engobe primario: Café pálido a claro Engobe secundario: Rojo	Acabado:	
			Ubicación de engobe	00, 01, 03, 04
			Color de engobe	1
			Clase de pintura	light to pale brown
	Decoración	Negativo Pintura: (negra o blanca) Varios motivos	Sustractivo	01-04,
			Engobe / articulación	any
			Descripción del color de pintura	0
			Motivos	0

	CATEGORÍA	ATRIBUTOS OBSERVADOS POR POLLARD/COHEN	ATRIBUTO	CÓDIGOS
Incised and Apliqué (IA)	Formas	Cuenco, jarras, incensarios	Entidad analítica	00-09
			Clase de pieza	00-01
			Tipo de vasija	00, 02, 04, 05
			Vasija tipo 2	00-07, 09-14
	Pasta	Medio a grueso Rojo amarillento a café	Pasta	02, 03
			Granulometria 1	2
			Granulometría 2	1
	Acabado/engobe	Pulido Sin engobe	Acabado:	00, 01, 03, 04
			Ubicación de engobe	0
			Color de engobe	1
			Clase de pintura	no color
	Decoración	Inciso: líneas paralelas, en V, semi-circulares, puntos, ondas Appliqué: circular, cónico	Sustractivo	1
			Engobe / articulación	00-03
			Descripción del color de pintura	2
			Motivos	browns