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Ancient Maya Obsidian Trade: Arvin's Landing and Foster Farm, Belize

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ANCIENT MAYA OBSIDIAN TRADE: ARVIN'S LANDING AND FOSTER FARM, BELIZE

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ABSTRACT

Arvin's Landing and Foster Farm are ancient Maya settlements located on Joe Taylor Creek near Punta Gorda in southern Belize. The abundance of obsidian and the number of sources in the artifact assemblage at Arvin's Landing and Foster Farm indicate the inhabitants of these settlement participated in long-distance trade with other Maya communities. The research was developed to examine the different geographic sources of obsidian as well as the distribution of these sources at both sites. The goal of this research is to determine whether these sites fit with existing trade patterns established by previous research over decades of obsidian studies. Researchers originally believed that obsidian was transported along the coast and by inland routes to the Maya in the lowlands during the Classic Period (AD 300-900). Researchers later argued that the pattern was more temporal; there was a shift from a dominance of El Chayal obsidian in the Classic to a dominance of Ixtepeque obsidian in the Postclassic (AD 900-1500). Tests were performed using a Bruker portable XRF tracer to assay obsidian from Arvin's Landing and Foster Farm in order to determine their geographical source and evaluate the sites' role in trade. The sources present and the distributions of source type at both Arvin's Landing and Foster Farm were then compared to other Classic and Postclassic Maya settlements. Although both Arvin's Landing and Foster Farm were originally thought to date to the Postclassic, upon comparison, the obsidian assemblage at Arvin's Landing appears to more closely match Late/Terminal Classic (AD 600-900) sites in both the types of sources and the distribution across the site. The Arvin's Landing assemblage also has an unusually high percentage of minor Mexican obsidian sources, suggesting a different role in the coastal obsidian trade than is normally performed by small settlements. If Arvin's Landing does date to the Late/Terminal Classic period, as the obsidian distribution suggests, Arvin's Landing possibly had a more significant relationship with major inland centers than was previously known.

CHAPTER 1. INTRODUCTION

The ancient Maya had extensive trade networks that served to both create a thriving economy and forge political relationships among centers and even between centers and small settlements. Archaeologists often focus on reconstructing the trade routes in order to learn about the state of the economy during a certain period or to analyze political alliances of the past. As more artifacts are uncovered during excavations, the web of trade patterns shifts accordingly with the inclusion of new information. The trade routes used to transport obsidian between ancient Maya sites is no exception.

This study examines the distribution of obsidian from distinct geographic sources at the adjacent sites of Arvin's Landing and Foster Farm in southern Belize using a portable x-ray fluorescence device. The device determines the elemental composition of obsidian samples. Each geographic source has a particular elemental composition that allows researchers to trace obsidian back to its source and gain a better understanding of trade among the ancient Maya. Focusing on two sites allows for a comparative study and analysis of the distribution of obsidian sources to determine if there are distinct differences between them, which could potentially indicate if they were non-contemporary. After comparing the two sites, a comparison was made of the distributions at Arvin's Landing and Foster Farm to neighboring coastal sites, such as Wild Cane Cay. The comparison allowed assessment of whether all of the sites shared a similar source distribution of obsidian artifacts, which would suggest that they have been part of the same coastal trade system, or if the sites' distributions differed, which would suggest they may not have been part of the same coastal trade system. Alternatively, the variance could again be due temporal disparity.

Figure 1. Research area and Punta Gorda, southern Belize. Created by K. Johnson.

1.1 The Ancient Maya

The ancient Maya were one of the major Precolumbian civilizations of Central America. Their civilization existed for hundreds of years and extended from the Yucatán peninsula in the north to El Salvador in the south. The ancient Maya are perhaps most well known for the great temples constructed at sites such as Caracol, Copán, Chichen Itzá, and Tikal, as well as the intricately painted murals at sites such as Bonampak and San Bartolo. The ancient Maya recently gained attention for the alleged end of their calendar in AD 2012, which was the end of one calendar cycle and the beginning of another. However, despite portrayals of the ancient Maya as stargazers with a unique and sometimes prophetic culture all their own, the Maya shared similarities with many other ancient civilizations. The Maya utilized varying forms of agriculture, such as terraces and irrigation systems that were specific to the terrain where they lived, as well as the population size of the surrounding areas. The Maya developed city-states that warred against neighboring city-states for power and resources. The Maya also participated in long-distance trade, over the land, through serpentine river systems, and along the coast.

Geography

The differences in terrain across the Maya region when coupled with the differences in climate, led to three distinct cultural sub-regions in the Maya area (McKillop 2004a: 29). The northern Maya lowlands consisted of the Yucatán peninsula, which is a dry region characterized by scrub vegetation (McKillop 2004a: 29, 34-36). The Maya flourished in this area in Postclassic period, between AD 900 and 1200, when major centers such as Chichen Itzá and Mayapán came to prominence. The southern Maya highlands were located to the west of the Southern Belize research area in the volcanic mountain range running through southern Guatemala, Honduras, and El Salvador (McKillop 2004a: 29). The highlands provided the ancient Maya with important resources, such as obsidian and basalt (Rathje 1971). The southern Maya lowlands stretched from the eastern coast of Belize to central Guatemala in the west (McKillop 2004a: 29). Although the southern Maya lowlands share a similar karstic topography to the northern Maya lowlands, they had a drastically different climate and therefore have different vegetation. The southern Maya lowlands had a wetter climate that could be classified as a tropical monsoon climate (McKillop 2004a: 34-35). The Maya flourished in this area during the Classic period, between AD 300 and 900 (see Table 1, pp. 4), expanding the major centers of Tikal, Caracol, and Copán.

Table 1. Maya lowland chronology (McKillop 2004a).

Formative	ca. 1800-1200BC
Preclassic	ca. 1200 BC-AD 300
Early Classic	ca. AD 300-600
Late Classic	ca. AD 600-800
Terminal Classic	ca. AD 800-900
Postclassic	ca. AD 900-1500

Agriculture

There is the belief that the earlier ancient Maya practiced swidden agriculture (Dumond 1961), which is a process of cutting down a swath of the rainforest, burning the vegetation, planting the crops, harvesting the crops, and then allowing the fields to lie fallow for a year or more until the rainforest reclaimed them. After the process was complete, the cycle would start over. Even single families had multiple fields in different stages of the process. As populations grew throughout the Classic period, this method of farming became inadequate at supporting the larger populations (Turner 1974). Depending on the terrain around the city, different forms of agriculture became prominent. For cities located in hilly or mountainous regions, terrace farming was used (Chase 1998). In contrast, for those cities located in or near wetlands, channels where created through the swamps and the swamps themselves were modified into raised fields that were used to cultivate crops (Jacob 1995).

Political system

By the Classic period, the Maya political system was organized into city-states, or major centers with urban settlements and occasionally satellite minor centers (Rice 2009). The elites of the city-states alternately formed alliances and went to war as their populations grew and the availability of resources fluctuated. Each city-state had a ruler or king who, upon his death, was most often succeeded by his eldest son (McKillop 2004a:156). Although rulers were not seen as gods themselves, they often were seen as intermediaries to the gods, thus strengthening their rule through their status of semi-divine beings (McKillop 2004a: 157). Alliances were woven among the city-states through marriages, control of resources, and trade (Lucero 1999). Many of the largest cities had elaborate centers containing various complexes composed of temples, administrative buildings, palaces, plazas, and ball courts. Although Maya elites were believed to have resided in the centers of the cities (McKillop 2004a:156), dense settlement popped up around the cities, leading to larger populations that needed to be fed (Chase and Chase 1998).

CHAPTER 2. REVIEW OF LITERATURE

2.1 Ancient Maya Trade

The domestic economy vs. the political economy

The ancient Maya economy has been studied from various perspectives through the history of archaeological studies in the area. One of these perspectives is through the dualism of the Maya economy. The Maya economy functioned on both a domestic and a state level. The domestic economy is defined as what the household does or produces and how the goods or labor of the household are consumed or distributed by members of the household (Hirth 2009). Some researchers have suggested that domestic economies are what gave rise to political and economic complexity in the Maya lowlands (Ardren et al. 2010, Hirth 2009). Households are often used as an analytical tool for examining demographic data in archaeology. Hirth (2009) describes households as economic units in which the main goal is to increase the prosperity and well-being of all members. Specialty craft production was closely tied to the domestic economy, as it often occurred in a domestic context. Members of households would produce goods necessary for the survival of the collective household and procure any goods that they could not produce through a system of market exchange with other households (Hirth 2009, Chase and Chase 2014). Political and economic complexity was thought to arise out of exploitation of household production and labor by institutions sponsored by the Maya elite.

For example, Traci Ardren and colleagues (2010) state that cloth production at Chichen Itzá was a domestic activity. They found spindle whorls, or the weights used to extend fibers when weaving, in household contexts. However, they argue when they find an excess number of spindle whorls within one household unit, it suggests the production exceeded the needs of the household and thus the household activity in that specific household was likely being coopted by the elite. The elite then used the cloth to establish economic relations with other centers or households, joining the complex economic trade network the Maya lowlands were known for.

The economy at a state level among the Maya was defined as a political economy. Ancient Maya political power was often directly associated with control over economic resources. Lisa Lucero (1999) succinctly defines political economy as a type of political system that requires the input of labor and goods by members of a society in order to function. Maya elites would utilize the resources and labor of the Maya people to create political power for themselves (Rice 2008). The amount and type of goods and labor vary based on the geography and existing political and social structures of the region. These factors make discussing the Maya political economy incredibly nuanced. Although the political structure was markedly similar throughout the Maya lowlands, politics varied slightly based on region, as certain areas had larger centers, such as Caracol and Tikal, while other areas had a larger number of smaller centers, such the Cahal Pech, Lower Dover, Baking Pot and others in the Belize River Valley. The variance in size and number of centers within a region would create differences in the interactions and policy creation by the Maya rulers at the centers.

Due to this regional variation, there are differing models of economic control among the ancient Maya. The tribute model describes cultures with singular centralized governments, such as the Aztec. The state gains control of resource-rich regions outside of the central geographical area, often through the use of a military, and then the state requires tribute payments from those regions (McKillop 2009). Although this model may have been in place in some parts of the Maya area, the tribute model did not apply to the region as a whole. Another model is the household production model. In the household production model, households are independent, producing their own necessary goods (Ardren et al. 2010; Hirth 2009). This model would result in little contact or interaction between these household groups and larger inland centers. This model may work in very specific regional situations, but is again not applicable for the larger Maya area. The model that perhaps fits best is the alliance model. In the alliance model, the elites establish trade or political alliances with elites in neighboring regions and solidify these alliances with regular rituals or feasts. This model seems to fit better with the developing picture of trade and political relationships among the inland Classic Maya, as can be seen at multiple sites throughout the Maya area (McKillop 2009).

The inhabitants at Colha (Brown et al. 2004) in northern Belize were known for their procurement and production of chert artifacts. Some researchers suggest that the Maya elite at Kaminaljuyú controlled the procurement and production of obsidian artifacts from the El Chayal outcrop (Braswell 2003; Brown et al. 2004). The elites at Cancuén, located in Guatemala between the Southern Maya highlands and lowlands, controlled production of jade preforms that were then distributed to elites at surrounding centers. The control of jade production strengthened Cancuén's role as a powerful trading center in that region (Andrieu et al. 2014). Lucero (2002) argues that the collapse of water management by Maya elites at sites with little access to fresh water, such as Tikal, Caracol, and Calakmul, during a drought at the end of the Classic period caused the dramatic decline in the Classic Maya civilization at the end of the period. The political economies of the ancient Maya likely revolved around elite control of access and production of resources ranging from rare goods used mainly by elites to essential goods used by everyone, such as water.

The development of economic complexity

The complexity of the Maya political economies did not arise without precipitating conditions. In 1971, William Rathje published an article hypothesizing that Maya trade developed out of necessity. He stated that particular areas were deficient in necessary resources and as such formed trade alliances with areas that were rich in the resources they were lacking. Rathje called this model of economic development the resource deficiency model. For example, he considered metates a necessity in every household, not only because of their function in processing corn, a staple in the Maya diet, but also because they are archaeologically ubiquitous. He goes on to describe that in areas where the type of stone necessary to make metates was lacking, metates made with the necessary stone were often still present. The metates made of superior non-local material indicated the people in this area developed a trade relationship with people in areas with access to the required resources. Rathje also incorporated the ideas of core zones and buffer zones. Core zones are areas that are important to the region but lacking in resources, while buffer zones are often peripheral zones that held less political importance but were rich in resources, giving them economic importance. Following the political economy model, core zone control of buffer zone resources and their distribution gave the core zone more political power. This consolidation of power through exchange of goods and resources gave rise to political and social complexity in the Maya lowlands.

David Freidel (1979) later built on Rathje's resource deficiency model and developed the interaction sphere model. Freidel assessed the validity of the idea that social complexity arose in the Maya lowlands out of differing responses to local conditions and found that the idea was not applicable at all sites. Instead, he proposed that social complexity arose out of inter-regional trade and communication among elites. Freidel notes that widely-separated communities in the

Late Preclassic shared ritual ideology in the form of masks on temples, and long distance trade of resources, including jadeite.

Figure 2. The Maya area with sites mentioned in text. Created by K. Johnson.

Coastal-inland trade systems

Politics were closely interwoven with trade among the ancient Maya, with trade relationships often serving as indicators of political relationships. Variations in trade patterns were not all caused by political alliances and rifts; they were also sometimes influenced by geography. Trade in the southern Maya lowlands differed from trade in the northern Maya lowlands because of the rivers winding from the interior of the southern lowlands out to the coast. Whereas the Maya in the northern lowlands relied on trade over land or by sea, the Maya of the southern lowlands had a riverine trade network that encompassed settlements in both the interior and the coast (Healy et al. 1984; Hult and Hester 1995; McKillop 2004a, 2005b, 1989; Valdez 1995). Inhabitants of inland sites often traded goods that were inaccessible at coastal sites, such as obsidian, jade, and certain agricultural products, by transporting those resources through the river system. In return, residents of coastal sites transported marine resources such as shells, fish, and perhaps more importantly salt, back through the river system. Evidence from sites along the coast also suggests that both coastal goods and goods from the interior were traded along coastal routes as well.

Researchers at coastal sites have recovered evidence that trade along the coast occurred throughout the time of the ancient Maya. Particular sites appear to have been used primarily as trading ports, or specific points to facilitate trade inland from the coast. Researchers state that there was interaction between the coastal sites and the inland sites, due to the presence of marine materials such as stingray spines, seafood, and salt at inland sites (McKillop 1989). Some coastal sites, such as the sites in the northern portion of Ambergris Cay in Belize, contained ceramics that either originated in inland regions, such as sites in the Puuc hills in the northern Yucatán or the Petén region in Guatemala, or were influenced by the ceramic styles of those inland areas

(Valdez et al. 1995). Lithics from sites on Ambergris Cay also suggest trade with inland sites such as Colha, which provided most of the finished chert tools at the site (Hult and Hester 1995). Farther south, the ancient trading port of Wild Cane Cay also had ceramics of the Tulum Red pottery type, a style that was popular in the Maya lowlands, particularly in the Yucatán (McKillop 2005a). Coastal sites to the north of Ambergris Cay, such as Sarteneja, also contain evidence of an inland-coastal exchange system (Boxt 1989).

More evidence of coastal trade and potentially riverine-based inland trade was found off the coast in southern Belize. Excavations in Paynes Creek National Park have yielded a canoe paddle at the K'ak' Naab' site (McKillop 2005a) and a canoe at the Eleanor Betty site (McKillop et al. 2014). Both artifacts were found at sites associated with the mass production of salt, an important Maya dietary item that was often difficult to procure at inland Maya lowland sites. Researchers suggested that the location of both artifacts when coupled with artistic depictions found on artifacts at inland sites, such as Tikal, could indicate that the Maya participated in canoe trade not only along the coast, but also along the inland river systems (McKillop 2005b; McKillop et al. 2014).

However, coastal-inland exchange systems did not always involve long distances as some inland sites were located relatively close to the coast. The elite at these sites exploited the exchange system as a way of bringing smaller fishing villages and other coastal sites into their spheres of political and economic influence, if not under direct control. McKillop (2009, 2010) has argued that Paynes Creek Salt Works in southern Belize were likely not a part of the political economy of major inland sites located near the coast like Lubaantun. The people producing salt at the sites in Paynes Creek were not likely under political control of inland centers, despite the relative proximity of the sites. Distance between the inland centers and the salt works was significant. The decentralization of the Late Classic centers of southern Belize make inland control unlikely. Instead, McKillop suggests that the inland elite Maya negotiated trade agreements and possibly marriage alliances with the economically and politically independent salt-making communities of the coast.

2.2 Obsidian Sourcing

Background on obsidian studies

Obsidian was a valued commodity among the ancient Maya as a sharp cutting tool. Since there are no naturally occurring sources of obsidian within the Maya lowlands, obsidian also is useful for reconstructing trade. Obsidian is a volcanic glass that is structurally uniform and hard, which makes obsidian an invaluable resource for stone tools. However, as with most glass, obsidian is also fragile. Obsidian is not a good material for tools that have heavy pressure applied to them as the pressure will cause the material to break, rendering obsidian useless for that purpose. Obsidian can be formed into tools with extremely sharp edges (Braswell 2013). The sharpness of obsidian made it a perfect material for tools, such as knives, that were used in ceremonial bloodletting ceremonies (McKillop 2004a). W. James Stemp (2016) has performed experimental use-wear analysis on obsidian blades to compare to the use-wear analysis of obsidian found at ancient Maya sites. There are many artistic depictions of ancient Maya rulers piercing their own flesh with a variety of sharp tools including stingray spines and obsidian as part of ceremonies that were believed to put them in communication with the gods. These ceremonies were often used to mark special occasions, or to appease angry or displeased deities and also served the purpose of legitimizing and reifying the power of the elites performing the ceremony. Although obsidian was extremely valuable in a ritual sense, it differed from most elite and ritual goods, as it was also very widely-trade throughout the Maya area. The amount of obsidian found at major centers and even smaller settlement groups suggests that the volcanic glass was accessible to both the elite class and the common people (Braswell 2013).

Obsidian and other stone artifacts were all but excluded from the early stages of Mesoamerican archaeology. Those studying archaeology from a cultural-historical perspective learned little from lithic artifacts, and obsidian studies in Mesoamerica did not begin to gain traction until the late 1960s and early 1970s as processual archaeology began to proliferate the field (Levine 2014). Processual archaeologists began to use use-wear analysis and chemical sourcing techniques to answer questions about how the civilizations and polities developed or rose to power. As previously mentioned, William Rathje (1971) argued that the complexity of the ancient Maya civilization arose through necessary trade networks that provided the region with goods they were lacking, such as obsidian, basalt for metates, and salt. Meanwhile in Mexico, Michael Spence, René Millon, and other researchers were studying obsidian trade at Teotihuacán. The researchers noticed that obsidian procurement and production expanded greatly as time progressed. The expansion seemed to correspond with Teotihuacán's increasing political power. Spence and Millon suggested that obsidian trade and craft production played a significant role in Teotihuacán's rise to power (Millon 1973; Sanders and Santley 1983; Spence 1967).

In Mesoamerica, archaeologists built on processual archaeological ideals and analyzed political economies and how the elite or ruling class controlled trade and craft production as a means of gaining and maintaining power (Levine 2014). The shift in thought particularly helped processual archaeologists with a concept that had not been thoroughly understood: the role of ideology. Arthur Demarest (1992) expounded on the idea that ideology is often used to normalize or disguise class inequalities. He argued that ideology had been ignored or given a secondary position in analysis of cultural change, when ideology likely played a more prominent role. Archaeology in Mesoamerica then continued to evolve into two directions. Some have archaeologists continued following the well-established materialist train of thought, while others looked at the agency of individuals and smaller groups as a catalyst for cultural change. One such example is provided by Takeshi Inomata in his study of elite specialized craft production at Aguateca in Guatemala, which included obsidian analysis (Inomata 2001; Levine 2014). Obsidian studies have been continually adapting to changing archaeological theory, although obsidian sourcing does tend to be more heavily utilized in processual or materialist studies.

Uses for obsidian source studies

Determining the source of obsidian has important archaeological implications. Provenance studies calculate the distance between the source of an object and the site where the object was found by archaeologists, which tells researchers how far that particular artifact has traveled. However, sourcing artifacts can also aid in the development of hypotheses involving economic, political, and social motivations behind the movement of the objects. Recently, obsidian sourcing has become increasingly utilized as a means to reconstruct trade routes, social complexity, cultural contact, potential migration, and even identity, among many other aspects of life in the past (Freund 2013; Shackley 2008).

Determining the location of an artifact's source, examining the geography between the source and said artifact's terminal location, and closely examining the artifact assemblage at the terminal location can help researchers determine potential trade routes and exchange systems, much as Hammond did in his development of the bimodal obsidian trade model in the Maya region (1972). Raymond Sidrys (1976) developed a hypothesis based on the distance of the source from the site of the artifact without performing elemental or visual analysis of the obsidian to ascertain the source. Instead, Sidrys studied the overall density of obsidian distribution across the site and distance of obsidian from the source nearest to each of the 17 archaeological sites and used the data to support his position on the rise of social complexity in Mesoamerica. Sidrys argued that the high density of obsidian at major centers and the long distance the obsidian was transported suggested obsidian was a utilitarian but elite artifact. He suggested that, as an elite artifact, obsidian could have been used in association with religious or political practices, the presumed prevalence of which would suggest an increase in social complexity. Processual archaeologists in the late 1960s and early 1970s used obsidian source studies to answer similar questions.

Other researchers have taken this line of thought a step further and used exchange systems between sites as instances of cultural contact. However, interpreting the significance of cultural contact is often dependent on whether the artifact in question is procured through direct or indirect trade, which is often difficult to verify in the archaeological record. The presence of an exchange of exotic materials at a site does not indicate cultural contact on its own and should be interpreted within the complete context of the site (Freund 2013).

Some archaeologists have suggested that people who share a similar culture will share a similar material culture. This idea is how researchers are using obsidian sourcing to analyze cultural identity. For example, Steven Shackley (2002) has used x-ray fluorescence obsidian sourcing studies in the North American Southwest to suggest that groups that shared a similar distribution of artifacts are often more closely culturally identified with each other. In Mesoamerica, Braswell (2003) discussed cultural identity among a more complex and nuanced set of exchange systems. His obsidian exchange spheres included sites that contained obsidian from the same sources. He noted that occasionally cultural boundaries, such as language or ethnicity, do coincide with the exchange spheres, although that is not always the case.

Obsidian has also been used to study the migrations of people. However, this mode of study is more often used to examine the movements of hunter-gatherer groups through procurement ranges or large-scale events, such as colonization, through assemblage expectations (Braswell 2003). As the ancient Maya were not hunter-gatherers and there is no concrete evidence of mass migration among the ancient Maya, this line of inquiry is often inapplicable to obsidian sourcing studies pertaining to the ancient Maya. However, as obsidian sourcing studies are becoming more prevalent, researchers are developing new and more complex interpretations that can be derived from the results.

Visual and chemical sourcing

There are two methods of sourcing obsidian: visual and chemical. Visual sourcing of obsidian involves examining and classifying the obsidian based on a set of physical aspects, including color under both refracted and reflected light, transparency, inclusions, texture, and the diffusion of light passing through the obsidian. In order to evaluate these aspects of obsidian and properly attribute a piece of obsidian to the appropriate source, researchers must have a reference collection with which to compare the samples as well as appropriate lighting, which normally involves the use of a light table. There have been studies performed where researchers have a high accuracy rate in correctly attributing samples to their respective sources (Braswell et al. 2000, McKillop 1995). Other researchers have struggled to visually source samples, citing similarities in optical characteristics between different sources as leading to misidentifications of source (Moholy-Nagy 2003). Chemical sourcing uses the relative elemental composition of the obsidian, which is markedly less variable than appearance, to attribute the obsidian to a particular source. Each geographical source of obsidian has a unique chemical signature, which allows researchers to more confidently determine the source.

Issues with chemical sourcing

Despite being more accurate, there are a few issues with chemically sourcing obsidian. An early issue with chemically sourcing obsidian in Mesoamerica was that each individual outcrop of obsidian was considered a source. This assumption understandably caused confusion for researchers when trying to classify different each different physical outcrop as distinct through chemical analysis (Stross 1976). Research later found that each physical outcrop was not a distinct source but that some outcrops are separate "extrusions" of the same obsidian source, as is the case of the obsidian from the San Martin Jilopteque and Río Pixcaya outcrops. While these two outcroppings are discrete locations, the obsidian that comes from both locations is almost chemically identical (Hurtado de Mendoza 1978). As such, researchers now understand that obsidian from two different outcrops in close proximity to each other may be from the same regional source, and thus share the same chemical signature. Another issue with chemical sourcing is that samples of material that are heterogeneous often have to be ground up and analyzed in pellet form. This is obviously destructive to the artifact and is not repeatable. However, obsidian is a homogeneous material and as such, the artifacts do not need to be destroyed for analysis.

2.3 Ancient Maya Obsidian Trade

Hammond's obsidian trade model

After a review of obsidian from 23 lowland Maya sites, including obsidian from undated surface collections, Norman Hammond (1972) developed a trade model that was heavily dependent on two obsidian sources, El Chayal and Ixtepeque. Both are large outcrops of obsidian located in the Guatemalan highlands roughly 350 kilometers away from the Maya lowlands. The El Chayal outcrop is near modern-day Guatemala City. The Ixtepeque source is approximately 85 kilometers southeast of El Chayal. Hammond found that El Chayal was more prevalent at sites in the highlands and lowlands to the west of the source in Guatemala, northeast portion of the Petén region in northern Guatemala, the Belize River valley, and in the Toledo district in southern Belize. Ixtepeque was more prevalent at sites to the east and north of the source and along the Caribbean coast and the Yucatán. Based on the distribution of obsidian types among the 23 sites, Hammond developed a trade model in which obsidian was traded down from the highlands along river valleys. In the bimodal trade model, one route carried obsidian from the Ixtepeque source down the Río Motagua to the coast where the obsidian was then traded north along the coast and the other route was from El Chayal down the Usumacinta River or through the Sarstoon basin to the lowland Maya sites. Hammond then claimed trade routes that followed rivers or the coast resulted in the obsidian on that trade being traded longer distances. The longer distances are due to the comparative ease of transporting trade goods via canoe rather than on foot (Hammond 1972). Canoes can be loaded with more goods and travel faster than individuals walking on land, often through dense forest.

Figure 3. Obsidian sources found in Arvin's Landing and Foster Farm samples. Created by K. Johnson.

The obsidian trade model was adjusted as later studies obtained more obsidian source data from other periods and sites, building on the number of sources examined by Hammond. The inclusion of new sources and distributions of sources at specific sites that did not match the originally-proposed dual trade path resulted in a trade model where no one source had a monopoly on obsidian trade in a particular area and obsidian was instead traded as needed. New studies indicated there was a temporal change in obsidian source use: San Martin Jilotepeque was dominant in the Preclassic period; El Chayal was the major source in the Classic period; and Ixtepeque was the main source in the Postclassic period, although its prominence began in the Terminal Classic period (Dreiss 1989; Healy et al. 1984; McKillop 2005a; Moholy-Nagy 2003).

Figure 4. Norman Hammond's bimodal obsidian trade routes. Created by K. Johnson.

Formative and Preclassic periods

There is evidence of obsidian trade from as early as the Archaic period, or roughly 3000-2000 BC, when Barbara Voorhies recorded finding obsidian in the Sononusco region on the Pacific coast of southern Mexico near Guatemala from remote areas. Although the most abundant obsidian was from the Tajumulco source nearest to the region, there was also obsidian that originated from sources farther away, like San Martin Jilotepeque just east of modern

Guatemala City and distinctive green Pachuca obsidian from central Mexico near Teotihuacán to the north. The presence of foreign obsidian suggests that there was some sort of distribution from the sources, if not a complete exchange network (Nelson and Voorhies 1980).

The presence of obsidian from far away sources at Maya lowland sites continued into the Preclassic period as well. At Colha, in Northern Belize, researchers found obsidian from San Martin Jilotepeque, El Chayal, located near modern day Guatemala City, and Ixtepeque, located approximately 85 kilometers southeast of the El Chayal outcrop. While El Chayal is the most dominant source at Colha, dependence on El Chayal increases as dependence on San Martin Jilotepeque decreases. David Brown et al. (2004) noted that the increasing dependence on El Chayal coincides with the rise of the Classic period site of Kaminaljuyú, located adjacent to the El Chayal source. Researchers also noted that Ixtepeque, which is not commonly present at Preclassic sites, represented a larger than expected portion of the sample. However, Ixtepeque had also been found at other Late Preclassic sites and the significant presence of Ixtepeque obsidian at the site could reflect increased trade relations with sites near the Motagua river valley or along the coast, if trade of Ixtepeque obsidian followed Hammond's model in the Preclassic period.

A wide variety of obsidian sources were also utilized at Aguateca and Seibal in the Petexbatún region of Guatemala. Kazuo Ayoama (2008) stated that the number of sources present at the site increases from the Preclassic period to the Classic period. In his sample of several thousand obsidian artifacts, only 20 pieces of obsidian were found in Preclassic contexts. These 20 pieces were visually sourced to reveal obsidian from San Martin Jilotepeque and El Chayal. The small sample size from the Preclassic period created difficulty when analyzing trends in reliance through time, although the majority of the sample consistently originated from

El Chayal. The trend does not follow with the idea that San Martin Jilotepeque obsidian was the most heavily used during the Preclassic period, which could suggest a more focused trade relationship with sites adjacent to the El Chayal source rather than the San Martin Jilotepeque source, although the two sources are relatively close together.

Classic period

At Tikal in northern Guatemala, 2,235 pieces of obsidian were sourced. Most of the obsidian appeared to come from the Guatemalan highland sources of El Chayal and Ixtepeque (Moholy-Nagy et al. 2013), precisely as Hammond’s model would predict. The northeast Petén and southern Belize are two areas in which the distribution of the Ixtepeque and El Chayal obsidian overlap (Hammond 1972). However, there was also obsidian from another Guatemalan highland source, San Martin Jilotepeque as well as numerous sources in central Mexico, including Pachuca, which made up 29.5% of the 1984 study sample, and Ucareo (Moholy-Nagy et al. 2013). The additional sources suggested another possible inland trade route to the lowlands sites from central Mexico (Moholy-Nagy et al. 2013).

At Uxul and Calakmul in the Campeche region in southern Mexico, El Chayal has the highest percentages of samples at both sites, at 91.4% and 86.3% respectively. Ixtepeque makes up 0.4% of the sample at Uxul and 4.4% of the sample at Calakmul. What is interesting about these sites is that like Tikal, they have obsidian from sources within central Mexico. The second most utilized source at Uxul and Clalkmul is actually Pachuca, which comprises 7.5% of the sample at Uxul and 4.7% of the sample at Calakmul. Three other central Mexican sources of Ucareo, Zaragosa and Otumba are also represented. The Uxul sample was composed of 1,200 pieces of obsidian and the Calakmul sample was composed of 451 pieces. Due to the disparity in the amount of obsidian found at each site Braswell (2013) posits that Uxul had greater access to the obsidian trade than Calakmul during the Classic period. The greater access to the obsidian trade could also explain the higher percentages of Mexican obsidians at Uxul than at Calakmul. The location of these two sites between the Maya lowlands and the Mexican sources of obsidian coupled with the relatively high percentages of Mexican obsidian present at the sites supports the idea presented by Moholy-Nagy and colleagues (2013) of an additional inland obsidian trade route from central Mexico into the Maya lowlands.

Mexican obsidian is also present at Aguateca and Seibal during the Classic period. Twenty-four finished artifacts of obsidian from the Pachuca source, five pieces of finished obsidian artifacts from Zaragosa and four finished obsidian artifacts from the Ucareo source were recovered. Aoyama (2008) noted that the import of Mexican obsidian to the region comes in waves throughout the Classic period, with the first wave being during the Early Classic period and the next wave following during the Terminal Classic. Although Aoyama also stated that these sources were traded solely as finished products, meaning they were not brought to the area as cores, transport and retouching of finished artifacts produce debitage. The sample previously discussed consisted of only finished artifacts, obsidian from these sources probably makes up a significant percentage of the 4,748 obsidian artifacts collected and studied in the region. The majority of obsidian artifacts in the region from Guatemalan sources were from El Chayal. At Aguateca, roughly 96% of the obsidian came from the El Chayal source, while only 2.7% were from Ixtepeque and 1.2% were from San Martin Jilotepeque (Aoyama 2006).

Excavations at Kaminaljuyú located in the Guatemalan highlands also yielded Mexican obsidian sources, perhaps most interestingly a high amount from Pachuca. The Pachuca obsidian found at Kaminaljuyú was mostly in burials located in Mound A and B at the site. The context of green Pachuca obsidian at Kaminaljuyú, Tikal, and other various sites suggests to researchers that while Pachuca obsidian may have been used in everyday contexts, Pachuca obsidian tools were often used in ritual contexts (Moholy-Nagy et al. 1984; Moholy-Nagy et al. 2013; Spence 1996). Michael Spence (1996) suggested that the seeming ritual role of Pachuca was because Pachuca obsidian was most often exported as a gift or specialized commodity from Teotihuacán to the Maya lowlands. He argued that the relatively small amount of Pachuca obsidian found in the Maya area, especially during the Early Classic period when Teotihuacán was at its apogee, suggests that the trade of Pachuca obsidian between the Maya lowlands and Teotihuacán was not a vital part of either economy. Instead, he suggested that the rulers of Teotihuacán gave Pachuca obsidian goods to Maya rulers as gifts or Maya rulers had Pachuca obsidian imported as a sign of status through the ability to import exotic goods and a connection to the powerful empire of Teotihuacán. Although Mexican obsidian is thought to be rare in the Maya lowlands, Mexican obsidian is seen at a significant number of sites, both in the interior and along the coast.

The trend of El Chayal being the dominant source at Classic period sites was again mirrored by the obsidian from Moho Cay, a trading port located in the mouth of the Belize River, where out of a sample of 13 obsidian artifacts, 12 were chemically assigned to the El Chayal source (Healy et al. 1984, McKillop 2004b). However, Brown et al. (2004) also performed analysis of the obsidian from Late Classic period contexts at Colha. They found that Ixtepeque obsidian dominated the sample of 199 pieces, but only slightly at 51%. The majority of the rest of the sample, or 48%, was El Chayal obsidian. The remaining 1% was attributed to the San Martin Jilotepeque source (Dreiss et al. 1993). While slightly ahead of the temporal pattern that had been established, sites in close proximity to the coast often have a higher percentage of Ixtepeque than their inland counterparts during the Classic period. At Wild Cane Cay, a site occupied both during the Classic period and the Postclassic period, McKillop and colleagues (1988) estimated the distribution of obsidian to be almost equal during the Classic period, with approximately 55.6% of the obsidian being from Ixtepeque and 44.4% being from El Chayal. At San Juan on Ambergris Cay, a Late Classic period site, the obsidian sample had 82% El Chayal, 9% Ixtepeque, 5% Pachuca, and 2% Ucareo (McKillop 1995). Norman Hammond (1972) did note the coastal context of some sites seemed to affect the obsidian distributions patterns. Although he may have accounted for the pattern of coastal sites with high percentages of Ixtepeque, there were still inland sites that did not fit into the patterns of his trade model.

One of these notable exceptions that did not fit with the dual route model was the lack of any Ixtepeque obsidian at the major site of Lubaantun which would have been on the trade route from Ixtepeque (Healan 1993; Healy et al. 1984). Recent obsidian source studies performed at sites in southern Belize by James Daniels and Braswell (2014) have found that there was Ixtepeque obsidian at Lubaantun. However, Ixtepeque composed 13% of the sample from Lubaantun, still a lower percentage than would be expected following Hammond's trade model. Researchers also noted the significant presence of obsidian sources other than El Chayal at sites in the western Maya lowlands that should have been dominated by El Chayal obsidian according to Hammond's original model.

Postclassic period

Following temporal trends, the Classic period was dominated by El Chayal obsidian and the Postclassic period was dominated by Ixtepeque obsidian. However, an increasing reliance on Ixtepeque over El Chayal was seen in the terminal portion of the Classic period. Braswell (2003) has attributed the decline in the prominence of El Chayal to two potential explanations. The first is that the largest center in the Maya highlands, Kaminaljuyú, declined at the end of Classic period. Some researchers believe the elites at Kaminaljuyú controlled the procurement and trade of obsidian from El Chayal. Thus, after Kaminaljuyú's decline there was no longer mass procurement of obsidian at El Chayal. The second explanation could be that the decline of the major centers of the Petén region in Guatemala at the end of the Classic period interrupted trade from the highlands through the Petén region to the lowlands (Braswell 2003).

At island sites along the coast of Belize, researchers' findings have followed the pattern of a decrease in the prevalence of El Chayal obsidian following the Classic period. Research at sites along the Yucatán coast of Belize and Mexico indicated that both El Chayal and Ixtepeque obsidian were traded along the Caribbean coast to trading ports such as Wild Cane Cay, Los Renegados on Ambergris Cay, and Isla Cerritos. Studies of sites in coastal Belize, such as Wild Cane Cay, revealed the ancient Maya continued to rely most heavily on Ixtepeque and El Chayal obsidian into the Postclassic (Healy et al. 1984; McKillop 1995; McKillop et al. 1988). At Wild Cane Cay in the Postclassic, Ixtepeque became the dominant source at roughly 90% of the sample (McKillop et al. 1988). The dominance of Ixtepeque obsidian at a coastal site or island trading port in the Postclassic followed what was to be expected if Hammond's model extended into the Postclassic, as well as the general temporal trend noted by later researchers.

The Postclassic site of Los Renegados on northern Ambergris Cay of the coast of central Belize is an exceptional example of the shifting dependence to Ixtepeque during the Postclassic period. Four other sites on the island dating to the Late or Terminal Classic period all show a clear majority of El Chayal obsidian ranging from 50 to 93% of the samples. However, at Los Renegados, the shift is drastic and Ixtepeque obsidian makes up 99% of the sample, which is composed of 278 obsidian artifacts, a significant number for a small site (McKillop 1995).

Laguna de On, a Postclassic site in Northern Belize, mirrors the distribution at Los Renegados. Marilyn Masson and Henry Chaya (2000) used a sample of 18 pieces from various contexts within the site and sourced them using x-ray fluorescence analysis. Seventeen of the 18 artifacts were designated as having come from the Ixtepeque source. Masson and Chaya believe the Ixtepeque obsidian was most likely traded down the Río Motagua to the coast and then traded north and eventually back inland to sites like Laguna de On, Colha and even sites as far inland as the Petén Lakes region. Evidence from other coastal sites like Wild Cane Cay and sites on Ambergris Cay seem to support the presence of a flourishing obsidian trade along these routes, as there is often more obsidian found at these sites than a population could realistically utilize, suggesting the sites were used as trading ports (McKillop 1995,1996, 2005a).

Isla Cerritos, located in the Yucatán, or northern Maya lowlands, has a completely different obsidian distribution than its lowland Postclassic counterparts. Anthony Andrews and colleagues (1989) chemically characterized a sample of 34 obsidian artifacts from the site. Eighteen of the samples were sourced to the Ucareo outcrop in central Mexico, nine to El Chayal, three to Zaragosa, two to Ixtepeque, one to Pico Orizaba, also located in Mexico, and one was unidentifiable. An additional 31 obsidian artifacts were visually assessed and determined to be green obsidian from the Pachuca outcrop in Mexico. Researchers believe the anomalous prevalence of Mexican obsidian at Isla Cerritos is because the site falls under the political and economic influence of Chichen Itzá, which in turn shared close economic and possibly political ties to Mexico (Andrews et al. 1989). These trade relationships can be seen not only in obsidian from Isla Cerritos but also from ceramics that were made in Chichen Itzá and transported to Isla Cerritos, which Andrews et al. (1989) considered to be a trading post between the major polity and the coastal trade routes.

Braswell’s obsidian exchange spheres

Braswell’s model of obsidian exchange spheres picks up where Norman Hammond’s obsidian trade model ends. Braswell (2003) developed a model of obsidian exchange spheres for many sites in Mesoamerica for the Late Classic period through the Late Postclassic period. The obsidian exchange spheres are developed following spatial patterns; where each sphere includes sites which seemed to utilize obsidian from the same source or sources. Braswell divides the chronology of his obsidian spheres into three periods: the Late/Terminal Classic Spheres, the Early Postclassic Spheres, and the Late Postclassic Spheres. The geographical boundaries of spheres fluctuate across each of these time periods as the distributions of obsidian change across sites over time. The fluctuation can be seen by Braswell’s creation of a Southeast Maya Sphere during the Late/Terminal Classic period, which then merges with the neighboring sphere to the west during the early Postclassic period to create the Lowland Maya Sphere. The distinction between the two spheres during the Late/Terminal Classic period seems almost to be a modification of Hammond’s bimodal trade model, as the coast and most of the eastern lowlands is in one sphere and the western lowlands near the Usumacinta river basin are in the adjacent sphere. The merging of the two regions during the subsequent period suggests a homogenization of trade during the period, or that trade patterns seemed to be more uniform across the majority of sites in the area. The sphere divides back into the Southeast Maya Sphere and the western neighbor again during the Late Postclassic period.

CHAPTER 3. MATERIALS AND METHODS

3.1 Site Background

General region

The aim of this research is to investigate obsidian source at two adjacent sites on the coast of southern Belize to evaluate how they fit into ancient Maya obsidian trade. Arvin's Landing and Foster Farm are considered part of the southern Maya lowlands. In general, the Maya lowlands are characterized by the karstic limestone landscape of limestone platforms with sinkholes (often called *cenotes*) as well as underground rivers that often rise to the surface in certain locations only to sink underground again in other locations (McKillop 2004a: 29-32). The climate in the southern Maya lowlands is classified as a tropical monsoon climate in which the dry season, usually February to May, can potentially have a significant amount of rainfall. The sites' proximity to the coast also influences their climate, as coastal regions receive more rainfall than the rest of the Maya lowlands. Some researchers even classify the Maya Caribbean coastline as a true tropical rainforest climate, with almost indistinct seasons in terms of rainfall (McKillop 2004a: 34-35). While located in the southern Maya lowlands, Arvin's Landing and Foster Farm are in a smaller more geographically distinct sub-region that is bounded on the east and south by the sea and river drainages and the north and west by the Maya mountains, which results in a smaller population of ancient Maya settlers when compared to sites to the north. Canoe trade along coastal and inland aquatic routes made the geographic borders penetrable and supported the creation and rise of major centers within the sub-region, including Lubaantun and Nim li punit. Occupation at other coastal sites in Belize has been confirmed by previous research, although Frenchman's Cay and Wild Cane Cay are two of the only other sites besides Arvin's

Landing with mounds (McKillop 2005a; Somers 2004; Steiner 1994) and many sites have been obscured by sea level rise (McKillop 2005a, 2010).

Arvin's Landing

Arvin's Landing is a site located on the southern coast of Belize in the outskirts of the modern town of Punta Gorda, next to Joe Taylor Creek which empties into the Caribbean Sea. McKillop was notified of the site's existence in 1991 (Steiner 1994). The site consists of a single mound located approximately one kilometer away from the mouth of Joe Taylor Creek. A scatter of pottery was visible on the surface in a garden next Joe Taylor Creek. Surface collections began on the site in 1991. Excavations on the mound and shovel tests nearby were carried out in the 1992 and 1993 field seasons (Steiner 1994). In the 1994 field season, transect excavations in the mound were carried out (McKillop 1996). Mound excavations revealed a low flat substructure made of locally-available chert river cobbles. McKillop proposed the mound may have had a public or ceremonial significance based on the presence of obsidian bifacial points on the platform. McKillop argued the obsidian points were not characteristic of a typical household platform, which would often contain blades rather than bifaces. The discovery of buried deposits and lack of other mounds at the site called for future research (McKillop 1996). Excavations in 2003 further examined the expanse of settlement at the site beyond the mound and into the uncleared foliage on the site. Shovel tests were carried out along transects extending into the forest, farther away from the creek and revealed that the site was much larger than originally thought (Somers 2004).

The collections and excavations yielded a variety of lithics, ceramics, and faunal remains. Cultural material was found only in the first humus layer and the subsequent gravel layer underneath. The ceramics found at the site are low-quality and likely locally made. These ceramics lacked any distinct characteristics that allow them to be classified using standards developed for the area or any other areas (Steiner 1994). The lack of any briquetage at Arvin's Landing from nearby sites within the Payne's Creek Salt Works revealed that Arvin's Landing was not involved in the salt-making process but proximity rendered it probable that the two areas engaged in trade. Analysis of the ceramics coupled with other collected artifacts revealed the site was likely occupied by a group of non-elite Maya who subsisted on local resources, both terrestrial and marine, but were also involved in long-distance trade with other Maya sites. Most of the activity at the site appears to have been centered on the mound and directly north towards the creek, based on the increased density of both lithic and ceramic artifacts in these areas (Somers 2004; Steiner 1994).

Obsidian was an unusually common artifact recovered in the transects through the forest; 41% to 53% of shovel tests contained obsidian. Researchers recovered 109 obsidian items, with 23 shovel tests containing more than one obsidian item, and some up to 13. The obsidian recovered included six prismatic blade fragments and 103 pieces of debitage, including flakes, some with cortex, associated with production of obsidian blades and biface production and/or thinning (Somers 2004). However, the relatively low number of cores found at both Arvin's Landing and Foster Farm and the low cutting edge to mass ratio, suggests obsidian blade production did not occur with great frequency at either site (Steiner 1994). Instead the blades were more likely produced at larger sites, such as Wild Cane Cay, where obsidian cores have been found (McKillop et al. 1988).

Foster Farm

Foster Farm was reported to the Belize government's Department of Archaeology by the owner of the property, Mr. Foster, in 1992 (Steiner 1994). McKillop was then notified about the site, and she directed surface collection at the site that same year. One unit of one meter by one meter was excavated, and that unit yielded artifacts that were similar to those recovered from the surface, which included obsidian, chert tools, a jadeite tool with a cutting edge, and pottery (Steiner 1994). The ceramics at Foster Farm were identified as Postclassic pottery through standards developed by Sabloff (1975), which analyzes vessel form, slip, diameter, decoration, paste, and temper to place the pottery into a specific temporal range. Foster Farm had no visible structures on the site but included deposits of artifacts (Steiner 1994).

There are no publications on the site of Foster Farm, as the site was only preliminarily investigated before the property owner disturbed the site (McKillop, personal communication 2017). Little is known about the extent of settlement at the site or the date of occupation other than what has been gleaned from the ceramics recovered during the surface excavations. The obsidian from Foster Farm had not been sourced visually or chemically prior to this research.

3.2 Materials

Obsidian sources

According to Braswell (2003), there were 29 sources in Mexico and 11 in Central America that were utilized by the ancient peoples of Mesoamerican during the Late Classic period through the Late Postclassic period. As previously discussed, the most abundant source of obsidian among the Classic period Maya was El Chayal. El Chayal obsidian is characterized as a cloudy grey obsidian that is only occasionally transparent or darker gray, almost black. El Chayal often has small inclusions that appear in the form of distinct banding or more dust-like inclusions (Braswell 2000). McKillop describes Ixtepeque obsidian as brilliant and clear in luster with a brown tint, as seen on a light table (personal communication, 2017). Ixtepeque obsidian also frequently has banding, while dusty inclusions or small inclusions are rare (Braswell 2000). San Martin Jilotepeque obsidian is identified as a dark gray obsidian with a brown tint that can sometimes be seen as black. San Martin Jilotepeque obsidian contains inclusions of all sizes as well irregular banding frequently. The Pachuca obsidian source is located in the Valley of Mexico and is characterized mainly by the green color. The Ucareo obsidian source is also located in central Mexico and is characterized as having an opaque black color (Moholy-Nagy et al. 1984). Based on her research, Moholy-Nagy (2003) stated that because of Ucareo's color and relative scarcity in the Maya area, at sites where the obsidian has been visually sourced, Ucareo may have been misattributed to El Chayal. However, McKillop and colleagues (1988) in their study on the obsidian from Wild Cane Cay, visually identified Ucareo obsidian as distinct from El Chayal obsidian.

Sample size bias

Studies on published obsidian source data revealed biases in small samples. For example, researchers have found that samples smaller than 10 items per site per time period showed the dominant source but did not show minor sources (McKillop 2005a). By way of contrast, samples larger than 10 items per time period per site had more variety in obsidian source use. Taking the preference for larger sample sizes a step further Moholy-Nagy (2013) and her fellow researchers attributed 2,283 obsidian artifacts from Tikal in the Petén region of Guatemala to their geographic sources. However, the sample is estimated to only be four percent of the obsidian at

Tikal, meaning that while the study is the most comprehensive obsidian source study to date, the results may change as more obsidian is sourced (Moholy-Nagy 2013). The results of both studies were statistically significant.

The importance of sourcing large samples to obtain the diversity of obsidian sources used at a particular site led to visual sourcing by John Clark, Heather McKillop, Geoffrey Braswell, and others (Braswell et al. 2000). Visual sourcing is a more affordable alternative to chemical sourcing, allowing researchers to quickly identify the source of an artifact. Braswell, McKillop, and others carried out a blind test consisting of each of them visually sourcing a sample of obsidian independently. The collection was chemically characterized by the University of Missouri Research reactor and found to be accurate, consistent with the visual characterization (Braswell et al. 2000). The advent of portable handheld XRF machines granted archaeologists the ability to assay the elemental composition of large samples of obsidian.

Samples

Figure 5. Obsidian flakes from Foster Farm. Photo taken by K. Johnson.

Obsidian samples assayed from Arvin's Landing were collected by Ted Steiner as part of his Master's thesis research 1992 and 1993 (Steiner 1994), by Bretton Somers as part of his master's thesis research during the summer field season in 2003 (Somers 2004), and by surface collection in 1991 and trench excavations of the chert-cobble mound in 1994 (McKillop, personal communication 2017). In 2016, under the direction of McKillop, a total of 162 samples of obsidian from Arvin's Landing were assayed, with 18 samples coming from surface collection, 36 from trench excavations, and 108 from shovel tests along the survey transects. The obsidian samples from Foster Farm were attained as part of Steiner's research in 1992. All 181 samples of obsidian from Foster Farm from surface collection and a single one meter by one meter unit were also assayed.

3.3 Methodology

PXRF

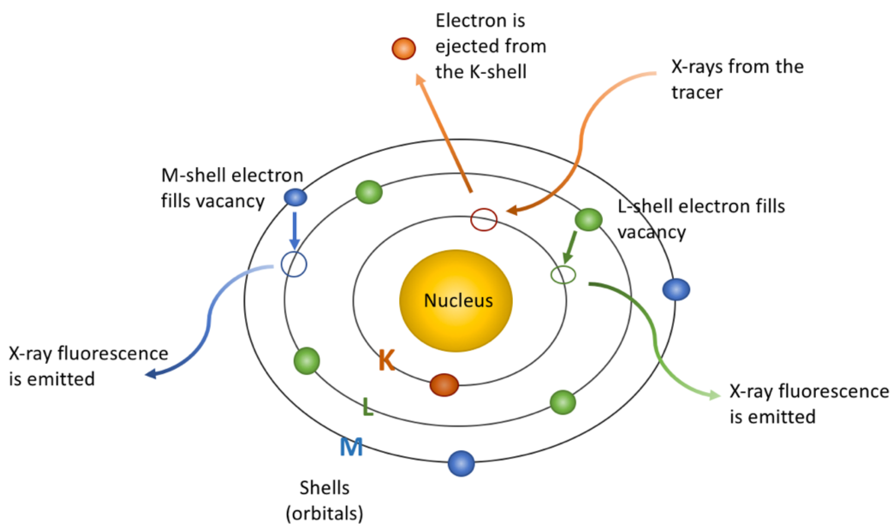

Figure 6. Electron movement and subsequent fluorescence that occurs when using PXRF. Image created by K. Johnson.

XRF analysis begins by bombarding a sample with controlled, high energy x-rays. The energy produced by the x-rays causes electrons to move between orbitals (see figure 6). The movement produces a fluorescence signature. Each element produces a different fluorescent signature, as is seen in the different amounts of fluorescence produced by each element. The PXRF device then records and displays the fluorescence of each element in a comprehensive spectrum. The peaks in each spectrum indicate which elements are present, and the heights of the peaks specify the relative amount of each element. The breakdown of the elemental composition of the artifacts can be used to match the artifact to the geographic source of the material as we know that each obsidian source has its own unique elemental composition. Samples of material used for PXRF analysis often have to be ground up and then assayed because of chemical variability throughout the object. However, obsidian does not require destructive processes, as the chemical composition is normally homogenous throughout the sample (Moholy-Nagy et al. 2013).

Portable XRF vs. laboratory XRF

Portable XRF, or PXRF, has recently gained prominence in archaeological provenance studies. Because PXRF usage is an older technique repackaged in a new and portable manner, many researchers have wondered if PXRF analysis is as reliable and accurate as laboratory XRF analysis. A study using obsidian from the Maya area compared the usefulness of the two methods, focusing on reliability and validity. Reliability was divided into two categories of precision, which is measured by whether the same measurements of the same sample were recorded each time, and accuracy, which was determined through comparison to known sources. Validity was determined through the results clear indication of the geological source of the obsidian and whether these results answered the research questions asked by archaeologists. In each of the designated categories, the researchers found that while there were small differences between the results produced by both instruments, overall, the PXRF analysis was able to meet their standards as well as the laboratory XRF analysis (Nazaroff et al. 2010). The findings of the study were corroborated by a study performed in 2011 that also aimed to assess the accuracy of PXRF in comparison to the conventional XRF machines located in labs. Based on a sample of 76 obsidian artifacts from the Patagonia region in Argentina, the researcher determined that PXRF analyses were as accurate as conventional XRF analyses (Vásquez et al. 2012).

Methods utilized

Research for this thesis was carried out in June of 2016. A Bruker portable X-ray fluorescence SD III tracer was transported to southern Belize to study the obsidian from Arvin's Landing. Roughly half of the Arvin's Landing obsidian sample was assayed in the field in Belize and then the rest of the Arvin's Landing obsidian sample and the complete Foster Farm obsidian sample were assayed in the PXRF lab at the Digital Imaging and Visualization in Archaeology (DIVA) lab at Louisiana State University (LSU). The obsidian assayed at LSU was exported from Belize with a permit given to McKillop by the Belize Institute of Archaeology.

The PXRF was set up using parameters that were previously successful when assaying obsidian from various other sites for the LSU Underwater Maya Project. First, the obsidian was cleaned of debris with water and gentle scrubbing using fingers. The obsidian sample was placed on the x-ray window platform of the tracer with as much of the cleaned obsidian in contact with the window as possible. A lead sample shield, or cap, was then placed over the sample on the platform in order to minimize radiation exposure. The backscatter was then disabled.

"Backscatter" describes the process of x-rays or lasers hitting a target and being reflected back to their origin point. Although backscatter is relatively unproblematic for larger samples, for small samples such as obsidian, backscatter can potentially skew results. The computer trigger was then enabled, allowing the researcher to initiate the bombardment of the sample with the click of a mouse, rather than pulling the tracer's trigger. Pulling the tracer's trigger would introduce the possibility of disturbing the careful placement of the sample over the x-ray window.

Each piece of obsidian was assayed for 180 seconds. The setting allowed for an accurate determination of elemental analysis while also using limited time in the field efficiently. The green filter, composed of three thin layers of aluminum, titanium, and copper, was selected specifically due to the four elements focused on during this study: rubidium, strontium, yttrium, and zirconium. To obtain greater excitation of the atoms of the four selected elements, the appropriate tube voltage settings of 40 keV and 30 microamps were used. These settings, when coupled with the layers in the green filter would achieve the desired results. Greater excitation of specific atoms provided clearer and more obvious spectra to allow for faster attribution to a specific source.

Each geographic source created a unique pattern of peaks across the spectrum for the four selected elements (see Figures 7-11). Ixtepeque is characterized by an increase in height in each peak across the spectrum from left to right, except yttrium, which is the smallest. El Chayal is characterized by peaks that are equal in size, except for yttrium, which, again, is the smallest. Ucareo has roughly equal rubidium and zirconium peaks, which are larger than the roughly equal strontium and yttrium peaks. San Martin Jilotepeque is characterized by a strontium peak, which is significantly larger than the peaks of the three other key elements. Pachuca obsidian has a zirconium peak much larger than the other key elements. Although the spectrum of each individual sample may not align perfectly with the others, the general shape across the spectrum for the four elements is the same for each sample of a geographic source, and is distinct enough to attribute the individual sample to a specific source with accuracy (see Figures 12-16).

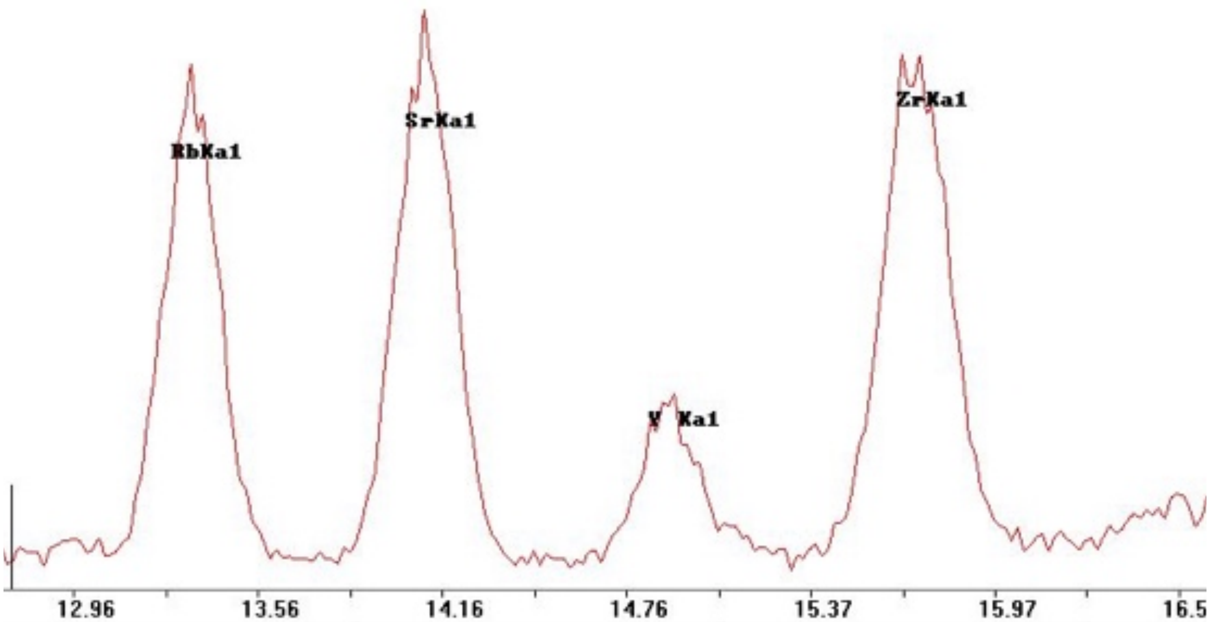

Figure 7. Sample spectrum of El Chayal obsidian. Rb stands for rubidium, Sr stands for strontium, Y stands for yttrium, and Zr stands for zirconium. Image created by K. Johnson.

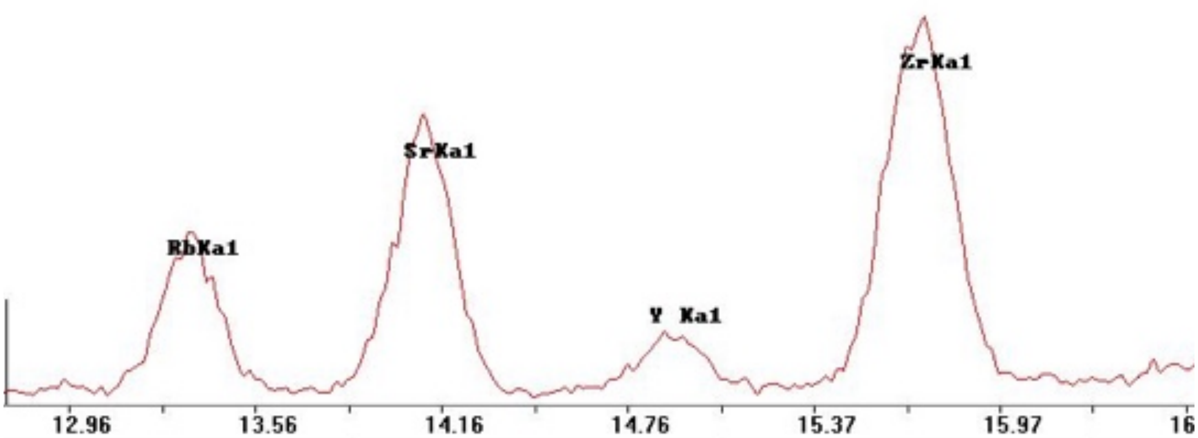

Figure 8. Sample spectrum of Ixtepeque obsidian. Rb stands for rubidium, Sr stands for strontium, Y stands for yttrium, and Zr stands for zirconium. Image created by K. Johnson

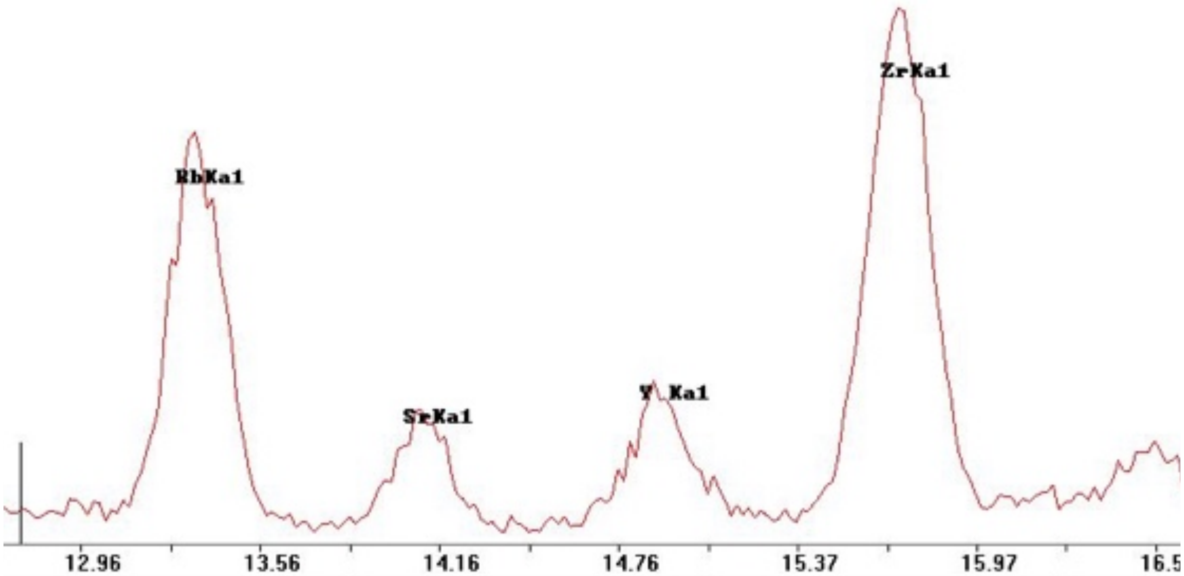

Figure 9. Sample spectrum of Ucareo obsidian. Rb stands for rubidium, Sr stands for strontium, Y stands for yttrium, and Zr stands for zirconium. Image created by K. Johnson.

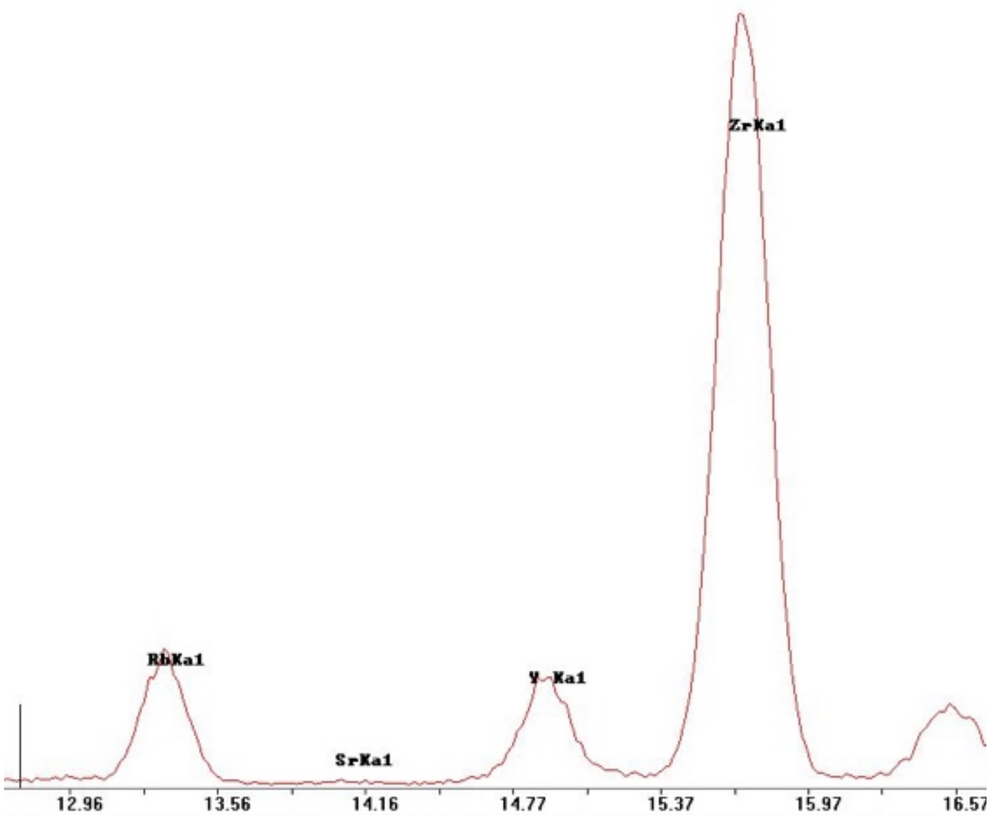

Figure 10. Sample spectrum of Pachuca obsidian. Rb stands for rubidium, Sr stands for strontium, Y stands for yttrium, and Zr stands for zirconium. Image created by K. Johnson.

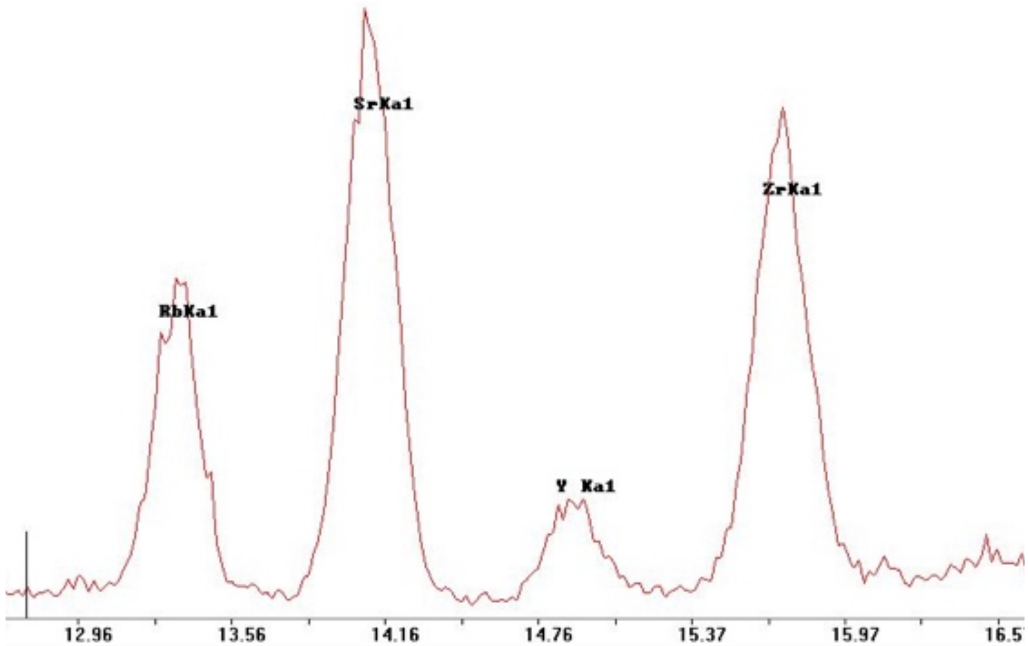

Figure 11. Sample spectrum of San Martin Jilotepeque obsidian. Rb stands for rubidium, Sr stands for strontium, Y stands for yttrium, and Zr stands for zirconium. Image created by K. Johnson.

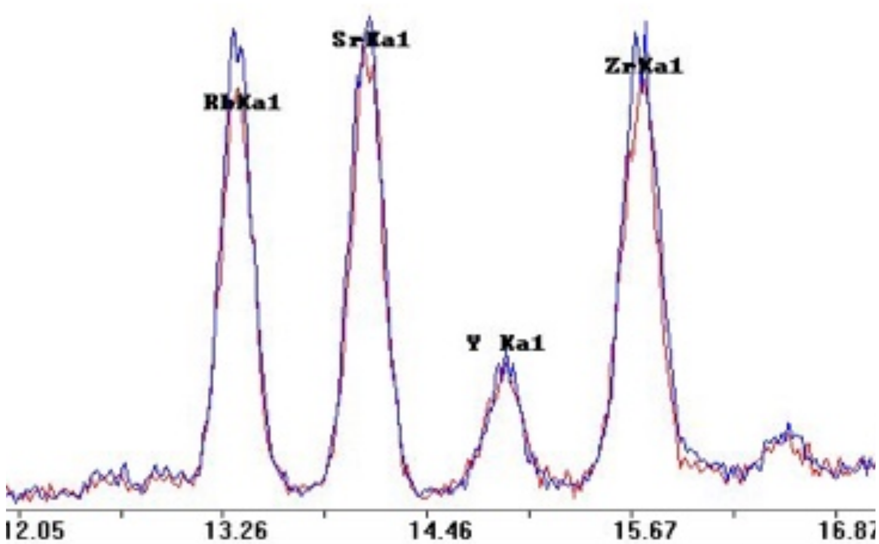

Figure 12. Spectra overlay of El Chayal obsidian. The blue spectrum represents the comparative samples while the red spectrum represents the study sample. Although the spectra do not align exactly the pattern of peaks is the same. Rb stands for rubidium, Sr stands for strontium, Y stands for yttrium, and Zr stands for zirconium. Image created by K. Johnson.

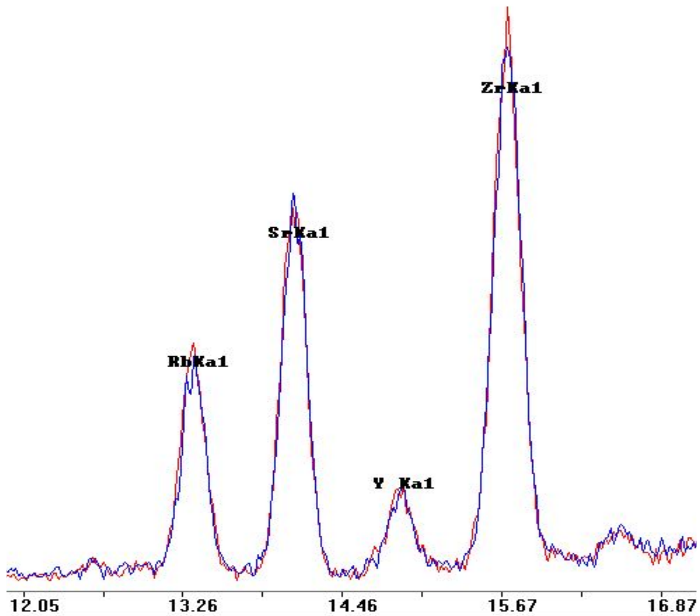

Figure 13. Spectra overlay of Ixtepeque obsidian. The blue spectrum represents the comparative samples while the red spectrum represents the study sample. Although the spectra do not align exactly the pattern of peaks is the same. Rb stands for rubidium, Sr stands for strontium, Y stands for yttrium, and Zr stands for zirconium. Image created by K. Johnson.

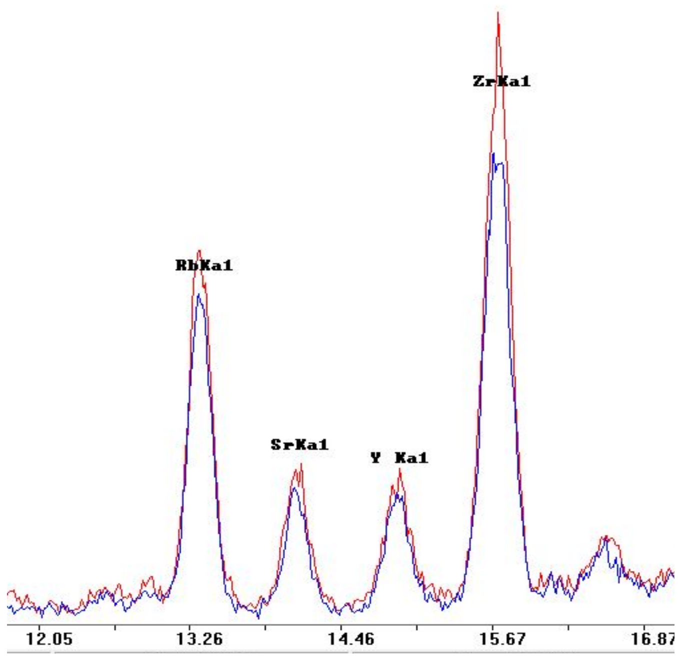

Figure 14. Spectra overlay of Ucareo obsidian. The blue spectrum represents the comparative samples while the red spectrum represents the study sample. Although the spectra do not align exactly the pattern of peaks is the same. Rb stands for rubidium, Sr stands for strontium, Y stands for yttrium, and Zr stands for zirconium. Image created by K. Johnson.

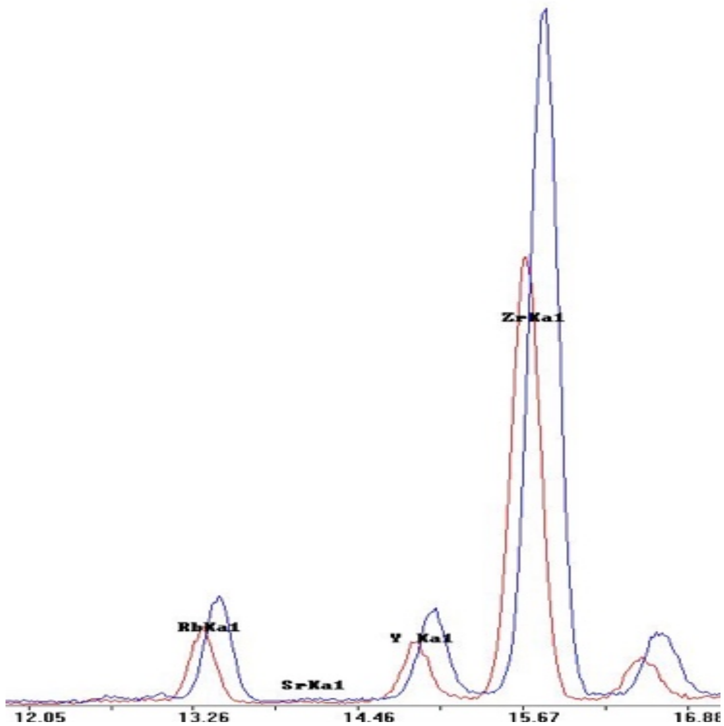

Figure 15. Spectra overlay of Pachuca obsidian. The blue spectrum represents the comparative samples while the red spectrum represents the study sample. Although the spectra do not align exactly the pattern of peaks is the same. Rb stands for rubidium, Sr stands for strontium, Y stands for yttrium, and Zr stands for zirconium. Image created by K. Johnson.

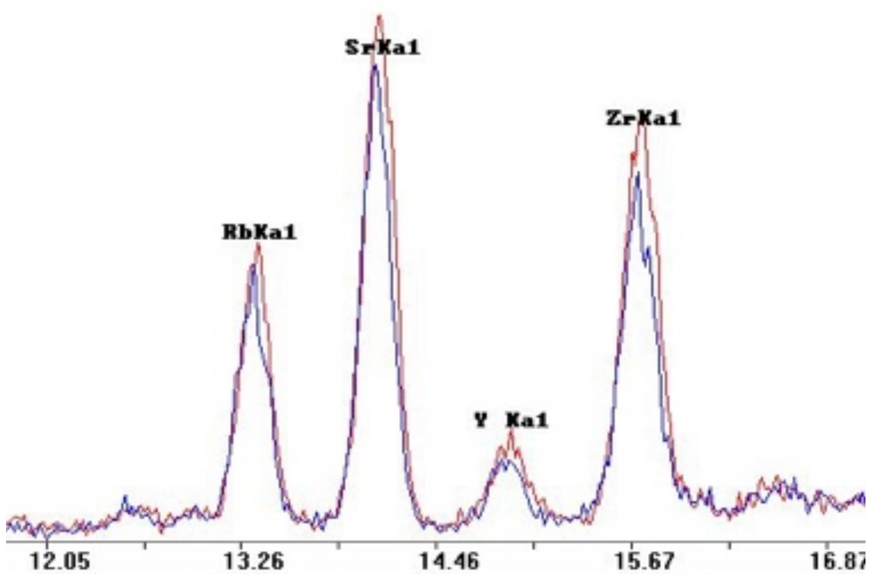

Figure 16. Spectra overlay of San Martin Jilotepeque obsidian. The blue spectrum represents the comparative samples while the red spectrum represents the study sample. Although the spectra do not align exactly the pattern of peaks is the same. Rb stands for rubidium, Sr stands for strontium, Y stands for yttrium, and Zr stands for zirconium. Image created by K. Johnson.

CHAPTER 4. RESULTS AND DISCUSSION

4.1 Results of PXRF Analysis

The results of assaying the large sample of 162 obsidian artifacts from Arvin's Landing revealed obsidian from five sources, including El Chayal, Ixtepeque, and San Martin Jilotepeque, and Ucareo and Pachuca in central Mexico. There are 76 samples of Ixtepeque obsidian, 70 samples of El Chayal, 12 samples of Ucareo, three samples of San Martin Jilotpeque and one sample of Pachuca. Among the 162 artifacts there was a roughly even distribution of 47% Ixtepeque obsidian and 43% El Chayal obsidian.

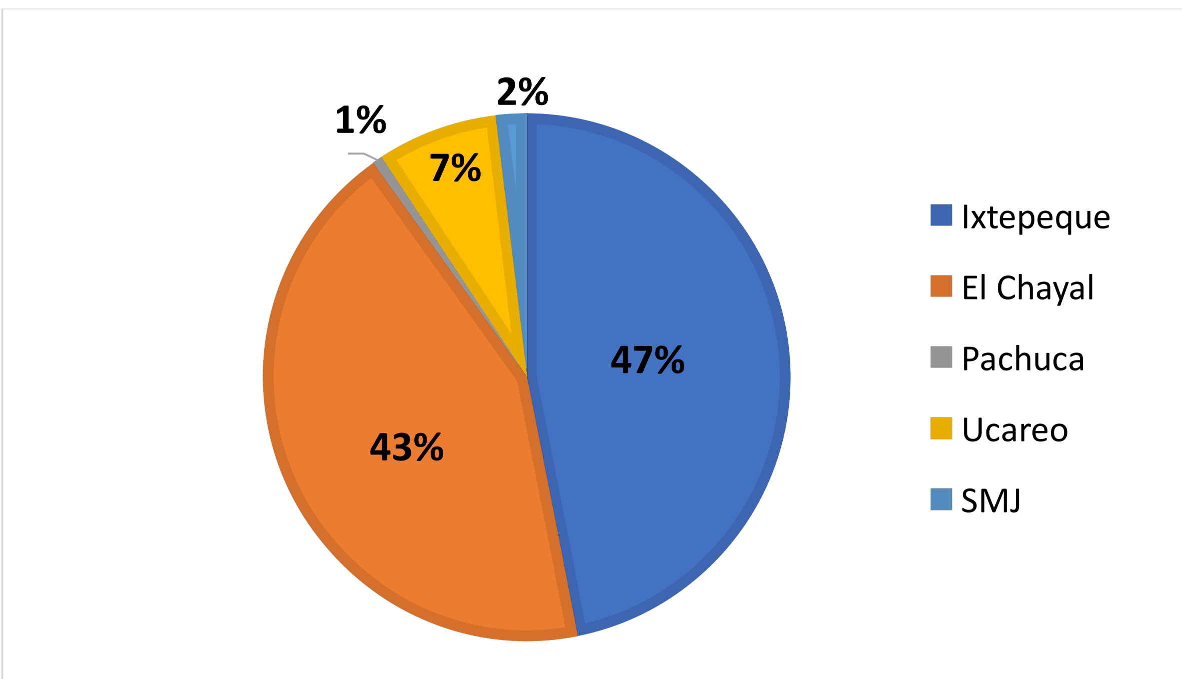

Figure 17. Sources of obsidian at Arvin's Landing. Image created by K. Johnson.

The sample of 181 obsidian artifacts from Foster Farm contained obsidian from only three sources, El Chayal, Ixtepeque, and one unknown source. There are 164 samples of Ixtepeque obsidian, 16 samples of El Chayal obsidian, and one sample of the unknown obsidian.

Ixtepeque obsidian comprises roughly 90% of the sample, El Chayal makes up 9% and the unknown source composes the remaining 1% of the sample.

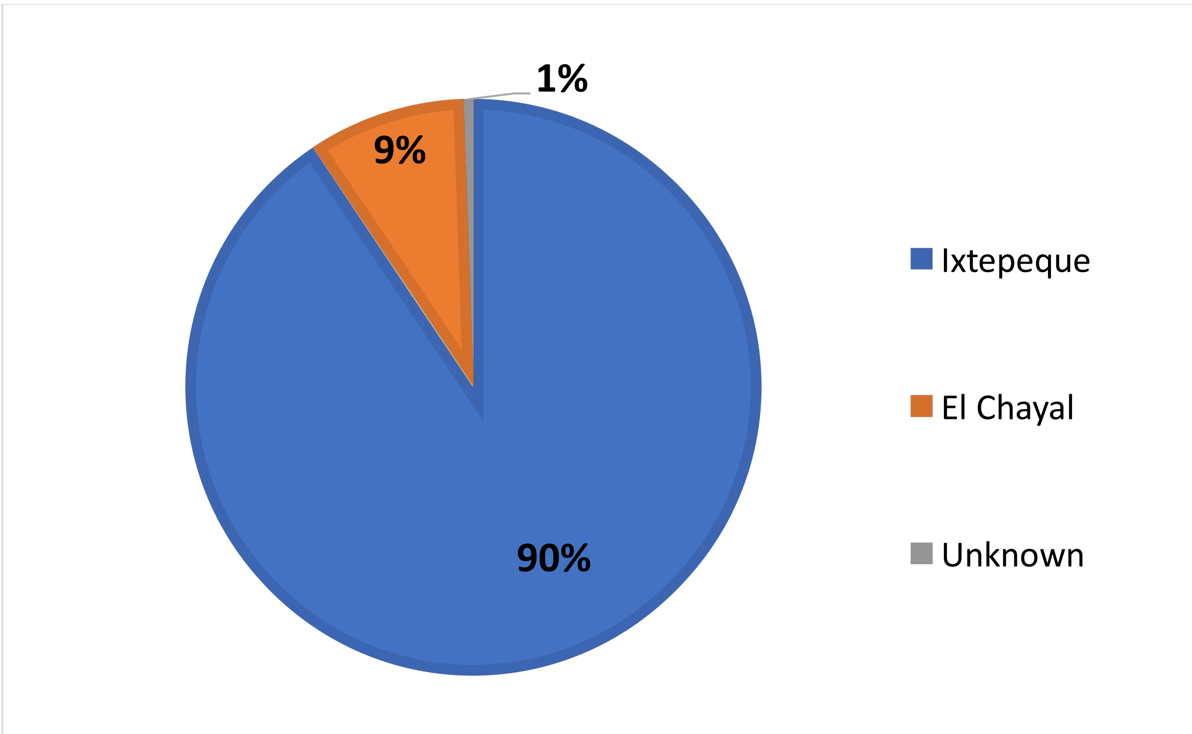

Figure 18. Sources of obsidian at Foster Farm. Image created by K. Johnson.

4.2 Discussion

The roughly even distribution of Ixtepeque and El Chayal obsidians at Arvin's Landing matches the distribution during the Classic period at Wild Cane Cay, whereas the preference for Ixtepeque obsidian over El Chayal obsidian at Foster Farm reflects the distribution of obsidian during the Postclassic period at Wild Cane Cay. The differences in obsidian-source distributions at Arvin's Landing and Foster Farm could represent a temporal shift in settlement location. If the even distribution at Arvin's Landing is interpreted as an illustration of the shift in source reliance from El Chayal in the Classic period to Ixtepeque in the Postclassic period, Arvin's Landing would best fit into Braswell's (2003) spheres of exchange as part of the Late/Terminal Classic

Period Lowland Maya Sphere, rather than the Southeast Early Postclassic Period Sphere, which is characterized by a markedly dominant reliance on Ixtepeque.

The presence of Ucareo obsidian at Arvin's Landing and the absence of Ucareo obsidian at Foster Farm also conforms to the idea that Arvin's Landing and Foster Farm belong to two different periods. Moholy-Nagy (2003) has noted that lowland Maya reliance on Mexican obsidian sources also shifted over time. In the Late/Terminal Classic period the lowland Maya utilized Ucareo and Zaragosa more than other Mexican obsidian sources. In the Postclassic period, the reliance shifts to the green Mexican obsidian of Pachuca. The pattern could suggest that Arvin's Landing was occupied during the Terminal Classic period. Then occupation in that specific area shifted to Foster Farm in Postclassic period.

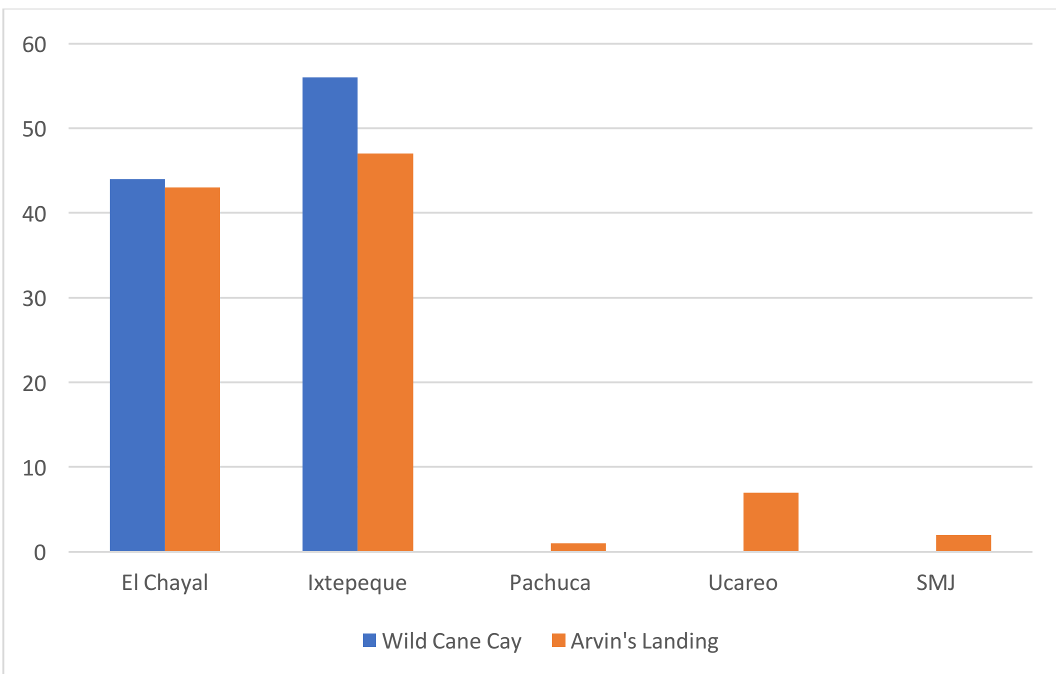

Figure 19. Source distribution at Late Classic Wild Cane Cay and Arvin's Landing. Created by K. Johnson.

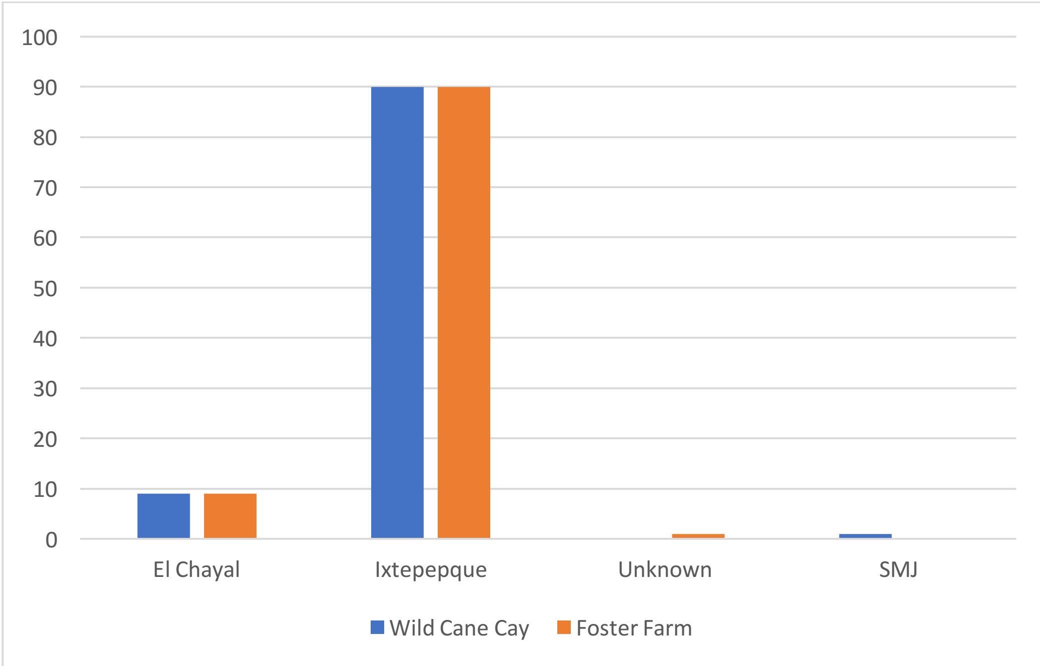

Figure 20. Source distribution at Postclassic Wild Cane Cay and Foster Farm. Created by K. Johnson.

Although the Ucareo follows the emerging pattern of source distribution at Arvin's Landing, central Mexican obsidian, such as Ucareo and Pachuca, is an unusual find. Mexican obsidian is unusual because there is a larger presence, at eight percent of the sample, than has been previously noted at any neighboring site. Ucareo was present at the inland center Lubaantun in the Classic period and key trading ports of Wild Cane Cay and Isla Cerritos in the Postclassic period. Pachuca was found at the Classic period major center Tikal and at Postclassic trading ports. The presence of Ucareo suggests that Arvin's Landing, despite being a smaller site, may have held a unique and potentially unprecedented role in Maya obsidian coastal trade. If Arvin's Landing dates to the Classic period, the site could be connected to major inland centers, which in turn had a trade relationship, and potentially a political relationship, with Teotihuacán in Mexico. If Arvin's Landing dates to the Postclassic period, the site may have had strong trade relations with important trading ports. Depending on the relationship with other sites, Arvin's Landing may have been part of the more centralized trade of the Classic period or the more decentralized trade of the Postclassic period. Also, if Arvin's Landing is from the same time period as the neighboring site of Foster Farm, why are the obsidian assemblages so dramatically different? Why would Arvin's Landing deviate so notably from expected norms for the Postclassic period? Would the deviation suggest two culturally or politically distinct groups living at the adjacent sites? To even begin to explore these questions radiocarbon dating is necessary. An accurate assessment of potential trade relationships with nearby sites, without knowing roughly what time period Arvin's Landing dates to, cannot be made. The assessment would then run the risk of attempting to place the site into a chronologically-variable trade pattern during the incorrect time period. The number of sources present at Arvin's Landing would be more fitting at Wild Cane Cay or a larger inland center like Lubaantun, as a larger representation of sources would make more sense at a major trading location. However, many researchers have noted that the studies performed with chemical analysis often had small sample sizes due to the destructive or expensive nature of chemical analysis (Braswell et al. 2000; McKillop 2005a). Smaller sample sizes can lead to skewed results.

A smaller sample size can mean that major sources will be represented but minor sources may not be included despite being present at the site, leaving El Chayal and Ixtepeque sources to dominate the results. Ucareo obsidian may be present at more sites than recorded, but has been unintentionally excluded from the sample due to the sample's limited size. Moholy-Nagy (2003) has also noted that Ucareo and other sources of grey or black Mexican obsidian can often be incorrectly be attributed to the widely variable and popular Guatemalan grey obsidian El Chayal in visual analysis, although other researchers have not had issues distinguishing between Ucareo and El Chayal obsidian (McKillop et al. 1988, Braswell et al. 2000). Even with accurate visual sourcing, sometimes unknown source attributions may not be made without instrument analysis, showing that instrument analysis may be necessary for more accurate studies. As PXRF tracers become more accessible, studies of larger samples can be performed.

Table 2. Results of obsidian source studies mentioned in this thesis.

	El Chayal	Ixtepeque	San Martin Jilotepeque	Pachuca	Ucareo
Formative Period					
Soconusco region (Nelson and Voorhies 1980)	6	-	4	1	-
Preclassic Period					
Colha (Brown et al. 2004)	42	26	35	-	-
Seibal/Aguateca (Aoyama 2008)	11	-	5	-	-
Classic Period					
Tikal (Moholy-Nagy et al. 2013)	1,806	38	54	16	5
Uxul (Braswell 2013)	1,097	5	-	90	4
Calakmul (Braswell 2013)	389	20	7	21	11
Aguateca/Seibal (Aoyama 2006, 2008)	2,091	59	26	24	4
Colha (Brown et al. 2004; Driess et al. 1993)	96	102	2	-	-
Wild Cane Cay (McKillop et al. 1988)	12	15	-	-	
Moho Cay (Healy et al. 1984)	12	1	-	-	-
San Juan (McKillop 1995)	36	4	-	2	1
Lubaantun (Daniels and Braswell 2014)	165	28	-	-	9
Postclassic Period					
Wild Cane Cay (McKillop et al. 1988)	6	63	1	-	-
Los Renegados (McKillop 1995)	3	276	-	-	-
Laguna de On (Masson and Chaya 2000)	1	17	-	-	-
Isla Cerritos (Andrews et al. 1989)*	9	2	-	31	18

* The Isla Cerritos data includes chemically characterized grey obsidian and visually sourced green obsidian, skewing the data towards disproportionate representation of green obsidian.

CHAPTER 5. CONCLUSIONS

Norman Hammond's 1972 model laid the basis for the development of further obsidian studies. The major inconsistency found with his trade model was the presence of Mexican obsidian at a significant number of sites. Hammond's model focused on El Chayal and Ixtepeque obsidian, not accounting for or putting effort into explaining the presence of Mexican obsidian at numerous Classic period sites, such as Tikal, Uxul, Calakmul, Aguateca, Seibal, and Kaminaljuyú, all of which are discussed in this paper. Another inconsistency is the strong presence of Ixtepeque at sites that are supposed to be dominated by El Chayal and vice versa. Lubaantun's location along the coast, if findings had followed Hammond's model, means the obsidian assemblage should have been dominated by Ixtepeque. Instead, in original studies on the Classic period, they found none (Healy et al. 1984). The break in the coastal pattern can also be seen at Colha in Northern Belize.

As obsidian studies progressed beyond Hammond's original model, researchers noted a temporal shift in dependence from El Chayal in the Classic period to Ixtepeque in the Postclassic period with some regional variation, particularly along the coast. Even with the more general, yet more nuanced model of trade, there are still sites that do not seem to fit within the pattern. For example, Isla Cerritos eschews all standards set by the model, as most of its obsidian came from Mexican outcrops.

Even Braswell's Late Classic through Postclassic period obsidian exchange spheres do not place the trade at every site into its regional patterns. Generally, sites in the Maya lowlands do follow Hammond's original trade model, and those sites do have evidence of a temporal shift in dependence. Sites also have similarities in regional and temporal trade as suggested by Braswell (2003). The conclusion that may be drawn from the review of obsidian models, in conjunction with reviews of obsidian distribution at select sites, is that trade models function more as guidelines, or patterns that may be noted between most sites, but not all. No trade model will ever account for all variations and deviances from the main mode presented, as trade often varies for complex political, social, and economic reasons. Researchers would be hard-pressed to develop a model that captures these intricacies when, despite even long term studies, they do not fully understand these intricacies at a single site, and perhaps never will. While more in-depth studies are creating a more detailed picture of these inter-site relationships, considering a site's role in ancient Maya obsidian trade through the framework of general trade patterns and models can prove useful.

The results of this study generally followed the conclusions drawn from previous research at the site. The obsidian distribution at Arvin's Landing is almost equally split between El Chayal obsidian and Ixtepeque obsidian (Steiner 1994). Since El Chayal is not the dominant source at either site, researchers can surmise that Arvin's Landing and Foster Farm do not date to the Classic period. However, as there are an almost equal number of Ixtepeque samples and El Chayal samples at Arvin's Landing, the shift in obsidian source reliance to Ixtepeque could have only just begun, which would place the site in the Terminal Classic period or Early Postclassic period as had previously been estimated. Since Ixtepeque comprises 91% of the sample at Foster Farm, the shift in reliance to Ixtepeque may have been further along, suggesting that Foster Farm may have been occupied at a later date than Arvin's Landing. The presence of Ucareo obsidian at Arvin's Landing is also congruous with a pattern noted by Moholy-Nagy (2003) that lowland Maya reliance on Mexican obsidian sources mirrored the shift in Guatemalan obsidian between time periods. The amounts of Ixtepeque and Pachuca obsidian in comparison to El Chayal and Ucareo at Arvin's Landing could place the site in the transitional period between the

Late/Terminal Classic period and the Early Postclassic period, although the relative dating seems more biased towards the Terminal Classic period. The presence of Postclassic ceramics at Foster Farm, as well as the high amount of Ixtepeque obsidian place the site firmly in the Postclassic period. Further analysis and research, such as a radiocarbon date for Arvin's Landing, are needed to solidly determine the role of both sites in the liminal period between the Terminal Classic period and the Postclassic period in the coastal Maya obsidian trade.

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VITA

Kelsey Johnson was born and raised in Southern California. She received her bachelor's degree at the University of California, Santa Barbara in 2014. The summer after graduation, she attended the Belize Valley Archaeology and Reconnaissance field school in San Ignacio, Belize. Following her work in Belize, she made the decision to enter graduate school in the Department of Geography and Anthropology at Louisiana State University to study the ancient Maya with Dr. Heather McKillop. She received at two-year assistantship from the Department of Geography and Anthropology. During her time at LSU, she was elected as the 2016 President of the Geography and Anthropology Society. She also was the Director of the Department's Krewe du Monde in the 2017 Southdowns Mardi Gras parade. She was a member of the Digital Imaging and Visualization in Archaeology Lab and served as the Archaeology Lab manager during the 2016-2017 academic school year. She received funding for her research through the Robert C. West Grant and the Research Materials Grant from the Department of Geography and Anthropology. She will receive her master's degree in August 2017 and then plans to work in cultural resource management.