Productive Differentiation and Pottery Consumption Among House Groups in Three Districts of Lower Dover During Late Classic Period: A Geochemical Perspective

by

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The rise of the Late Classic (AD 600-900) Maya polity of Lower Dover, Belize involved a number of changes, including in political organization, economic policies and ritual activities. However, during the process of nearby intermediate elites integrating into the newly formed polity with their subjective commoners, how exactly the pottery used in daily life was exchanged and distributed remains unclear. This research uses a geochemical method to identify production units of pottery for daily use and compare the procurement patterns of this pottery among house groups from three districts at Lower Dover, to study the exchange and distribution mechanisms of utilitarian pottery among ancient Maya people in the Late Classic period.

Investigation revealed that people at Lower Dover had a modest degree of economic interdependence and a moderately integrated local economy in the Late Classic period. All the house groups very likely procured their pottery for daily use at the same marketplace located at the civic center of Lower Dover polity despite their wealth differences, length of occupation history, and distance to the civic center. It is hard to identify a specific source for any production unit, and it is very likely that most potters communicated and shared recipes. Another interesting finding is that Belize Red was produced in a more specialized way than other types and may indicate other exchange mechanisms at a larger scale with connections to nearby polities. This dissertation also discuss methods to evaluate data collected on ceramics by pXRF (portable X-ray fluorescence) and show that a relatively large sample, proper preparation of specimens and taking multiple readings can provide reliable enough data for our research purposes.

Table of Contents

List of Tables

List of Figures

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1.0 Introduction

1.1 Economic control, pottery production and distribution

Traditionally, the Classic period has been viewed as the "golden age" of Maya society, with eye-catching monumental art and architecture, mature writing systems, advanced mathematics and calendrics. Within the Maya area, it has usually been argued that the centralization of power of Maya rulers was not based on centralized economic management, instead, among the different sources of political power (e.g., ideology, economy and the military) that could foster complex societies (Earle 1977), many archaeologists agree that the significance of ritual is more obvious in the development of Maya political power, rituals were both the principal source of power for local elites and the basis of networks of alliance between the rulers (Demarest 2004; Freidel 1992), the widespread political ideology among Classic Maya societies emphasized the central role of divine kings (Schele and Freidel 1990). However, there are also controversial opinions about just how centralized ancient Maya societies were and the degree of elite control over the economy. Some argue that the Maya state was highly centralized and the urban elite had strong control over the economy, in both prestige and subsistence economies (Chase and Chase 1996; Fox et al. 1996; Marcus 1993; Demarest et al. 2020; Kovacevich et al. 2007). Others argue that the Maya states were quite weakly integrated and the urban elite only had loose control and management over the economy and only focused only on the prestige economy. The rulers and elites are argued to primarily have focused on control of the exchange of exotic prestigious status-reinforcing goods, including jade, pyrite, fine polychrome pottery, imported pottery, shell, coral, feathers of tropical birds, finely worked chert, obsidian artifacts and occasionally metal objects, some of which were used by the rulers during public rituals, which were performed in front of subjects to reinforce elites' status (Demarest 2004). Most other economic activities were not of much concern to the elites, and there was also only little integration among polities (Ball and Taschek 1991; Demarest 1996; Freidel 1981;Schele and Freidel 1990; Schele and Mathews 1996;

Lucero 1999; Masson and Freidel 2002). There were other economic activities that were also important to the rulers, such as the construction and maintenance of irrigation systems, or organizing corporate groups and intensive agricultural systems. Actually, in some regions, relatively decentralized and locally controlled agricultural systems were more sustainable and more successful (Dunning et al. 1997; Fedick 1996). Another view of the power of the rulers is that the degree of centralization and control of economy by the urban elite varied geographically and had fluctuations over time (Marcus 1993).

There are further debates over various parts of Maya economy, including degree of craft specialization, nature of exchange and scale of exchange. Some argue that there were skilled craft specialists (Ball 1993; Foias 2007; Rice 2009b), and some suggest a low degree of specialization with crafting more likely a part time activity (Rice 1987; Hirth 2009). Usually, production and distribution patterns have been used to evaluate social complexity: full-time, high intensity craft production is usually associated with more complex societies, whereas, part-time, lower intensity craft production is associated with less complex societies (Costin 1991; Costin 2000; Feinman and Nicholas 2007). However, this is not necessarily true, the production of relatively rare luxury or prestige goods used only by elites is sometimes supported or managed by the elites, and shows higher degrees of centralization. As for the production of utilitarian goods that are used in the daily lives of most of the population, most domestic craft production is a part-time, not intensified, but not necessarily less skilled or associated with lower levels of development (Clark and Parry 1990; Feinman and Nicholas 2007; Torrence 1986). However, relatively little research has focused on the production of utilitarian goods. Pottery production, as an important component of craft production, is a very meaningful lens to provide information about ancient economy, and research on pottery production is no exception in being more focused on prestigious products. Although exquisite polychromes can tell us some interesting things, mostly about exchange among elite groups (Ball 1993), they are only a small part of pottery production in the society, not only does utilitarian pottery form the bulk of most artifact assemblages in prehistoric periods, but the production of these utilitarian goods are also an important part of domestic economy that helps understand a big part of ancient economy.

There has been ongoing disagreement among lowland Maya ceramicists about the degree of specialization and scale of production of lowland Maya pottery during the Classic Period (Rice 1987; Sharer and Traxler 2005; West 2002). Previous studies often agree that polychrome vessels were produced under the control of the elites (by attached specialists), or by elites themselves sometimes because of the complicated glyphic designs, or scenes of courtly life. They are often considered to have higher level of specialization and central redistribution (Inomata 2001; Ball 1993; Bishop 1994; Rice 1987; McAnany et al. 1993). Conversely utilitarian vessels were produced by the commoners, and they circulated among people at different scales through different mechanisms (Ball 1993). Ethnographic and archaeological evidence indicates that utilitarian pottery production in the Classic Maya world, as well as in much of Mesoamerica, occurred at the household level and that not all households were equally responsible for pottery production. There might have been a few households that were more responsible for pottery production and the products they made were distributed at larger scales (Deal 1998; Feinman and Nicholas 2007; Hayden and Cannon 1984; Hirth 2009; Reina and Hill 1978; Rice 2009b). There may have been a degree of specialization at the community level in some cases (Fry 1980; Fry 1979: 495), but in most cases, it was at the household level, tending to use locally available raw materials (Jordan et al. 2020). Rice 2009b has suggested that utilitarian pottery is likely to be made relatively close to where it was used because the transportation costs of pottery are high. These high costs may well be justified by special elite items brought from far away but are not likely to be supported for large quantities of utilitarian pottery. However, there remains a wide array of possibilities for just how local utilitarian pottery was produced and just how its networks of distribution were organized.

Pottery production specialization is a complicated concept and difficult to define in the first place (Rice 1987; Hirth 2009), and the Maya area has its special characteristics making things more difficult. The motivations of craft specialization including ceramic production were low in the area, most house groups located on or very close to rather fertile alluvial soils and could be self-sufficient in subsistence (Walden 2021: 312; 411); Arnold 1988), but the production and exchange mechanism of pottery remains unclear.

It is difficult to find out about production through consumption as well if the degree of specialization is relatively low, since ceramic producing and non-producing households usually had similar composition and density of ceramic assemblages when the ceramic production happens only at a household level (Santley et al. 1989: 108). This is why I want to try using geochemical methods to investigate production and distribution of pottery for daily use in a Maya polity.

1.2 Marketplace exchange

There has been great interest in reconstructing commercial exchange systems in the ancient New World recently (Blanton et al. 2013; Stark and Garraty 2010; Hirth 2020; Hirth and Pillsbury 2013; Cap 2020). There were assumptions that the Maya area would have a low level of commercialization due to the uniform habitat, dense vegetation, low level urbanism and dispersed settlement patterns, but, this is not necessarily true (King 2020). Instead of a ditchtomy, commercial development is actually a continuum of intensity (Masson and Freidel 2012; Smith 2004) and could vary through time and locations and at different scales and through different methods. The importance of barter could be equal to that of market exchange (Hirth and Pillsbury 2013). However, barter has lost in history; even marketplaces are hard to find. They could be only for a short time and not regular (Shaw 2012; King 2015a); usually marketplaces are guessed at through distribution of artifacts and materials and sometimes architectural forms or plaza placements (Hirth 1998). There are several marketplaces identified at the civic-ceremonial centers of some Maya polities, including Tikal (Jones 1996), Caracol (Chase et al. 2015), and Chunchucmil (Dahlin et al. 2007; Dahlin et al. 2010). There also cases in the Belize River Valley like Xunantunich (Cap 2019, 2020; Keller et al. 2010) and Buenavista del Cayo (Cap 2015, 2020). However, how exactly marketplace exchange could affect distribution patterns of artifacts is not rigidly determined (Hutson 2020), and market exchange does not have to happen at large scale marketplaces in the physical sense (Feinman and Nicholas 2007).

Products exchanged on the marketplaces include obsidian and lithic tools, at production stands where final touches were put to them, textiles, and food (Cap 2015, 2019; Heindel et al. 2012; Keller et al. 2010: 203). Pottery was also sold on the market, at least fancy items (Hutson 2020), however, the fact that there was distribution of similar pottery styles in a certain area could already be a result of economic effects during political centralization (Rice 1987; Rice et al. 1981). Pottery spheres could also be associated with market exchange in the area (Hirth 1998), the standardization of a single pottery type could indicate limited production locations or groups of potters and consumption across broader area (Chase et al. 2015). And some special types of pottery could have larger than local scale exchange routes (Chase and Chase 2012).

The role apical elites played in the marketplace might have been as patrons, controlling exchange, regulating and taxing exchange (Cap 2019; Hirth 2010; Masson and Freidel 2012; Yaeger 2010), due to the fact that they often lived close to the plazas at the polity centers where the marketplaces were mostly likely located (Guderjan 2007), it might have been easy for them to manage market exchanges. However, during the exchange process, social stratification was temporarily removed in the marketplace with elites and commoners both buying and selling goods in the same venue (Hirth 2012). Although utilitarian pottery is very likely to be exchanged through face-to-face exchange, instead of through central marketplaces as some have proposed because a decrease in the frequency of certain types of paste as the distance from the production location goes up (Rands and Bishop 1980; Fry 1980; Hammond et al. 1976), still no research based on compositional analysis has been carried out to investigate this question. Fry (1980) mentions that it seems that serving vessels decrease less with distance, and a comparison between serving vessel types and storage vessel types could provide more information about the distribution mechanism of pottery for daily use, probably including multiple scales of exchange.

1.3 Research questions to be discussed in this dissertation

The Maya lowlands saw the introduction of ceramic in the Preclassic period which dates from roughly 1200 BC to AD 250, and the earliest well-documented Maya pottery dates around 1100-900 BC in the Belize Valley (Awe 1993). By the Late Preclassic period (250 BC - 250 AD), Maya pottery was very well made and the styles were quite stable and widely spread across the Maya lowlands. The Classic Maya was a much more developed stratified society with pronounced monumental architecture and art, as well as elaborate polychromes. During the Terminal Classic period, many sites were abandoned and polychromes became less frequent. This research choose Lower Dover, a Maya polity in the Belize River Valley, as the settlement to study.

Ethnographic and archaeological evidence indicates that the ancient Maya lived in both nuclear family households and extended family households, and the households usually clustered into neighborhoods (Ashmore 1981; Bullard 1960; Hutson et al. 2016; Wilk 1988; Willey et al. 1965) and a few dozen neighborhoods could form a district (Walden 2021: 298; Chase 2016; Thompson et al. 2018). Lower Dover is made up of several districts which each contain a few dozen neighborhoods, and each neighborhood contains four to ten house groups (Walden 2021: 298). Its civic center emerged in Late Classic, but the house groups around it had a much longer history, with starting dates varying from Early Preclassic (1200/1100-900 BC) to Late Classic (AD 600-900). Many also lasted to the Terminal Classic period (AD 800-900/1000). The whole area was surveyed, and 27% (96/252) of the house groups were excavated (Walden et al. 2023; Walden et al. 2017; Walden and Biggie 2017; Walden 2021; Ellis et al. 2020; Shaw-Müller et al. 2018; Shaw-Müller et al. 2020; Nachamie and Walden 2020). However, the remains dating to the Late Classic from only a few house groups had large enough numbers of sherds of a few popular types of pottery to meet my sampling requirements, which are about 50-55 of each type from each house group (see also Chapter 3.4.1 Sampling method). My focus in this research is mainly the distribution differentiation of daily-use pottery among house groups and districts in the Late Classic period of Lower Dover. The interactions among households are likely to be stronger within the same neighborhood or district than with households outside the neighborhood and district. The pattern of their choices in procurement of daily-use pottery could reflect this if the pottery vessels redistributed or circulated at neighborhood or district level. Also, the procurement strategies might be different among households of different wealth levels, and locations, which potentially reflecting varying accessibility to marketplaces. A marketplace facilitated market exchange and allowed the redistribution of products and the conversion of products for both the household and the institution.

This research relies on compositional data collected using a portable X-ray fluorescence (pXRF) instrument on sherds of the three most popular types of pottery in the area, and a set of production units are identified. A production unit corresponds to a compositional group, meaning a group of potters using the same recipe in pottery producing. All the discussion in this research relies on the distribution of products from those production units. The final goal of this research is to learn the distribution patterns, in other words, the procurement strategies of daily-use pottery in a set of house groups that include both elite house groups and commoner house groups. Several specific questions are asked to reach this goal: first, the relationship between types of pottery and production units; second, the pottery procurement strategies adopted by different districts in the study area; third, then the pottery procurement strategies adopted by different house groups; and finally, the spatial extent of the production units.

1.3.1 Research question 1

Do any production units seem dedicated entirely or in large proportion to single types? Or, conversely, does each production unit make a variety of types? Looked at another way, do particular types come from one or a very few production units? Or was each type represented in many production units?

There is detailed ceramic typology research from Barton Ramie, which is the northern half of the Lower Dover polity, separated from the rest by the modern Belize River (Gifford 1976). In Gifford and his colleagues' classification system, the pottery is organized hierarchically into wares, groups, types and varieties; among these, type is defined as the basic ceramic unit that has a group of recognizably distinct characteristics and provides a fast way to organize sherds into different time frames and zones (Gifford 1976: 9). Based on the mature typology of pottery in the area, the three most popular types at Lower Dover that could provide the largest numbers of specimens were selected for study: Belize Red, Cayo Unslipped and Dolphin Head Red. By definition, these three types are different from the surface to the paste (Gifford 1976). They look obviously different on the outside; it is interesting to investigate how similar or different they actually are in terms of composition. Also, vessel forms of Belize Red and Dolphin Head Red are mostly serving vessels (bowls and dishes), and the vessel forms of Cayo Unslipped are mostly storage vessels (medium to large jars) (Gifford 1976). It is also interesting to find out if vessel functions have any relations to production units. It is also worth mentioning that Belize Red is a quite special type for its prominent prevalence in the whole Belize Valley (Gifford 1976). Its production and distribution are proposed to be different by some researchers (Sunahara 2003; Chase and Chase 2012). This first research question aims to provide some information on the distribution of this special type.

1.3.2 Research question 2

Based on the production units identified, how similar or different were the networks through which house groups within the same district acquired their pottery? How similar or different were the networks through which districts as a whole acquired their pottery?

After looking into the relation between types and production units, the next step is to find out how products of different production units are distributed into house groups from the perspective of house groups. In other words, among the products each house group decided to procure, how many are from each of the production units? As stated above, the Lower Dover polity is made up of several districts defined by the excavators according to several different methods (Walden 2021: 290), and the local elite groups of the districts do not always have identical trajectories of involvement in production and possession of wealth items (Walden 2021). In this question, I want to look further into whether pottery procurement strategies of house groups are related to districts. I will first compare the house groups within the same district, then move to comparison among different districts to find out if different districts behave differently due to different degrees of control by the elite groups of those districts.

1.3.3 Research question 3

Based on the production units identified, what other reasons may have caused house groups to have similar or different pottery procurement patterns, being elite groups or commoner groups? Having different lengths of occupation history? Locating at different distances from the civic center of the Lower Dover polity?

The comparison then moves on to cross the district boundaries and consider different sets of house groups regardless of the districts they are from. Three perspectives are taken. First, there are comparisons between elite groups and wealthy commoner groups which are often the heads of the neighborhoods they come from to see if wealth makes a difference in terms of daily-use pottery selections. Second, there are comparisons among house groups of different occupation lengths to see if house groups that have different length of history have different exchange networks. And finally, house groups at different locations are compared to see if there is a marketplace at the civic center, will the distance to it would affect pottery procurement strategies of different house groups.

1.3.4 Research question 4

What is the spatial extent of the networks of distribution of pottery from individual production units? Did they usually cover the entire region my research concerns? Or only part of it? To what extent did these networks overlap?

After making comparisons from the perspective of choices house groups and districts make, the perspective is then moved to the production units to discuss their spatial distribution to further learn the distribution mechanism of daily-use pottery in the area and find out if there are any traces of political economic control. In this question, I will look at how many of the products of each production unit are distributed to each house group and district. Although the distribution of the products reflects more of the distribution and consumption process in the life cycle of pottery, and locating the specific source of each production unit is not the goal of this research, it could also provide a chance to look for the production locations if the distribution patterns show clear concentrations of any of the production units.

2.0 Regional Background and Materials

2.1 Brief history of research at Lower Dover

Lower Dover (AD 600-1000) is a Maya polity located in the Belize River Valley of western Belize, in the eastern Maya Lowlands (Guerra and Awe 2017; Figure 2.1). It is not far away from several other similar sized Classic Maya peer polities along the Belize Valley, 7 km east of Baking Pot and 3 km west of Blackman Eddy (Garber et al. 2004a; Helmke et al. 2012; Walden et al. 2019) The Belize River Valley saw the rise and fall of several polities following Marcus's model (Marcus 1993). Large villages formed in the Early to Middle Preclassic period (Awe 1993; Brown et al. 2011; Ebert et al. 2016; Garber et al. 2004b; Sullivan, Awe and Brown 2018); the villages became capitals of small regional polities and political centers emerged in Late Preclassic period (300 BC-AD 300) (Hoggarth 2012; LeCount et al. 2019); and political centers rose and fell in the Early Classic period (AD 300-600) and Late Classic period (AD 600-900)(Yaeger et al. 2011).

During the past 80 years, there have been sporadic archaeological investigations in the Lower Dover hinterlands. Barton Ramie, once seen as a rural "community" by itself (Gerry 1993: 48), or as peripheral to Baking Pot (Weller 2009: 3), or part of Blackman Eddy (Garber et al. 2004b: 67; Yaeger 2003: 52), is now believed to be the northern half of the Lower Dover polity after the Lower Dover center was discovered only 500 m to the south of Barton Ramie (Hoggarth et al. 2010: 178; Wölfel et al. 2009: 33). It was excavated by Gordon Wiley and his colleagues (Willey et al. 1965). The minor center to the southwest of Lower Dover, Floral Park, was also surveyed by Willey and his colleagues (Willey et al. 1965), and the Belize Valley Archaeological Project excavated it later on (Brown et al. 1996; Driver et al. 1997; Driver and Garber 2004; Glassman et al. 1995). It is now believed to be part of Lower Dover (Wölfel et al. 2009). Much research has been carried out to understand the settlement pattern and developmental trajectory of Lower Dover (Driver and Garber 2004; Glassman et al. 1995; Guerra 2011; Petrozza

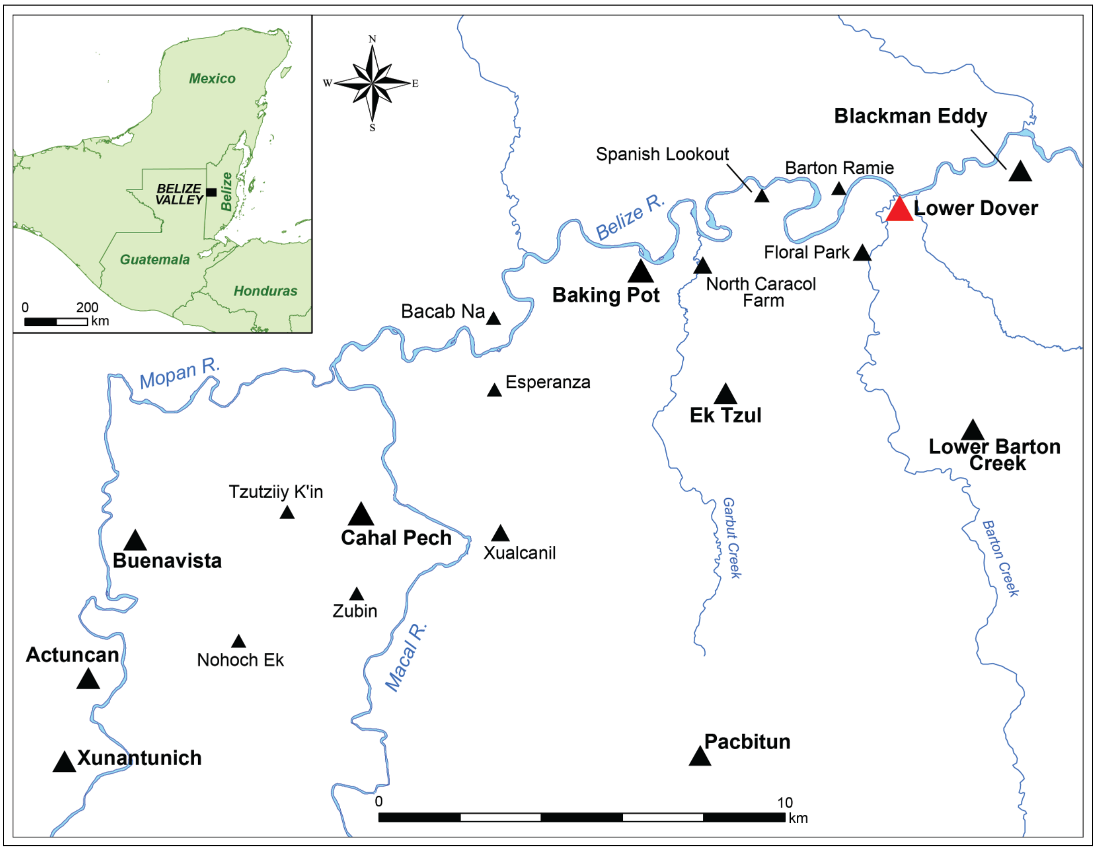

Figure 2.1: Sites in the Belize River Valley (Adapted from Walden 2021 Fig. 1.3).

2015; Willey et al. 1965). The civic center of Lower Dover was surveyed and excavated in the past decade (Guerra 2011; Guerra and Awe 2017; Guerra and Morton 2012; Wölfel et al. 2009). It includes two monumental plazas surrounded by elite groups, and a few dozens structures, including eastern triadic structures, aguada (Guerra and Awe 2017; Guerra and Collins 2016), ballcourt, and *many other structures. Excavations at the civic-ceremonial center indicate that most monumental architecture dates to Late Classic (AD 600-900), and Terminal Classic (AD 800-900/1000), with only very few Early Classic (AD 300-600) remains (Guerra and Awe 2017; Guerra and Collins 2015: 12, 2016: 224). Other than the civic center of Lower Dover and the minor center at Floral Park, the rest of the polity was less studied until recently. John Walden and his colleagues (Walden and Biggie 2017) ran a full coverage settlement survey in 2016 and excavated the elite compound of Tutu Uitz Na and an adjacent commoner group. He and his colleagues have been excavating part of other settlement groups in Tutu Uitz Na and Floral Park in the following years (Walden et al. 2017; Walden and Biggie 2017; Walden et al. 2018). We also organized and analyzed some Floral Park collections collected by previous projects. The settlement pattern of Lower Dover consists of several smaller centers led by local elites around the civic-ceremonial center, and these local elites and their subject commoners had a much longer history that started from Middle Preclassic (900-300 BC) and often lasted to Late Classic (AD 600-900). They were autonomous before the rise of Lower Dover and integrated into a Late Classic polity as Lower Dover rose (Walden 2021). Now they are distinguished as different districts forming the polity described in the next section.

2.2 Districts, neighborhoods and settlement groups

Traditional ways to divide settlements are visually identifying residential clusters on the landscape based on distances among mounds, topography, walls, boundaries, and transportation routes (Bullard 1960: 367; Hutson et al. 2016: 73; Kintz 1983: 181; Kurjack 1974: 80-81; Lemonnier 2012). At Lower Dover, Walden and his colleagues (Walden et al. 2017) employed K-means analysis (Kintigh and Ammerman 1982), the interaction model (Alden 1979) and a demographic surface (Drennan and Peterson 2006) to delineate neighborhoods. An inverse distance contour model (Drennan and Peterson 2006), a Kernel density model, and the Xtent model are also used by Walden (2021: 290-299) and suggest that the settlement organization of Lower Dover does not cluster around the civic-ceremonial center, but around hinterland intermediate elite households, thus forming different districts, which each includes several neighborhoods.

Walden and his colleagues have surveyed and excavated many settlement groups within the Lower Dover polity. Settlement group is a term consistent with those excavation site reports, often abbreviated SG in the text below, and it has the same social meaning as house group, household group, or household. A house group usually contains one to four structures depending on wealth, occupation history and other factors (Walden 2021), usually four to ten low/middle status commoner house groups cluster around one high status commoner house group which is the residence of a neighborhood heads and together they all form one neighborhood. The neighborhood is an intermediate social unit between house group and district made up of larger clusters within the polity. A district has a clear local center and includes a population around 100-300 (Walden 2021: 298; Chase 2016; Thompson et al. 2018). In this research, there are mainly comparisons among house groups and districts.

Based on previous survey, excavation and research, I have picked nine settlement groups from three better-investigated districts (Walden 2021): four from the Tutu Uitz Na district, four from the Floral Park district and one from the Texas district. Specific characteristics of each district and the settlement groups chosen are described below.

2.2.1 Tutu Uitz Na district

The Tutu Uitz Na district (Figure 2.2) is the closest to the polity center. It contains 46 settlement groups, several of which have been partly excavated (Walden et al. 2018: 173; Walden and Biggie 2017; Walden et al. 2019; Garcia, Walden and Martinez 2020; Shaw-Müller et al. 2018; Walden 2021: 274). The minor center functioned as an elite residence and a medium-sized ceremonial center starting from Middle Preclassic (900-300 BC) and abandoned in Terminal Classic (AD 800-900/1000). It was occupied contemporaneously with the Lower Dover political center (Wölfel et al. 2009; Walden and Biggie 2017). The district was situated on relatively good soils and the majority of the commoners' house groups were situated on medium quality soils that require improvement but could still support specific plants (Walden 2021: 312; Fedick 1995: 22; Walden et al. 2023).

I have chosen four settlement groups in this district from which to collect specimens: the intermediate elite group (SG1), three higher status commoner groups (SG3, SG42 and SG52) which are likely to be heads of the neighborhood they come from. Specific

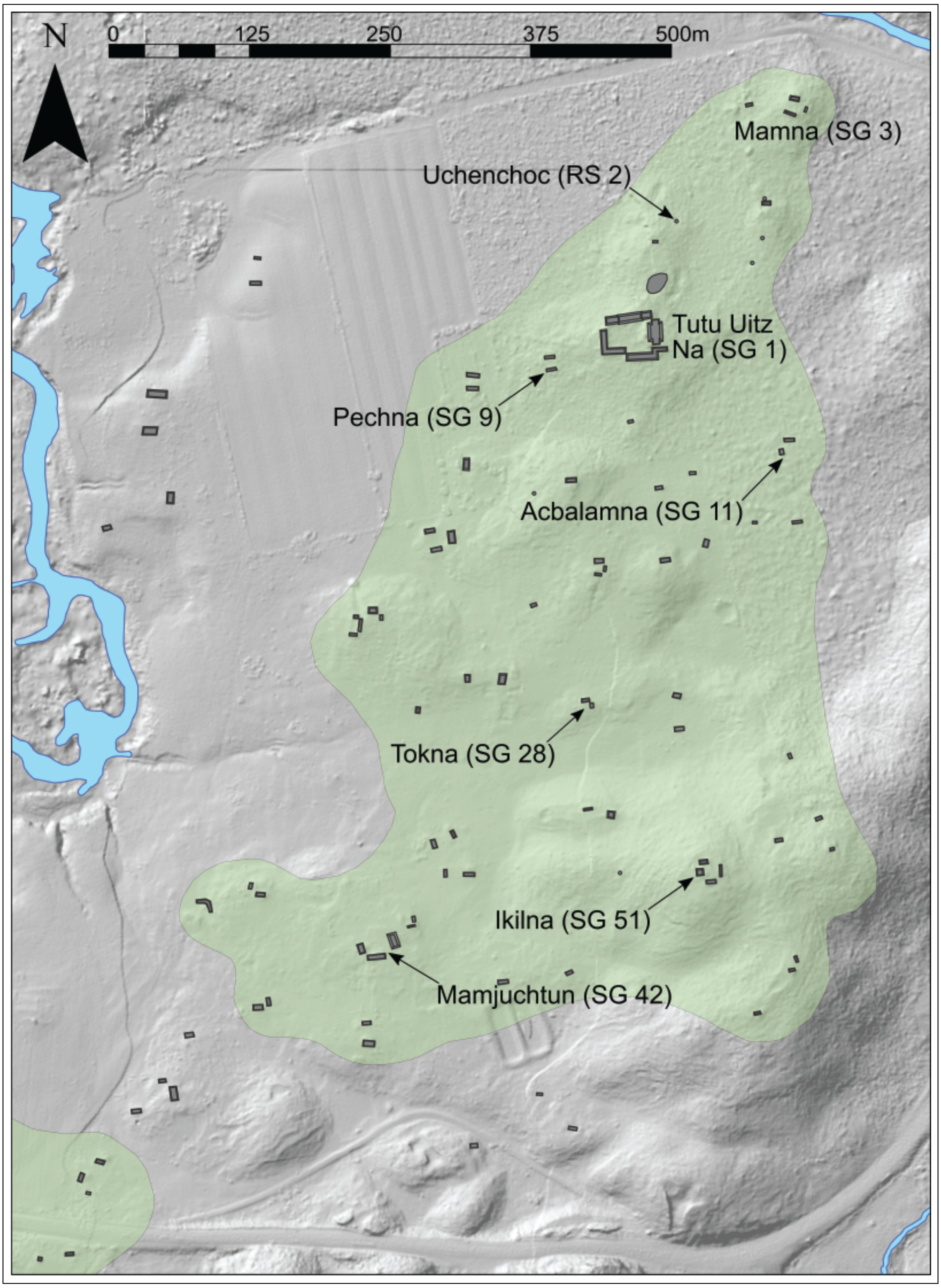

Figure 2.2: Map of Tutu Uitz Na district (Adapted from Walden 2021 Figure 6.15).

numbers of specimens are listed in Table 3.1 in Chapter 3.4.1 Sampling Method. Only relevant details of each house group are introduced below.

Remains in SG1 provide information about the changes of Tutu Uitz Na elites. The name Tutu Uitz Na means "*jute* sacred mountain house" because a large amount of *jute* was deposited at the first excavated structure at the elite residence (SG1), and a low platform was also found there, all dating back to Middle Preclassic (Walden 2021), suggesting that the Tutu Uitz Na elite had power to acquire labor from their subjects from the beginning (Walden 2021). Other artifact assemblages also indicate that the elites held ceremonial rituals and hosted feasting at the large plaza. They were involved in the production of wealth items at this time (Walden 2021: 371). More shrines and other structures were constructed later, and in Early Classic burials were added to shrines while few changes were made to the other structures in the center (Walden 2021: 371). In the Late Classic, more dramatic changes happened. The size of the N1 structure in SG1 doubled, and many architectural elaborations were added to it at this time, indicating much greater labor control (Walden 2021: 371). Also, during this time, the proportions of feasting and ritual-related artifacts increased at the center, indicating increasing feasting as well as ceremonial events that integrated district-level populations (Walden 2021: 588). The intermediate elite located at the district center also seem to have been involved in production of wealth items less than before in the Late Classic period. They were heavily engaged in the production of marine shell jewelry in Middle Preclassic, but this decreased dramatically in Late Preclassic, and they became less involved in the production of wealth items in general. This increased again slightly in Early Classic and stayed at a similar level in Late Classic. The degree of involvement in productive activities of each house group also varies (Walden 2021: 547). Furthermore, the proportions of wealth items with the Tutu Uitz Na elite decreased in Late Classic, and became more similar to those of the commoners. However, elites are still set clearly apart from commoners since items like jade and greenstone are only found in elite assemblages (Walden 2021: 528). There are also variations among commoners in the proportion of wealth items in this period (Walden 2021: 527).

Settlement Group 3 was named Mamna, meaning "house of the elder" because an elderly individual was found buried within the northern patio. It is a high status commoner patio group (Walden and Biggie 2017, Walden et al. 2018: 169) with a long occupation history, possibly from Middle PreClassic (300-900 BC), or least Late Preclassic (250 BC-AD 250) to Terminal Classic (AD 800-900/1000). It also has signs of strong association with the Tutu Uitz Na center (Walden and Biggie 2017: 177), and is located near SG1 and the polity center as well. This group has a long construction history that went through at least eight building phases, and Structure N1 was extensively remodeled during the Late Classic. It also has large quantities of *jute* deposited just below the Preclassic patio floor, probably emulating the local elite parctices (Walden and Biggie 2017). Findings from Structure N1 are mostly domestic assemblages, such as agricultural tools and storage and serving vessels. Incensario fragments, figurines, musical instruments and speleothems are also found in the burials or possible offering pits, indicating domestic ritual activities (Walden and Biggie 2017: 192).

Settlment Group 42 was named Mamjuchtun, meaning "old shell rock" because a chert cobble with fossilized *jute* snails within it was found in the terminal structure fill (Shaw-Müller et al. 2018). It was a high status commoner group first settled in the Late Preclassic or Terminal Preclassic and likely abandoned and then resettled in the Terminal Preclassic-Early Classic phase before its final abandonment in the Terminal Classic (Walden et al. 2018: 169; Shaw-Müller et al. 2018: 243). It was located approximately 1 km south of the Lower Dover center. It has a large elevated patio surrounded by mounds on the east, west and south. "There was another very small house-group (SG 43) several meters northeast that was likely an extension of the household "(Shaw-Müller et al. 2018: 228). SG 42 was expected to have a longer occupation time, given its large size, but excavation revealed very little evidence of Late or Middle Preclassic. Thus its founding was likely during Terminal Preclassic or even Early Classic. Also, it seems that all major construction phases of S1 happened before the Late Classic period. It was argued that SG 42 rose quickly through Early Classic, had a brief hiatus after Terminal Preclassic and relocated again in the Late Classic (Shaw-Müller et al. 2018: 243). It has yielded some unique special finds such as a bark beater, conch spiral and fossils from the Late Classic materials, possibly indicating wealthy habitants or offerings deposited after abandonment (Shaw-Müller et al. 2018: 243).

Settlement Group 51 was named Ikilna, meaning “windy house” in Yucatec Mayan because it is located on the most prominent hilltop in the Tutu Uitz Na district, 450 m south of Tutu Uitz Na center. It was also believed to be a high status commoner group and the heavy wind truly brings coolness in this tropical area during excavation, although not necessarily a quality people look for when making a home (Walden and Biggie 2017). It was suspected to have a longer occupation, but excavations show that it was constructed only in the Late Classic period. The general construction materials seem lacking skilled labor, but a small amount of traded goods (two *Olivella* shell beads imported from the coast) were found here. Excavators think this group is located in a marginal zone and reflects population expansion across the Belize Valley during the Late Classic period. Also, it may be separated from Lower Dover because of the nearly 1km of hilly terrain (Walden and Biggie 2017).

2.2.2 Floral Park district

The Floral Park district (Figure 2.3) is located southwest of the Lower Dover center. The Floral Park center is also the residence of the elite household of this district. The elite settlement group was first occupied in the Middle Preclassic, like Tutu Uitz Na, and was also abandoned in the Terminal Classic (Driver and Garber 2004: 294; Garber et al. 2004b: 28; Walden and Biggie 2017). In Floral Park, 26 settlement groups have been identified (Willey et al. 1965, Glassman et al. 1995: 58; Driver and Garber 2004: 292-4; Kirke 1980: 282-285); Brown et al. 1996). One commoner house group was excavated by M.Kathryn Brown and colleagues (Brown et al. 1996), and pottery has been analyzed from that group (Walden et al. 2020). Five more commoner house groups were excavated (Levin et al. 2020; Garcia et al. 2020; Ellis et al. 2020; Nachamie and Walden 2020; Shaw-Müller et al. 2020).

I chose four settlement groups in this district to collect specimens: the intermediate elite group, Floral Park (Group 2-Structures 2A&2D), two higher status commoner groups (SG34, SG129) that are likely to be heads of the neighborhoods they come from

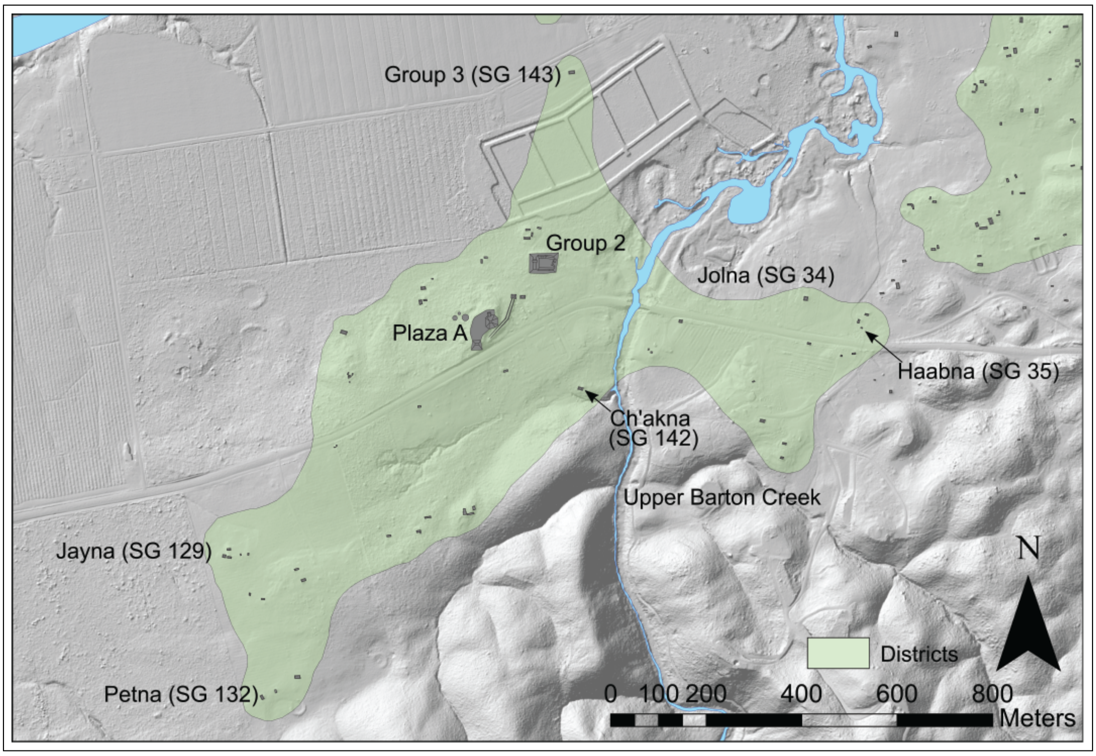

Figure 2.3: Map of Floral Park district (Adapted from Walden 2021 Figure 6.93).

(Walden 2021), and another house group that is very close to the site core (SG143). Despite being a relatively small house group, SG143 has clear ritual activities and the location probably means it is also a higher status house group (Walden 2021). Specific numbers are listed in in Table 3.1 in Chapter 3.4.1 Sampling Method, and only relevant details of each house group are introduced below.

Structures 2A and 2D both belong to Group 2 which is a sizable elite residential compound located 150m to the north of a public ceremonial plaza found at the site core of Floral Park. Structure 2A was a small eastern mortuary shrine that contains nine burials, and structure 2D was more likely to have a residential function based on the assemblages (Brown et al. 1996). None of the specimens were collected from any of the burials. The collections of this house group only date to Late to Terminal Classic period (Glassman et al. 1995: 64). Compared to local centers like Tutu Uitz Na and Texas, burials at Floral Park have less luxurious assemblages and seem to have less access to wealth items (Walden 2021: 434). Some researchers believe that this minor center is peripheral to inter-polity economic networks (Sunahara 2003). However, despite low proportions of wealth items compared to other minor centers, the Floral Park elite still had the ability to command commoner labor for monumental construction (Walden 2021: 434). Probably the elite of Floral Park had different strategies for controlling their subjects than Tutu Uitz Na.

Settlement Group 34, named Jolna, was a high-status commoner settlement group with only a single mound. It is located close to the Floral Park minor center. An excavation unit whose horizontal dimensions were 5.5m by 2m was put perpendicularly on the south side of the only visible structure of SG34. Findings reveal that SG 34 was occupied from the Middle Preclassic to the Late Classic. Also, there is a higher proportion of slate here than in other households in the Lower Dover polity. The proportion of marine shell debris in Early to Late Classic construction phases was also relatively high compared to other households. Another thing worth mentioning is the presence of large flakes of obsidian, all indicating that SG34 was a middle to high status commoner house group and its residents likely engaged in different kinds of low-level craft production activities (Levin et al. 2020).

Settlement Group 129, named Jayna, was a high-status commoner residence located approximately 600m from the minor center of Floral Park. The group contains five mounds on the top of a low hill (Ellis et al. 2020). It is possibly the head of a small corporate group including lower status commoner households around it Walden and Biggie 2017). An excavation unit whose horizontal dimensions were 4m by 2m was placed along the centerline of the largest structure in this group and findings show that this house group was occupied from Late-Terminal Preclassic to Late Classic period. This house group had access to wealth items at first, including a large amount of polychrome pottery mostly concentrated in the Terminal Preclassic to Early Classic occupation. Then the number of polychromes dropped greatly in the terminal phase, possibly showing drop-off in overall household wealth. The presence of these fine serving vessels in the earlier period may indicate that the household had higher status in earlier phases and may have hosted feastings, but this was not supported by faunal remains which occurred in only limited amount (Walden 2021: 451).

Settlement Group 143 was named structure 3A by the first excavators (Brown et al. 1996) and was renamed SG143 to fit in the Belize Valley Archaeological Reconnaissance (BVAR) naming system. It was one of the abundant house mounds in the area extending north from the site core towards the Belize River and was selected to be tested and excavated because it appeared to be part of a small informal group surrounding a possible courtyard area (Brown et al. 1996). An excavation unit whose horizontal dimensions were 6m by 2m trench was placed roughly on the medial axis of the structure and two units were placed on the courtyard. Findings suggested that it dated to the Late Classic Period, and had some ritual activity despite being a relatively small commoner household (Brown et al. 1996). It also revealed a Postclassic period jar rim in the humic level, indicating Postclassic revisitation, consistent with the fact that many house groups close to it had evidence of reoccupation in the Postclassic period, probably because they were located on productive soils (Walden 2021: 461).

2.2.3 Texas district

Barton Ramie is the north part of the Lower Dover polity, and it contains several districts. I sampled the most prominent one, the Texas cluster (Figure 2.4), which contains 54 settlement groups. Among them only the elite residences were excavated decades ago (Willey et al. 1965), and several groups were surveyed recently (Walden and Biggie 2017). Most house groups in this district are located on alluvial soils that allowed the growth of cacao and cotton (Willey et al. 1965; Wright et al. 1959). I only had access to remains collected through survey and only had 52 Belize Red specimens from BR168/180, two mounds that are the elite residence of the Texas district. This house group is only included in limited comparison in Chapter 5 due to lack of specimens.

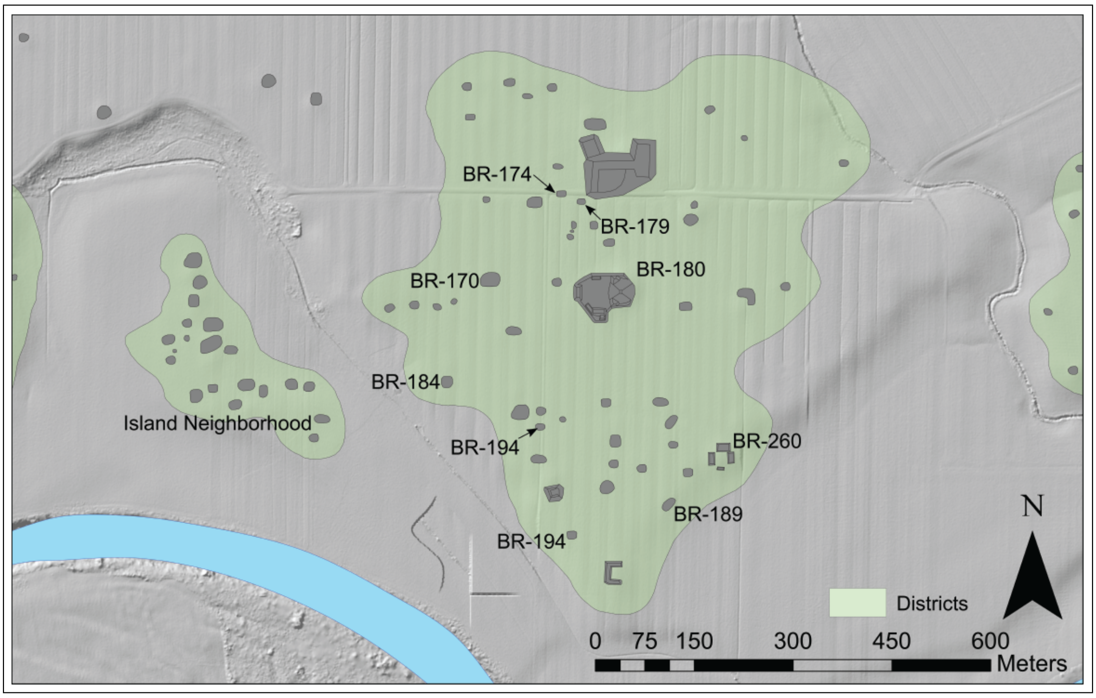

Figure 2.4: Map of Texas district (Adapted from Walden 2021 Figure 6.121)

3.0 Methodology, Pilot Study Results and Sample Collections

3.1 Introduction to pXRF techniques

Geochemical methods have been used on archaeological materials for a long time to study the origin and movements of people and animals (Arnold et al. 2007; Ericson Jonathon E. 1985; Price et al. 2014; Cecil et al. 2007; Culbert and Schwalbe 1987; Hammond et al. 1976; Little et al. 2004; Rands et al. 1978), as well as exchange networks, alliances, political economy, diet and other topics (Braswell et al. 2011; Hunt and Speakman 2015; Scherer and Wright 2015; Speakman et al. 2011). However, because pottery is compositionally heterogenous because it is a synthetic product with natural inclusions and sometimes temper added on purpose (Rice 2016; Emmitt et al. 2018), it is harder to use the same techniques that work well with more homogeneity raw materials like obsidian and metals. It is hard to identify the exact origin locations of clays (Sinopoli 1991: 10). Even within the same clay source, there is often variation in composition depending on the exact strata and exposure to other elements (Arnold et al. 1999; Rice 1987; Rice 2016). Also, during the process of levigating the clay and adding temper, the composition of the clay can be substantially altered (Ceccarelli et al. 2016; Frahm 2018; Rice 1987). Even so, analytical instruments can still be used to investigate archaeological pottery, and have been used for a long time in many different areas of the world and for different time periods with useful results (Barone et al. 2011; Emmitt et al. 2018; McCormick and Wells 2014; Hammond et al. 1976).

Handheld X-ray fluorescence was developed in the early 1960s (Piorek 1997) and also began to be used in archaeology around mid-2000 (Aimers et al. 2012; Barone et al. 2011; Bonizzoni et al. 2010; Emmitt et al. 2018; Forouzan et al. 2012; Forster et al. 2011; Frahm 2012; Goren et al. 2011; Romano et al. 2006; Shackley 2010; Shugar and Mass 2012; Speakman et al. 2011; Malainey 2010). It basically works similarly to bench-top energy dispersive X-ray fluorescence. In short, the basic theory of all XRF is that when x-rays interact with matter, the irradiated matter will react in certain ways.

Their reactions (loss in energy) can be captured, and the elements all have their own characteristics in this reaction, thus providing a chance of knowing their presence by analyzing the reaction (Malainey 2010).

There is research comparing pXRF and other compositional analysis techniques regarded as more accurate, like *NAA, INAA, and LA-ICP-MS. Its results show that, although pXRF often provides concentrations of fewer elements and is less accurate, it can still provide good enough results for broad regional provenience study of pottery (LeMoine and Halperin 2021; Glascock 2011; Lynch et al. 2016; Speakman et al. 2011; Moholy-Nagy et al. 2013).

Researches has compared results generated by pXRF and lab-based bench-top XRF which also show that, although pXRF has less powerful X-ray tubes which will decrease the range of elements that can be excited properly, it can still perform as well as a bench-top ED-XRF for most elements useful for archaeological purposes and provide data that show a satisfying correlation with those produced by ED-XRF instruments in obsidian provenance studies (Nazaroff et al. 2010) as well as pottery and sediment studies (Aimers et al. 2012; Hunt and Speakman 2015; Goodale et al. 2012). Also inter-instrument performances have been compared to each other and to bench-top XRF. These studies show that, although pXRF provides less accurate data than bench-top XRF for some elements, it still performs well for most elements and has its own advantages (Goodale et al. 2012).

Additional research has investigated how different sample preparation protocols may affect the final results (Aimers et al. 2012; LeMoine and Halperin 2021). Some take readings from cross-sections of sherds (Speakman et al. 2011; Frahm 2018; Forster et al. 2011; Barone et al. 2011); some take readings on prepared surfaces (Emmitt et al. 2018) , and some ground specimens into powder (Goodale et al. 2012; Hunt and Speakman 2015; Ioannides et al. 2016). Researchers have found that taking multiple readings, reduces contamination from taphonomic processes and that minimizing the distance between the sherd and the reading window can also help improve accuracy (Forster et al. 2011; Frahm 2018).

In general, there are advantages and disadvantages of using pXRF. Advantages are that it is relatively non-destructive, fast and cheap and thus can easily process larger numbers of specimens with limited time and funding. Large numbers of specimens are hard to export and transport to limited labs that can do certain tests (Aimers et al. 2012; Emmitt et al. 2018). Disadvantages are lower accuracy than some other technique, and although usually 20-30 elements can be tested, there are often only five to ten useful ones (Aoyama 2017; Glascock 2011; Lynch et al. 2016, Speakman et al. 2011). But pXRF is sensitive enough to elements such as Fe, Rb, Sr, and Y, which are often "highly representative of the geochemical age of strata and thus are useful for provenance research" (Allègre 2008). Many case studies also prove that sufficient numbers of elements are quite reliable, and only a few elements are important for answering many questions (Barone et al. 2011; Ceccarelli et al. 2016; Emmitt et al. 2018; Hunt and Speakman 2015; McCormick and Wells 2014).

Although pXRF does not work as accurately as some other instruments, and may not be able to identify the precise origin of clays, as long as different groups of products that share similar compositional recipes can be identified, then the same recipe is still likely to be produced by the same group of potters (Emmitt et al. 2018) and thus help us answer some production related questions.

3.2 Local use of pXRF and other compositional analysis methods

Compositional analysis has been used on Maya pottery in limited cases (Hammond et al. 1976; Little et al. 2004). pXRF has mostly been used in the Maya area on obsidian to investigate exchange system across regions (Cecil et al. 2007; Aoyama 2017; Moholy-Nagy et al. 2013; Braswell et al. 2011). It has not yet been widely used on pottery in the area (Aimers et al. 2012; Rands et al. 1978; Culbert and Schwalbe 1987). This is probably because Maya pottery is very stylistically varied and observable characteristics have been adequate for chronology and broad comparative studies (Aimers et al. 2012), but still compositional analysis can provide us more information than we can get just from the appearance of pottery.

Although pXRF has not been widely used on Maya pottery yet, one study mentioned above evaluated the similarity of results generated by a handheld XRF and by a benchtop XRF is by Aimers and his colleagues (2012) using pottery in the Maya region with quite promising results. Some comparisons between INAA and pXRF mentioned above also used Maya pottery and also proved that pXRF is able to provide useful data after proper sample preparation and calibrations (Aimers et al. 2012). In my research, I do not intend to locate the exact origin of each sherd, but as long as they are compositionally distinguishable, the results can be used to discuss possible differentiation in production of pottery among different levels of social units. So, to test if a hand held XRF instrument will be useful enough to collect data to answer my research questions, I carried out a pilot study on pottery from three polities in the Belize Valley. The results show that there are identifiable compositional groups that have anthropological meaning, as introduced in the next section of this chapter.

3.3 Pilot study

To test if this instrument can generate data that helps answer my research questions, I did a pilot study on pottery found in three similar sized Maya polities in the Belize River Valley: Cahal Pech, Baking Pot and Lower Dover. They are all among the largest centers in the region and served as the capitals of small kingdoms in the Classic period (Helmke and Awe 2012).

Three popular ceramic types in the Late Classic period, which were all were found in large quantity in all of the three polities (Gifford 1976) were mainly considered in the study. A handheld Niton XL3t GOLDD+XRF Analyzer equipped with a 50kV and 200 µA tube and an Ag node was used to collect compositional data from 66 ceramic sherds from Baking Pot (n=24), Cahal Pech (n=22), and Lower Dover (n=20). The same machine was used to collect data for this research as well. All sherds went through standard preparation during which they were polished with the same type of silicon carbide sandpaper until all weathering and slip was removed, providing a fresh smooth surface ready to test. Four readings were taken from each sherd at different places to mitigate sampling biases. For each pXRF reading, concentrations of up to 33 elements were recorded. Elements whose inclusion turned out to be lower than the detection limit of the instrument were removed from the analyses. Then the averages of these readings were calculated as a representative measure of the geochemical composition of each sherd. Hierarchical clustering (based on Euclidean distances on standardized variables) was applied to identify different geochemical groups, which should represent different production groups. Principal components analysis was conducted to identify which elements were most significant in causing variation in the overall sample, which also provided reference for my dissertation research. In the pilot study, it seems that Rb, Ca and K were mostly important for causing variations and all those elements are also kept in my list of useful elements in this research, as specified in Chapter 4.

According to the hierarchical clusters shown in Figure 3.1, the sherds from all three polities could be divided into four primary groups. All the groups contain specimens from all three polities, meaning each polity produced more than just one single group, which implies overlapping pottery distribution networks that span multiple polities. Among the four groups, both groups 1 and 3 are composed of a mixture of Dolphin Head Red and Garbutt Creek Red types analyzed from all three polities, which implies no strong correlation between these two types and composition groups, rather, each polity is more likely to have similar but slightly different compositions although they still fall in the same groups for now. This is probably affected by the small sample from each polity. If we had a large enough sample from each polity, we might see clearer differences within the same type from different polities, if ceramic production is likely to happen at the polity level with exchange across political boundaries. Or they may still be mixed up, probably indicating intense exchange systems. Group 2 includes just three sherds, of different types, all from Baking Pot, indicating that it is possible that composition group is more related to polity division instead of type differences. Again this could be better investigated if we had larger sample. Group 4 is composed of most of the Belize Red sherds analyzed from all three polities, suggesting a dominant production locale, or at least a limited source of material for that type. All

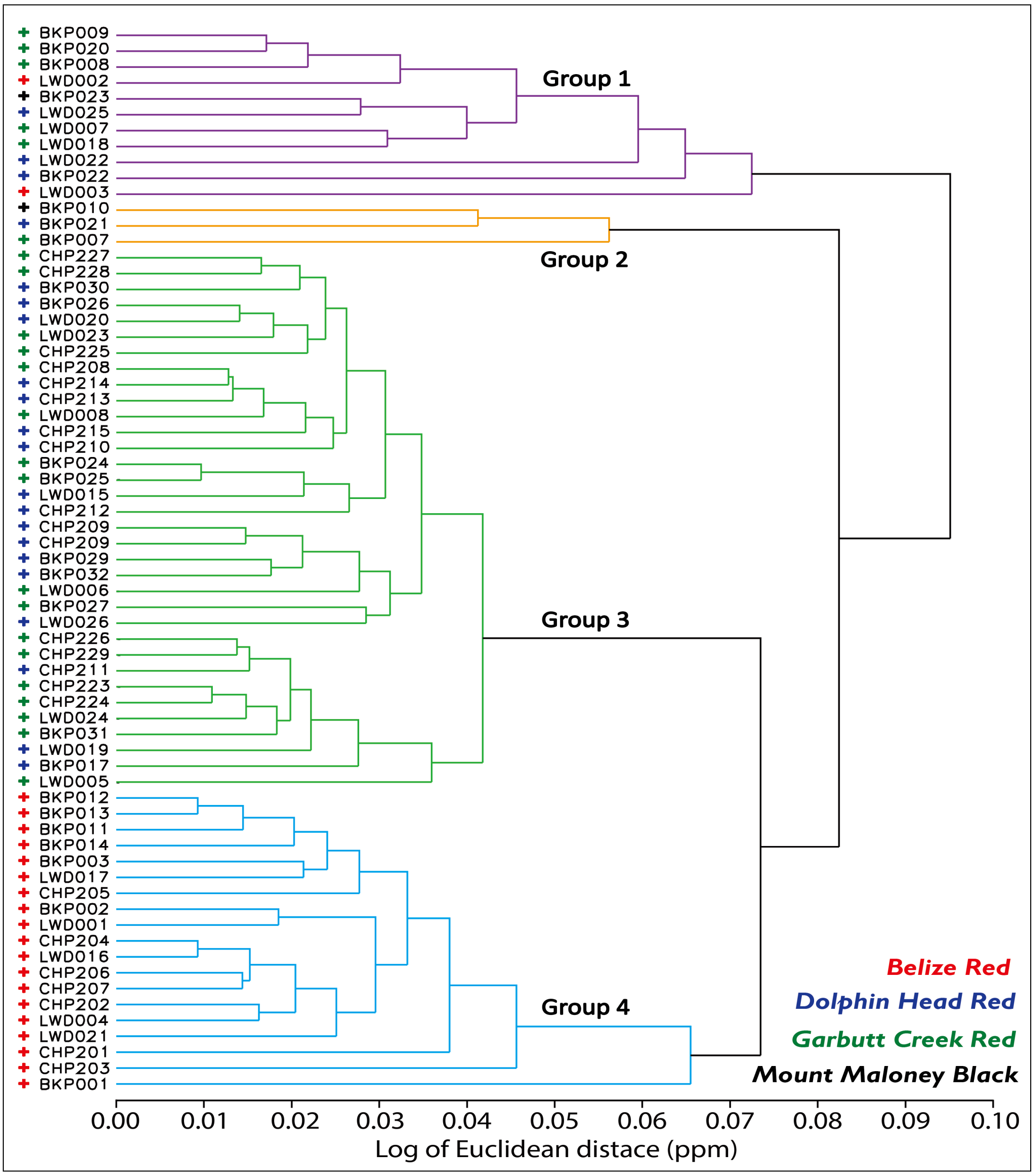

Figure 3.1: Hierarchical clusters of specimens from Baking Pot (BKP), Lower Dover (LWD) and Cahal Pech (CHP).

the Belize Red collected from Baking Pot and Cahal Pech fall into this group. However, what is interesting is that two sherds of Belize Red type from Lower Dover fall into a different group, potentially representing outliers, or showing that Lower Dover had its own modified version of Belize Red. Although the pilot study included three polities and Lower Dover is only one of them, and the sample from each of the three polities is very small and comes from a combination of contexts, it demonstrates that pXRF analysis can differentiate compositional groups with varied distribution patterns, and helped me design my sampling strategies for dissertation research. It also shows that the research questions that interested me could be better answered with larger sample which is discussed more in the next section, Chapter 3.4 Sampling method.

3.4 Sampling method, sample preparation protocol and data collection

3.4.1 Sampling method

There is a detailed ceramic typology study from Barton Ramie (Gifford 1976) which is part of the Lower Dover polity and well acknowledged in the whole valley. The types are very well defined and provide a fast way to organize sherds into different time frames. In Gifford and his colleagues' classification system, the pottery is organized hierarchically into wares, groups, types and varieties; among these, type is defined as the basic ceramic unit that has a group of recognizably distinct characteristics (Gifford 1976). My research is organized according to these well-defined types. I picked three of the most abundant utilitarian types during the Late Classic Period for my pilot study, and I have included two of these three again, Belize Red and Dolphin Head Red. Vessel forms of these two are mostly serving vessels like bowls, dishes and plates, usually with red slip. I am going to include another type in my research, Cayo Unslipped, of which vessel form is usually jars of various sizes. I am choosing the most abundant types to represent a large portion of the total ceramic production and to facilitate the acquisition of large samples. Also, I intentionally chose two types that mostly have serving vessels as vessel forms and one type that mainly includes medium sized storage jars to see if vessels of different functions might have different distribution patterns.

As for sample size, ideally I wanted to pick 50-55 sherds of each of the three types from each house group. The reason to pick this much was to make it possible to estimate the proportions of different compositional groups in each type in each house group with an error range no greater than 10% at the 90% confidence level. However, I ended up mixing all three types from each house group together because it provides clearer results and provided even smaller error ranges at the same confidence level as well. However, not all house groups have enough for all three types, and I ended up collecting a few less for some types in some house groups. For Tutu Uitz Na and Floral Park, I have picked the intermediate elite group and three high-status commoner groups, and for Texas, due to the limitation of access to the collections from that district, only enough Belize Red specimens of the intermediate elite group were collected. The specific numbers of specimens of different types from different house groups are shown in Table 3.1.

Table 3.1: Number of specimens from each house group.

District	Settlment Group	Belize Red	Cayo Unslipped	Dolphin Head Red	SUM
Tutu Uitz Na	SG1	55	55	55	165
	SG3	53	56	48	157
	SG42	45	53	53	151
	SG51	54	47	56	157
Floral Park	Group 2*	55	55	56	166
	SG34	55	53	48	156
	SG129	46	48	41	135
	SG143	49	55	45	149
Texas	BR168/180	52	0	0	52

* Structures 2A&2D

3.4.2 Sample preparation protocol

Although pXRF is regarded as convenient and could always do in situ non-destructive tests, specimens without any preparation tend to make it harder for the device to provide accurate readings and the influences vary from element to element because of contamination during taphonomic process and possible organic coatings left on the specimens, such as residues on the vessels (Forster et al. 2011). Thus, small modifications on the sherds need to be made to get more accurate data. Belize Red sherds feel very ashy and usually the red slip on them has already fallen off. Slip on Dolphin Head Red sherds mostly remained and helped to diagnose this type. Cayo Unslipped does not have slip, but usually has heavy weathering on the surface. Slip and weathering would all effect the actual materials the instrument is detecting, so the first step is to abrade each sherd on the surface with the same type of coarse sandpaper to remove all weathering or slip. I tried to select relatively flat pieces to minimize the distance between the sherd and the reading window on the device during the tests since air between specimens and the reading window would also distort the results to different degrees with elements of different atomic numbers. Elements that have atomic numbers ≥ 26 are usually more accurately measured (Emmitt et al. 2018; Forster et al. 2011; Ceccarelli et al. 2016;). This is easily achieved for most specimens. For medium size pieces I abraded the flattest part, usually the middle part of the exterior side. Smaller pieces are quite flat in most cases, so either exterior or interior side works fine. In these cases, I abraded the part that does not have slip first and tried to keep as much slip as possible if the part without slip is not big enough. For Cayo Unslipped jar pieces, which are often rims and necks, the place to be abraded depends largely on the specific shape. If the part close to the rim is wide and flat, I abraded that part; if the shoulder part is wide and flat, I abraded that part instead; if only the neck is available, the flattest surface I could get was abraded.

Much research has proved that averaging multiple readings taken on the same specimen can better represent the composition of the matrix (Forster et al. 2011; Emmitt et al. 2018). So, I decided to take four readings on each sherd. Although the diameter of the x-ray beam is only a few millimeters, the measurement window is about 1 cm^2, so I needed at least that amount of clean surface to get one proper reading and at least four 1 cm^2 of the surface were abraded for a few millimeters until I saw a clean, relatively consistent surface. However, in most cases, a larger area was abraded. I wanted to avoid shooting added temper as much as I so as to focus on the composition of the clay because shooting a grain of temper would make the numbers vary dramatically (Forster et al. 2011; Hunt and Speakman 2015). Thus I tried my best to at least avoid large inclusions that could be seen by the naked eye. For Belize Red sherds, it is usually not a big problem. They are often quite eroded anyway, and it has the least temper in it, so it is easy to find four $1cm^2$ areas to shoot, even if they are not abraded. But for some Belize Red pieces, I needed to abrade a little bit to find enough clean areas to shoot, about 5-6 cm^2. For Dolphin Head Red, usually there is not much temper, but it is not as "clean" as Belize Red, so often more area was be needed to find a good spot. I would say usually 6-7 cm^2 needed to be abraded. Cayo Unslipped jars are often quite coarse, and it's hard to find good spots, so for those, I usually abraded as much as I could from the flat parts, so as to find four good spots to shoot.

During the process of specimen preparation, I tried to make as few modifications as I could and keep as much slip as I could if there was slip. For Belize Red, they are usually quite eroded already, and they are super abundant, so I tried to select sherds that did not have slip left in the first place, and tried to abrade the part where slip had already eroded if a piece with some slip had to be selected. For Dolphin Head Red, I always tried to keep as much slip as I could, and this also helped me to double check my typing during the tests. Some of the households I selected did not have enough pieces with rims that could easily be diagnosed as Dolphin Head Red, so I had to select some body pieces to bring up the sample size. In these cases, the location of the slip and the texture of the slip, helped me type them. I recorded how certain I was of the typing of these body pieces at the same time. Thus in my analysis, if it turns out that some pieces that seem to have weird compositions are those that I am not too confident to be Dolphin Head Red in the first place, that might help me make some meaningful explanations. The typing certainty is ranked from 1 to 3, and the numbers of sherds ranked as different certainty levels are listed in Table 3.2.

Table 3.2: Number of sherds of different type at different diagnostic certainty.

	Belize Red	Cayo Unslipped	Dolphin Head Red
Rank 1	448	325	153
Rank 2	13	97	155
Rank 3	0	3	94
Total	461	425	402

Rank 1 means I am very sure this is the type: the shape of rim looks right, the feel and color of the paste at the cross-section are correct, color and texture of the slip are all correct. Almost all the Belize Red is ranked 1 certainty, even ones without rims because the ashy feeling ware is just very identifiable. Although there are other polychromes that are Belize Red wares with multi colored paint, they still have the same paste. Cayo Unslipped and Dolphin Head Red pieces that have rims are also ranked 1 certainty. Rank 2 means less certainty, and usually includes pieces that do not have a rim but seem to meet all the other standards other than the shape of the rim. For Cayo Unslipped, some pieces that look thinner than others but seem to have the right color and feel of the paste are put into this category. For Dolphin Head Red, if the thickness, color and texture of the slip, and color of the paste at the cross section all look good, I will rank it as rank 2 certainty. Also, the slip on Dolphin Head usually does not cover the whole vessel but only the interior and upper half to two-thirds on the exterior, so pieces that have slip on both sides or only one side could all very possibly be Dolphin Head sherds. Rank 3 means I think the piece is very likely to be the type but I am even less certain. I had to include these pieces, mostly for Dolphin Head Red to bring up the numbers of specimens. There are no rank 3 Belize Red, and only three pieces of Cayo Unslipped that I think must be medium sized jar body sherds, and very likely to be Cayo Unslipped, but I am not sure. But there are a lot Dolphin Head Red pieces that are rank 3 certainty. These pieces are also red slipped on one side or both sides, relatively thin body sherds that should belong to medium to small size bowls and plates that look like Dolphin Head Red, but the color of the paste might be darker or lighter. They still look very like Dolphin Head Red to me, but I am not sure. Actually, it turned out that those that I am not too sure about are not causing extra problems after the hierarchical clustering results are performed. Sherds of different certainty ranks of the same type often cluster together. Still, see detailed discussion in Chapter 4.2 Picking out the most convincing dendrogram.

3.4.3 Data collection process

I used the exact same device as the one I used in the pilot study, a handheld Niton XL3t GOLDD+XRF Analyzer equipped with a 50kV and 200 µA tube and an Ag node. I used the soil mode calibration that came with the device because clay is after all soil. Four to five readings were taken on each sherd, and I let the machine take each reading for one minute through each of the three filters that intend to collect the amount of different groups of elements. Usually, the numbers become stable after 20 to 30 seconds for each filter, but I still let it run as long as possible to achieve a more reliable result.

The device has a small built-in camera and shows what it sees from the perspective of the beam, and it also shows on the screen on my laptop, so I would try to put the part that has least temper that I could find on the reading screen and adjust it according to the picture on my screen. Sometimes there are pieces that need a little bit of support to make the flattest part touch the screen and best effort was given to make it work. I also recorded it if there were particular pieces with very big curves, but this is very rare and would not affect the final result.

Ceramic sherds often have more dust than some other types of artifacts even after being cleaned, so each sherd was brushed clean again and the dust was blown away by a small silicon air blower before being laid on the detection window. The window was also gently blown by the blower between readings or specimens as needed.

All specimens were then stored separately in small bags with a label stating the district name, house group number, number of the specimen and the type of the sherd.

I also kept a readings collection log, recording the order of readings consistent with records in the device, the order of readings taken for the same specimen, the diagnostic certainty for each sherd, and any other traits worth recording for that particular sherd.

During the data collection work, three standard samples that come with the device were tested and compared to the chart of supposed results to keep track of the consistency of the instrument before and after data collection work every time. Routine system checks run by the device itself were also done regularly.

After all the data were collected, they were processed carefully to find a reliable representation of chemical composition for each specimen for cluster analysis and proportional analysis presented in Chapter 4.

4.0 Data Analysis

4.1 pXRF data process

1288 specimens from nine households were tested, each sherd with four readings except two specimens with one extra reading because when I was observing each reading, I thought the four readings all looked quite different so I took a fifth reading on specimen like this. In total, 5376 valid readings were taken, including 4*1288+2=5154 readings; 4 routine system checks (2 readings each time, checked every two weeks) and 206 tests of check samples/standards that come with the instrument (3 checks every morning before testing specimens and 3 checks in the evening after doing the tests for 34 days, plus 2 more in the first day of work), and another 12 readings that are 4 readings on the same spot of 3 specimens I selected to reverify the stability of the instrument instead of only using the standard samples that come with the instrument. Also, there are a few problematic readings caused by the sudden shut down of the analyzer due to overheating which are not counted as valid readings here.

In the end, the analyzer provided a big spreadsheet with detailed information for each reading, including sequence number of each reading, time collected, filter settings, reading collecting duration, unit of measurement, label of each reading, and name of each element, amount of it and error range. All the irrelevant information was deleted and only the context information and quantity of each element detected in each reading were left for analysis.

Five steps were taken to reshape the big spreadsheet to data appropriate for further statistical analysis. First irrelevant readings were deleted. This includes readings of system check, and check readings of samples/standards that come with the instrument. Second, elements considered not providing reliable enough data were eliminated through a few steps. This includes elements that had high proportions of invalid data and/or elements that showed very large error ranges. Third, readings with small amounts of invalid data were fixed. Forth, outliers among the readings of the same sherd were fixed or deleted. Fifth, the average of the readings of the same sherd was calculated and used to represent the composition of that sherd for future analysis. Detailed steps are as below.

First, all the readings of samples/standards, system checks and problematic readings were deleted. For the two specimens that had five readings, one of them which looked most like an outlier was deleted for each element, so that all specimens would have four readings. The principles to pick out outliers will be specified in step four. At last, 5164 readings remained. This included four readings per specimen from 1288 specimens, and three sets of readings (four in each set) that were collected by shooting the same spot four times on each of the three randomly picked sherds. These three sets of readings were collected to work as a standard of variation among readings other than just using samples/standards that come with the analyzer. Those three sets of readings were only kept during the process of selecting useless elements, they were not used in any analysis beyond that, including fixing outliers of each specimen and averaging readings for a final set of data to represent each specimen.

Second, useless elements were eliminated in two steps.

(1) Some elements that have high percentages of invalid data were eliminated. Among the 33 elements the machine could detect (Mo, Zr, Sr, U, Rb, Th, Pb, Au, Se, As, Hg, Zn, W, Cu, Ni, Co, Fe, Mn, Cr, V, Ti, Sc, Ca, K, S, Ba, Cs, Te, Sb, Sn, Cd, Ag, Pd), there are often situations when the amount (ppm) of an certain element within the range of the X-ray turns out to be lower than the instrumental limits of detection. This would not provide a number but a reading of "<LOD" in the spreadsheet downloaded from the machine. The percentage of invalid data for each element was calculated and elements that had higher percentages of invalid data (shows "<LOD") were eliminated. Thus, Mo(88.9%), U(53.3%), Au(78.2%), Se (99.9%), Hg (87.9%), W (82.1%), Co (92.1%), Sc (27.6%), S (87.6%), Te (19.3%), Sb (24.7%), Sn (17.6%), Cd (82.5%), Ag (88.0%), Pd (99.7%), were first deleted from the list of useful variables. The rest of the elements all have less than 1% of invalid data or no invalid data at all, except for Cs (7.4%), Cr (2.8%) and As (2.5%).

(2) The elements that have a high degree of erroneous readings were eliminated. The

instrument provides the concentrations of each element and the error at the same time for each reading. The error divided by the concentration could provide an indicator of how reliable the concentrations are. This number was calculated for each reading of the rest of the elements except those that showed invalid data (shows "<LOD") and formed a batch of numbers for each element, in the form of percentage. Then the average percentage of error, standard deviation, coefficient of variation and proportion of readings that had higher than 20% error were calculated for each element, as shown in Table 4.1. Those data were used to decide if this element was reliable enough for further statistical analysis. If the average percentage of error was over 20%, this element was ruled out directly; if the average percentage was less than 5%, it was considered useful directly; if the average percentage was between 5% and 20%, the coefficient of variation (also known as relative standard deviation) and the proportion of readings that have higher than 20% of error were taken into consideration. In this step, 5164 readings were all taken into consideration, including four readings for 1288 specimens and 12 readings collected from three specimens at the same spot (four readings from each specimen).

Among the 18 elements left, five elements that had relatively high percentages of error are first ruled out: Cu, As, V, Cr and Th. Seven elements were considered useful directly: Ca, Fe, Ti, Zr, Sr, K and Ba. Among these, K had quite a high CV, but the degree of error was still endurable since the average percentage of error was quite low in the first place and the proportion of readings that had higher than 20% of error was quite low. Among the six elements that had an average percentage of error between 5% and 20%, two more elements were ruled out (Ni and Pb), because they had a high percentage of errors and high proportions of readings that had higher than 20% of errors. Four more elements were considered useful: Rb, Zn, Cs and Mn. Among these, although Rb had a high CV, it was still within the acceptable range for the same reason as K: both had few readings with greater than 20% of error. Mn and Cs were acceptable for a similar reason: the average percentage of error was not very high and the proportions of readings that have higher than 20% of errors were not very high. After these two steps were done, 11 elements were considered reliable, because they had low percentages of invalid data and a low degree of errors. They were Mn, Cs, Zn, Rb, Ba, K, Sr, Zr, Ti,

Table 4.1: Proportions of error to the quantity of each element.

Element	Average % of Error	SDV	CV	N of error>20%	% of error>20%
Cu	33.63	0.0848	0.2521	4991	96.65
As	30.55	0.0975	0.3192	4559	88.28
V	25.86	0.0818	0.3164	3697	71.59
Cr	20.16	0.0870	0.4315	2082	40.32
Th	20.10	0.0613	0.3051	2401	46.49
Ni	19.11	0.0711	0.3722	1637	31.70
Pb	17.04	0.0526	0.3086	1247	24.15
Mn	13.57	0.0721	0.5312	772	14.95
Cs	11.10	0.0842	0.7588	451	8.73
Zn	9.13	0.0248	0.2720	4	0.08
Rb	6.53	0.0758	1.1610	421	8.15
Ba	4.58	0.0204	0.4469	18	0.35
K	4.43	0.0590	1.3323	180	3.49
Sr	2.96	0.0100	0.3379	0	0.00
Zr	1.71	0.0033	0.1919	0	0.00
Ti	1.65	0.0030	0.1792	0	0.00
Fe	0.59	0.0008	0.1422	0	0.00
Ca	0.45	0.0025	0.5494	0	0.00

Fe, and Ca.

Third, readings that still had small amounts of invalid data were fixed or deleted.

Most of the elements (8 out of 11) did not have invalid data at all, they were Zr, Sr, Rb, Zn, Fe, Ti, Ca and K. Only two elements had a few invalid data values, Ba had 9 and Mn had 16. One element had much more: Cs had 382 invalid data values. The principle by which invalid data were fixed was as follows. If more than two, including two readings from the same specimen showed "<LOD", then those invalid numbers were changed to 0. If only one of the four readings showed "<LOD", it was replaced by the average of the other three readings.

Fourth, outliers among the readings for the same sherd were identified and excluded.

There were usually four readings for each specimen, a fifth reading was taken sometimes because there seemed to be at least one reading in the previous four that looked dramatically different from the others. This was determined during data collection and it only based on observations of limited elements that showed on the first page of the screen on the analyzer. So more objective calculations were made to identify and delete outliers for each specimen. Even for several readings at the exact same spot, there is still variation, let alone several readings at different spots. As long as the differences are within a certain range, the reading will be considered normal. In short, the basic idea is to set a threshold of percentage of differences between each reading and the other readings. As long as one reading was similar enough to at least two other readings, this one reading and the other readings that are close to it were first considered normal, and the rest of the readings would be judged again if any were left. If that one was close to any of the readings considered normal, it was also considered normal. For each specimen, each element was calculated separately. If the reading for one element was regarded as abnormal, that abnormal reading was omitted, and the average for that element for that specimen was calculated based on one fewer reading.

The specific steps of the calculation method are listed below:

1. **Calculate the percentage of difference between each pair of readings:** The percentage of difference between each pair of readings was calculated by this equation: $p = \frac{|x-y|}{x}$, where p is the percentage of difference between each pair of readings, and x is the current reading we are judging, and y is all the readings other than the current reading we are judging. Calculation does not move to the next x value until calculations of the percentage of differences between all the other readings and this one have been done. After all the percentage of differences between other readings and the current reading that we are judging had been calculated, p was

compared with the upper acceptable limit of percentage of difference, and the value was recorded if it was close enough to the current reading. Calculations then move-on to the next reading as denominator and continued until all the pairs of readings had been calculated. The specific process was first to calculate the percentage of difference of the other three readings with the first reading a, by calculating $p_a^1 = \frac{|R_a - R_b|}{R_a}$, then $p_a^2 = \frac{|R_a - R_c|}{R_a}$, then $p_a^3 = \frac{|R_a - R_d|}{R_a}$, where R_a, R_b, R_c, and R_d represent the four readings for the one sherd respectively. Then to compare p_a^1, p_a^2 and p_a^3 to the threshold that had been set, for example 20%, then to record if p_a^1, p_a^2 and p_a^3 were higher or lower than 20% to decide if R_b, R_c and R_d was close enough to R_a to be regarded an acceptable reading to be kept for the next step of calculations. Calculations then moved on to the next R_b, to calculate $p_b^1 = \frac{|R_b - R_a|}{R_b}$, then $p_b^2 = \frac{|R_b - R_c|}{R_b}$, then $p_b^3 = \frac{|R_b - R_d|}{R_b}$, then compare p_b^1, p_b^2 and p_b^3 to 20% and decide if R_a, R_c and R_d were close enough to R_b, and then moved on to the next reading and so on. In this step (1), each reading was judged separately by always calculating the percentage of difference between the current reading to all the other three readings. It was possible that with R_a as denominator, R_b seemed to be close enough to R_a, but with R_b as denominator, R_a did not seem to be close enough to it. In those cases, I still considered R_a and R_b close enough. The purpose of this step was to gather as many readings as possible that were close enough and then in step (2), confirm the group of close enough readings to use as the base to judge if other readings could be included in this group of normal readings in step (3).

2. **Decide the basic group of close readings:** As long as one reading seemed to be close enough to more than one other reading (for example p_a^1 and p_a^2 were both lower than 20%) then at least three readings R_b, R_c and R_a were relatively close to each other. Then these three readings were considered a group of good readings and calculation moved on to judge whether the fourth reading R_d was also close enough, if it had not been included already. It was possible that the other two readings were only close to this reading separately but not close to each other (as when one was below and the other was above the current reading). But this provided no logical reason to decide which pair was more reliable or meaningful, so they were all retained

temporarily as normal. If this normal group already contained all four of the readings of this element for this specimen (meaning for at least one reading all the other three readings were close enough) then all the readings were considered normal and there was no need to go to the next step. The average reading to use for the sherd was calculated based on these four readings. If this normal group only contained three readings, step 3 was performed to judge whether the fourth reading was added to this group. If this group could not be formed (meaning none of the readings were close enough to at least two other readings, the situation was dealt with separately in step 4.

3. **Judge the left-out reading:** If a reading was close enough to any of the readings already in the normal group, then either other readings were close to this one when this one was the denominator, or this one was close to other readings when they were the denominator. In such a case, the same logic was followed as in step 2 (it was impossible to determine which pair of similar readings were more reliable or meaningful), so all were taken as normal. This procedure could form a chain of readings in which the largest and the smallest were not as close as we would want them to be, but they were still considered similar enough for our purpose of analysis, so the average was calculated based on all four readings. If the fourth reading was close enough to none of the three readings already in the group, then the three readings in the normal group were averaged and used to represent this element for this specimen.

4. **Procedures when no normal reading group could be formed:** If no normal readings group could be formed for element for specimen, there were three possible situations which were dealt with as described below.

   - The four readings were all very different (none close enough to any other readings). In this case, other elements of the same specimen were be examined, if there were more than five with similar issues, this specimen was be excluded from further analysis. If there were fewer than five problematic elements for this specimen, all the readings were left as they were, since there was no way to decide which one(s) were better than others, and the average of all four readings represented this specimen for this element.

- One reading had one other reading close enough to it (mutually or not) and the other two readings were far away from those two and from each other as well. In this case, those two were taken as normal readings and the average of the two nearby readings represented this specimen for this element.
- The four readings formed two pairs of close readings, but the pairs were far from each other. In this case, other elements were examined. If more than five had similar issues, then this specimen was excluded from further analysis. Otherwise, since we were not able to decide which pair was better, the average of the four represented this specimen for this element.

As described above, a threshold needed to be set to judge if the readings for the same specimen of each element should be regarded as close enough to each other. I experimented with setting different criteria for judging relationships among readings, using error percentages of 20%, 30% and 50%.

According to my method of fixing readings and finding the best set to represent each specimen, there were five possible outcomes, three good ones and two problematic ones. In the first good outcome, all four readings were close to each other according to the procedures described above. In the second good outcome, three readings formed a normal group but the fourth reading stood apart from it. And in the third good outcome, two readings were close, but the other two stood apart from them and from each other as well. All three of these outcomes yielded averages (of four, three, or two readings respectively) that were used for further analysis. The two problematic outcomes (all four readings were far from each other or formed two pairs distant to each other) were dealt with as described above.

I've calculated the proportions of these five situations at different settings of the standard of percentage of difference. For 1288 specimens, there are 1288 groups of readings and each group includes 11 numbers for 11 elements, so there are 1288*11=14168 numbers (readings for all the elements) to compare. The number of all five situations described above at different threshold settings are shown in Table 4.2.

Table 4.2: Numbers and percentage of normal and problematic readings at different threshold or error.

Situation	Threshold: 20%	Threshold: 30%	Threshold: 50%
All four are good	12365 (87.3%)	13364 (94.3%)	13881 (98.0%)
Three are good	1116 (7.9%)	505 (3.6%)	151 (1.1%)
Two are good	311 (2.2%)	112 (0.8%)	27 (0.2%)
All four different	116 (0.8%)	93 (0.7%)	88 (0.6%)
Two pairs	260 (1.8%)	94 (0.7%)	21 (0.1%)
Sum of bad ones	**376 (2.7%)**	**187 (1.3%)**	**109 (0.8%)**

Although setting the standard at 20 % would create more problematic numbers that need to be fixed, lowering the standard does not make great changes, so in the end 20% difference was set as the standard for judging whether the four readings of the same specimen are close enough to each other and all the specimens were kept in the analysis.

Also, during the process of identifying problematic numbers, I noticed that another element (Cs) could be deleted from the list of reliable elements for two reasons. First, it has a higher proportion of problematic readings (Table 4.3). Most "all four different readings" situations happen in this element, so deleting Cs reduced the number of problematic numbers from 376 to 257, leaving only 1.8% [$(376-257)/14168 \approx 0.0181$] of the numbers classed as problematic. This is not a big difference, but better fewer problematic numbers than more. Second, this element was the one that called for the largest number of changes in the above steps. Among the 11 elements shown in Table 4.3, 382 of the total of 407 unacceptably low ("<LOD") readings pertain to Cs. The third reason is that in the hierachical clustering (Chapter 3.2) analysis without Cs produces cleaner, clearer, and more interpretable dendrograms, suggesting that one of the main effects of Cs is to include more random noise in the data. So for these reasons, Cs was omitted from future analysis.

Table 4.3: Numbers of normal and problematic readings of different element.

Situ.	Zr	Sr	Rb	Zn	Fe	Mn	Ti	Ca	K	Ba	Cs
(1)	0	0	0	2	0	12	1	4	1	2	**94**
(2)	0	4	10	25	6	86	11	63	18	12	**25**
(3)	1280	1259	1209	1143	1246	773	1209	940	1160	1227	919
(4)	8	23	64	102	35	306	62	201	93	40	182
(5)	0	2	5	16	1	111	5	80	16	7	68
SUM	1288	1288	1288	1288	1288	1288	1288	1288	1288	1288	1288

Situation: (1) All four different, (2) Two pairs, (3) All four good, (4) Three good, (5) Two good.

After Cs was deleted from the list of elements, the total number of problematic situations decreased from 376 to 257. The number of "all four different" situations dropped dramatically, but the situations of "two pairs" have not changed much. Finally, ten elements were left to have average readings calculated in the final step of data processing: Zr, Sr, Rb, Zn, Fe, Mn, Ti, Ca, K and Ba. Most of those elements have atomic numbers larger than 26 which tends to produce more accurate data (Forster et al. 2011), except that the atomic numbers of Fe and Mn are 26 and 25, respectively.

Fifth, as the final step in processing the raw data, the average of the readings for each sherd was calculated to represent its composition in producing dendrograms in the next section of this chapter.

After these five steps of data processing, elements that were not reliable were ruled out, and numbers showing "<LOD" had been fixed. Four readings for each sherd were either categorized as close enough to average directly or problems were fixed and modified averages were calculated to represent the specimen. In the end the database includes 1288 cases. Each case includes measurements for ten elements, and other related information like specimen numbers, and contexts. This data is available online (see Appendix).

The data was then standardized by subtracting the average measurement for each element, then dividing by the standard deviation, and it was ready for the cluster analysis forms the basis of this research.

Before moving on to cluster analysis, I also evaluated whether the numbers of problematic situations were related to type, to make sure data for all three types (some finer some coarser) were similarly reliable. So, I compared the numbers of problematic situations for different types, the numbers of elements that have problematic situations in the particular specimens and the numbers of specimens that have one, two, three or four problematic elements as shown in Table 4.4. There were very few instances where all four readings were different. Cayo Unslipped as a coarse type does have more problematic cases, but not significantly more, and most specimens that in this situation only have one bad element. For the two pairs situation, still Cayo Unslipped has more problems, but not dramatically more at all. The numbers of specimens that have the two pairs situation for Belize Red and Dolphin Head Red are quite similar. Belize Red sherds look fine to the naked eye, but it has a number of problematic situations similar to the other types. Although being a quite coarse type, Cayo Unslipped, which usually is made in medium sized jars should be no less reliable, given the fact that the numbers of problematic situations is similar to the other two better quality types.

4.2 Picking out the most convincing dendrogram

When making dendrograms, different hierarchical clustering algorithms can produce different results based on the nature of each algorithm. No one dendrogram is more "correct" than a different one, when using the same data, they are just making different characteristics of the data more obvious based on the nature of the algorithm. However, concerning compositional analysis of ceramic sherds looking for possible production sources, there are some expected characteristics of the results. We would expect clusters to be internally strongly similar, and quite different from other production sources. So, we expect the cases to first cluster at relatively low dissimilarities and form several big

Table 4.4: Numbers of problematic situations of different numbers of problematic elements.

Type	All four different		Two pairs	
	N. of elements	N. of specimens	N. of elements	N. of specimens
Belize Red	1	5	1	55
	2	0	2	5
	3	0	3	1
	4	0	4	0
	SUM	5	SUM	61
Cayo Unslipped	1	8	1	85
	2	1	2	10
	3	0	3	1
	4	0	4	1
	SUM	9	SUM	97
Dolphin Head Red	1	7	1	69
	2	0	2	6
	3	0	3	1
	4	0	4	0
	SUM	7	SUM	76

clusters, and maybe some small ones before combing into larger ones. Ideally, those clusters should only be put together at much greater dissimilarities.

Different combinations of clustering methods and ways to calculate distances are tried out to see if there are some general patterns despite using different algorithms, and to pick out the dendrogram that fits our expectation the most, which would also be the most convincing dendrogram to answer my research questions for proportional analysis. Clustering methods tried out include Ward's method, Nearest neighbor (Simple

Linkage), Furthest neighbor (Complete Linkage), within group linkage, and between group linkage. All those methods are tried using different ways to calculate distances, including Euclidean distance, squared Euclidean distance and cosine, respectively.

Quite a few dendrograms using different combinations of clustering method and distances show similar patterns. In particular, Ward's method yields consistent results regardless the ways of how distances are calculated. In the end, the dendrogram using Ward's method and Euclidean distance was chosen as the one that meets our expectations (Figure 4.1). It has a number of fairly large clusters, few very small clusters and the large clusters group many sherds together at very low dissimilarities, and then only at much greater dissimilarities those big clusters are put together.

Once the dendrogram is decided, the next step is to decide where to cut the branches. There could again be several subjective ways to decide how many clusters we want to count out. In the end, 11 clusters were divided at similar (although not identical) distances since small revisions were made to reach the clearest result. Each cluster represents one group of specimens that share similar clay composition and differ strongly from specimens from other groups. Although temper is unavoidable, the best effort was made to only focus on the clay during the data collection process in this research. Each group would be regarded as one production unit that indicates one recipe a potter or group of potters would use.

During the process of collecting data on each specimen, the certainty of diagnosing the type of each sherd was also recorded (see Chapter 3.4.2 Sample preparation protocol). Among the several characteristics a sherd of each type should have, rank 1 certainty means that all the characteristics are met, rank 2 certainty means fewer criteria are observed and rank 3 means even fewer, but even rank 3 sherds still meet at least some characteristics that the type should have. Comparison of the distribution of specimens of different certanty ranks and the dendrogram indicates that sherds of low rank of certainty did not influence the final result to an unacceptable degree. Figure 4.2 shows production unit 7 which contains fewer specimens as an example. It also has a high proportion of rank 2 and 3 certainty sherds. The cases are color coded by types, and the certainty rank is shown by the length of the colored bar on the left. Rank 1 sherds have

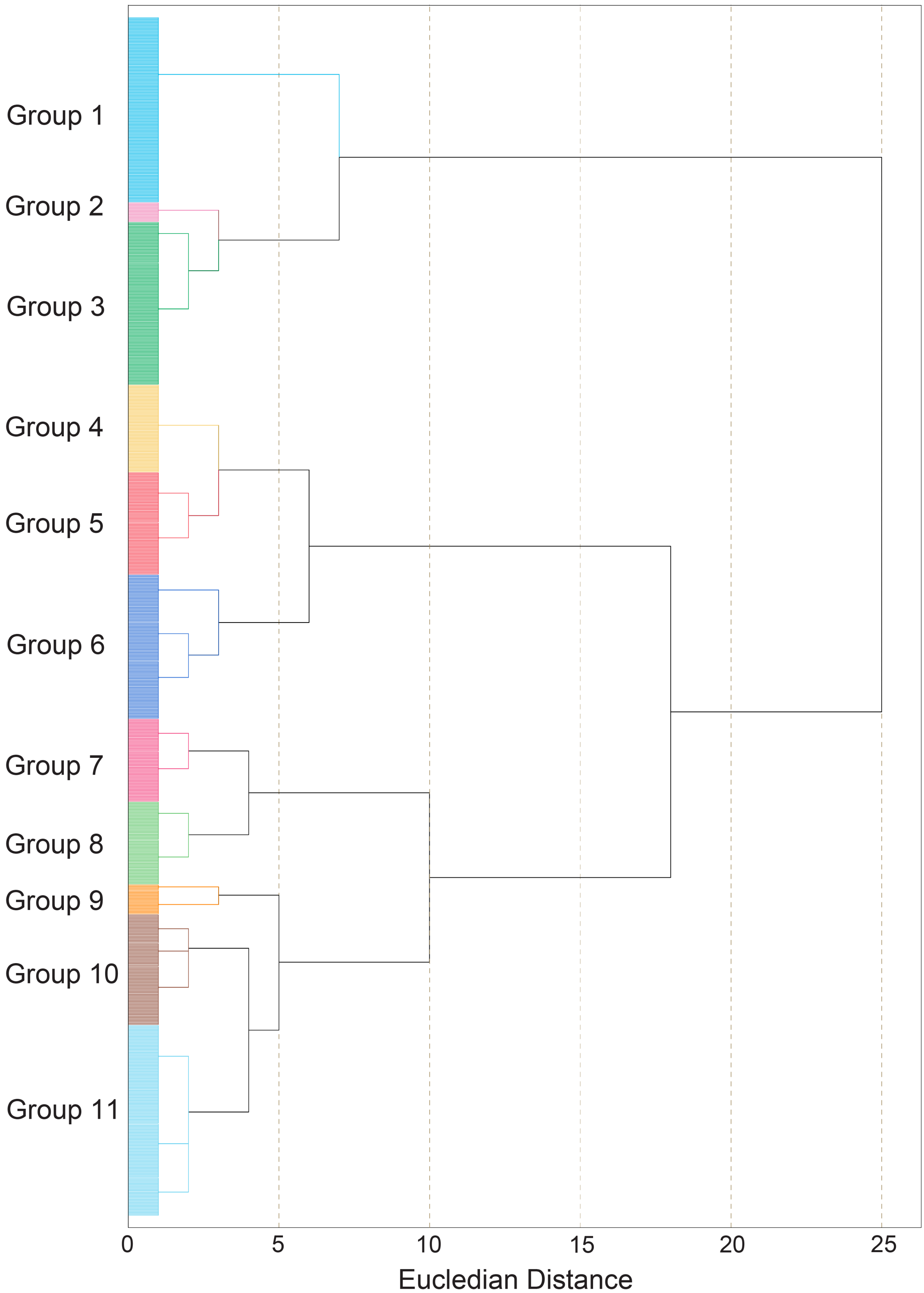

Figure 4.1: Hierarchical clusters using Wald Method and Euclidean Distance of standardized compositions of each specimen.

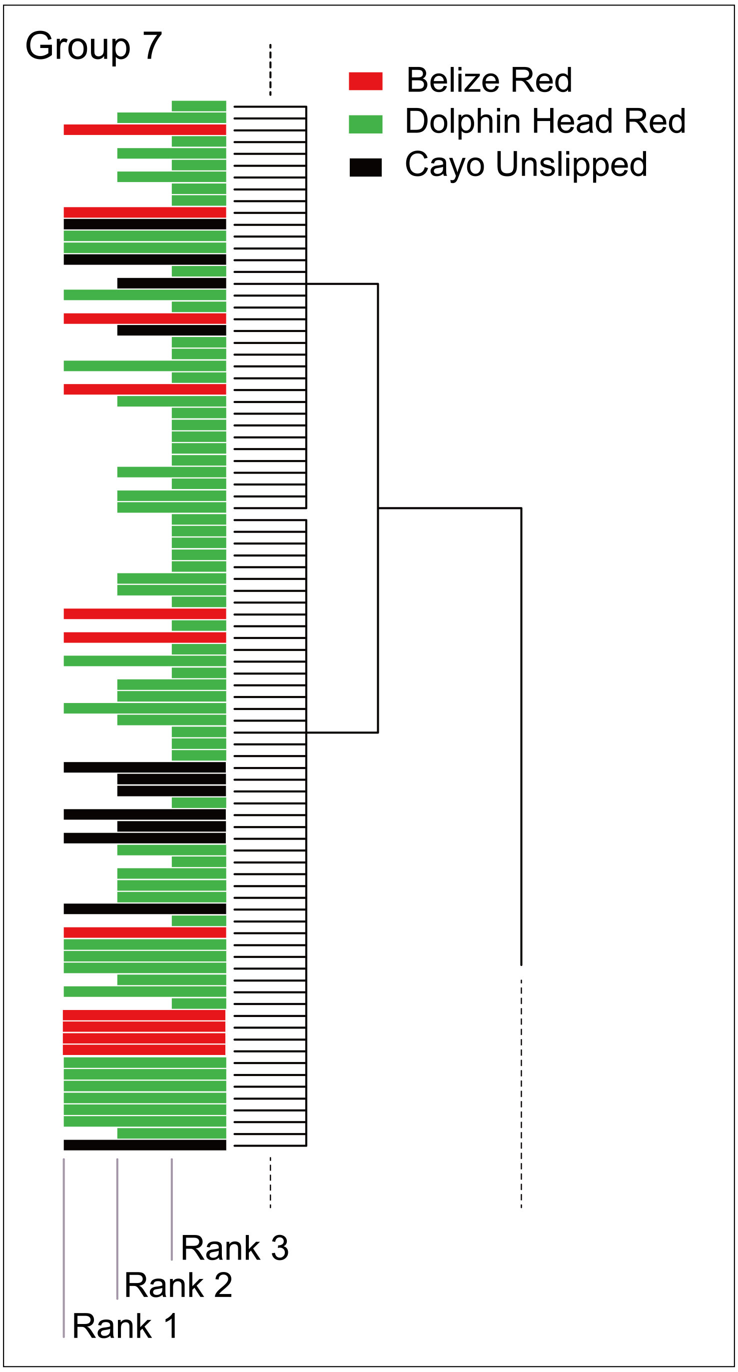

Figure 4.2: Differnt rank certainty of sherds in production unit 7.

the longest bar, rank 2 has a medium length bar, and rank 3 sherds are indicated by the shortest bar. We can clearly see that bars of the same color tend to cluster, despite the length of the bar, which means that, even for some sherds that have low rank of certanity in typing, they still often end up together with other sherds of the same type that I was very confident about their typing. Either the typing of some sherds that are not as certain as we would wish them to are not too off track, or maybe small red slipped bowls with thin walls do share similar chemical compositions in the first place. Either way, it should not cause big problems to future analysis.

4.3 Proportional statistics analysis

The data I use to evaluate productive differentiation at Lower Dover in Late Classic is a set of proportions. How products of different production units are distributed to house groups and districts help reveal the pottery procurement strategies of their residents and possible production locales and distribution methods. There is no way to determine if each production unit and potter or group of potters had a one-to-one correspondence. In other words, one potter or a group of potters could use the same recipe, or a few different recipes at the same time. Several different potters of several groups of potters located at different house groups could decide to use the same type of recipe, due to similar easy access to certain raw materials or knowledge shared or other reasons. Potters may choose the recipe they want to use according to the type, shape, or function of the products, this could be reflected through the composition of each sherd. It is also possible that they would decorate according to the fashion trends of potential buyers. Some potters would make special kinds of rims to leave their own signature (Arnold 2018), but the look of the vessels would probably not affect the clay potters want to use. This research only focuses on the patterns of the sets of production units different house groups would choose and make comparisons among house groups and districts.

The proportions of products from each production unit that are identified as each type of pottery, and the proportions of sherds identified as each type of pottery grouped into each production unit are used in Research Question 1 to investigate the variations among relations between pottery types and production units. The proportions of products from each production unit that are distributed to each house group and each district are used in Research Questions 2 and 3 to investigate the possible scale of utilitarian pottery exchange and the possible distribution/exchange system. Research Question 4 uses the proportions of products distributed to each house group and each district of total sherds grouped into each production unit to investigate the physical extent of production units.

Given the relatively large sample sizes, most proportions have satisfying significance levels when keeping the error range not too wide, usually at 90%. The specific calculations for error ranges are below.

First, all the proportions needed were calculated and the standard error was calculated using the equation, $SE = \sqrt{(\frac{p(1-p)}{n}}$. When calculating the proportions of products from each production unit in different types of pottery, n is the total number of specimens diagnosed as that type: for Belize Red, n=461; for Cayo Unslipped, n=425; for Dolphin Head Red, n=402. When calculating the proportions of products from each production unit that ended up in each house group, n for each house group is the total number of specimens from that house group. Other than BR168/180 that has only 52 Belize Red sherds, the other house groups have 135-166 specimens collected in total. When calculating the proportions of products from each production unit ended up in each district, n for each district is the total number of specimens from that district. For Tutu Uitz Na n=630, for Floral Park n=606, and for Texas, n=52.

When calculating the proportion of each type of pottery, each house group and each district in each production unit, n for different production unit is the number of specimens assigned to that unit (21-205). When calculating the proportion of each production unit in each type of ceramic, each house group, and each district, n>120 in most cases, except for house group BR168/180 which has fewer specimens collected. For those cases, if we want to reach a 90% confidence level, the value of Standard Error will be multiplied by the value of t corresponding to a 90% confidence level and different degrees of freedom $(n-1)$ depending on which set of proportions we are calculating, the number of n is as described above. The value of t used here is 1.645, which is the value corresponding to 120 degrees of freedom at a 90% confidence level for all the types and house groups except for BR 168/180. BR 168/180 has 51 degrees of freedom, and the value of t in this case is 1.671, which is the value corresponding to 60 degrees of freedom.

When calculating the proportion of each type of pottery, each house group and each district in each production unit, although the size of each unit varies a lot, most production units are still big enough for us to choose a relatively high confidence level without making the error range look too wide. The smaller clusters would have wider error ranges no matter what confidence level we want to reach anyway. Therefore, the error range calculated for the proportion of each type of pottery, each house group and each district in each cluster is still at a 90% confidence level to keep consistent with all the error ranges for the proportion of each cluster in each type of ceramic, each house group, and each district. The value of t in these cases vary from 1.645 (all the cases when d.f.>120) to 1.725 (at 20 d.f.). The error range is calculated separately according to the t value.

After all the proportions and corresponding error ranges have been calculated, all the data needed to make anthropological interpretations are ready to help me answer the research questions that interested me in the next chapter.

5.0 Differentiation in Procurement Strategies of Utilitarian Pottery by House Groups from Different Districts

There are often multiple steps in pottery making from raw material collection to finishing final products (Lemonnier 1986). Many attributes could be used to group the products and discuss possible production and exchange networks, including paste recipe, vessel form and decoration patterns. In this research, I would focus on the paste recipe.

It is hard to identify exact locations of production due to multiple factors like heavy vegetation, poor preservation and possibly the nature of local production (Rice 1987). Ethnography and archaeological evidence indicate that utilitarian pottery production among the Maya took place at household level, but not all households were pottery producers (Hirth 2009), especially for utilitarian storage vessels (Ball 1993). There may be potters in each household, or several potters in the same community, and they tend to share knowledge about the location of raw materials and pottery making technique. Among modern Maya, still much learning occurs through informal observation and imitation (Arnold 2008; Crown and Watson 2007; Deal 1998; Hayden and Cannon 1984; Minar and Crown 2001). Also, most polities in the Belize Valley were located in relatively homogeneous geology, and the resources are almost equally accessible to all the potters (Foias 2007; Freter 2004; Hammond et al. 1976; Howie 2012; Iceland and Goldberg 1999). Most potters tend not to travel long distances to acquire raw materials. They usually acquire clays within a 7 km range, most often not more than 1 km away, and acquire other resources within a 5 km range (Arnold 1988). To sum up, each potter or group of potters may share knowledge during each part of pottery production, including the procurement of clay. But still, there could be differences in raw material choices among different potters.

In the lifespan of a pottery vessel, it will be produced, distributed, consumed and discarded. Although the composition of each sherd seems mostly related to the production of pottery, the main goal in this research is not to locate where the pottery were made exactly or to find out the relations between potters and production units. Instead, the goal of this research is to try to make some interpretations of the distributional pattern of pottery products through comparing how different pottery products made by different production units end up in different social groups, namely different house groups and different districts. An additional goal is to see if different types of pottery easily identified by the naked eye could also be distinguished by composition and how production of different types was distributed across different production units.

In the analysis below, I will first look at how different types behave similarly or differently in respect to distribution across different production units, since pottery typology is very mature in the Maya area. Vessel forms of two of the types I have selected are mostly serving vessels, while the third type consists mostly of storage jars. I want to see if production units are related to different functions of vessels. The answer to the first research question would also be helpful for the second and third research questions which ask if different households and different districts follow similar or different pottery procurement strategies with respect to choice of production units. The last research question adopts the perspective of production units and investigates the extent of distribution from production units to see if whether it is related to social unit boundaries.

5.1 Research question 1

Do any production units seem dedicated entirely or in large proportion to single types? Or, conversely, does each production unit make a variety of types? Looked at another way, do particular types come from one or a very few production units? Or was each type represented in many production units?

A short answer to these questions is, some production units seem dedicated to a single type, Belize Red, but not to the other two types. Most production units produce all three types, but in different amounts. From the other aspect, Belize Red is still the special type; it mostly comes from two units while the other two types originate in all the other nine units although usually in different proportions.

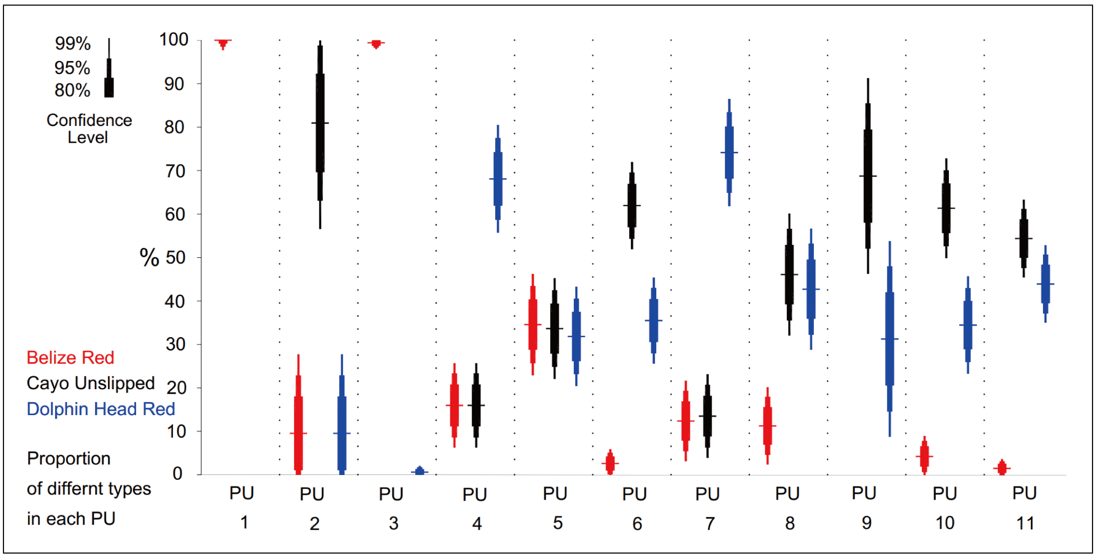

Figure 5.1: Different pottery types as proportions of all the sherds from each production unit.

Figure 5.1 shows different pottery types as proportions of all the sherds analyzed from each production unit. For example the second bar from the left is a red bar that belongs to production unit 2; it means that 9.52% (2 of 21) of pottery sherds identified as production unit 2 were Belize Red with error ranges for different confidence levels. Production unit 1 produced 100% Belize Red, so the first red bar has a different way of calculating the error ranges following the methods introduced in *Statistics for Archaeologists* (Drennan 2010: 251-254).

Other than production unit 1 that exclusively produced Belize Red, and unit 3 that almost exclusively produced Belize Red (except two pieces of Dolphin Head Red), other production units did not produce all three types in similar amounts either. Unit 2 produced much more Cayo Unslipped than the other two types, and unit 9 did not produce Belize Red at all. The rest of the production units do not have such strong tendencies, but usually tend to produce one type more than others. There are production units that focus more on Cayo Unslipped, like units 2, 6, 9 and 10. Among these, units

2 and 9 are small, which causes the larger error range, but units 6 and 10 have large enough sample sizes to reach acceptable error ranges, and we are confident in saying that those two production units focus more on producing Cayo Unslipped. There are also two units that focus more on producing Dolphin Head Red: units 4 and 7. In some production units, the proportions of two or three types are similar. In units 8 and 11, the proportions of Cayo Unlipped and Dolphin Head Red are similar. In unit 5, proportions of all three types are similar. To sum up, there are only two production units that exclusively focused on producing Belize Red. All the other units seem to have produced all three types, but most units had noticeable preferences.

Figure 5.2 shows sherds from different production units as proportions of the total sample of sherds analyzed, so that we can see the size of each production unit and take the scale of pottery production of each unit into consideration when we discuss the diversity of production of each unit. Each bar represents one production unit. For example the first bar on the left means that 15.5% (199 of 1288) of all the specimens are identified as production unit 1 with error ranges.

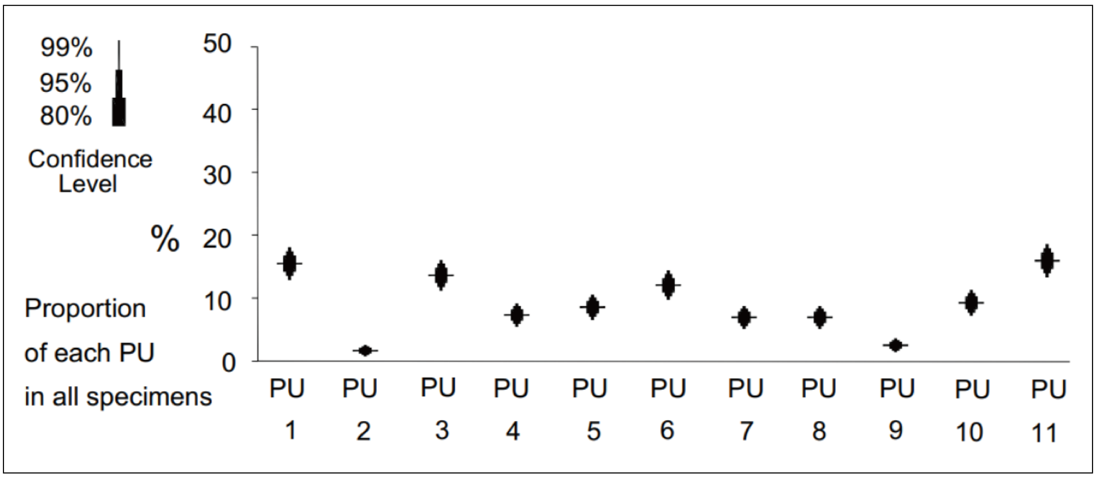

Figure 5.2: Sherds from different production units as proportions of the total sample.

As mentioned in Chapter 4, based on my sample, some production units had larger scale production, such as units 1, 3, 6, and 11, whose products comprise more than 10% of the entire sample each, and there are production units that had smaller scale production and account for very few sherds in the whole sample, like production units 2 and 9. These results are based on the numbers of sherds from each production unit that wound up in my sample. The units that have larger-scale production might indeed have produced more pottery, but it is also possible that they seem to have larger-scale of production because the residents of house groups in my sample preferred products from those units. And the production units that seem to have smaller-scale of production might only appear this way because residents of the house groups I sampled from did not like their products, or were less connected to their distribution networks. It is possible that a lot of the production of some or all the units might have gone outside the area of the districts and house groups I sampled from. More specimens collected from other house groups and districts could help provide information to make better guesses about this issue and later research questions also have more discussion of this, but for now I will just consider that the patterns shown in the production units that are more abundantly represented in my sample are more convincing than those shown in the less represented units in my sample.

It seems that there was some degree of specialization in the production of different types, but it was limited. Only Belize Red seems to be exclusively or nearly exclusively made by two production units, and those two are quite big. They produced 80% of the total number of Belize Red specimens. However, much smaller numbers of Belize Red did come from other production units. Clearly, specialization in production of Belize Red was not totally exclusive. The other two types were even less specialized in their production. A few production units had preferences in choosing types they wanted to make, but the preferred type was never nearly as exclusively made as Belize Red. The less preferred types amounted to 1/3 of the total production in most cases. The two small production units mainly produced Cayo Unslipped, especially production unit 2, but the samples are too small to provide convincing patterns. Overall, most of the production units showed a fair amount of diversity in what they produced, and the degree of specialization in the production of different types was very limited. The distribution of production units across house groups could possibly provide more evidence about the degree of specialization of each production unit, and this will be discussed more under the next research question.

The patterns I found also correspond to the results of previous research. Sunahara (2003) did thin section petrography on pottery from eight sites in the Belize Valley and identified five petrofabric groups. Among those there are two groups that involve volcanic ashes from two sources called Volcanic 1 and Volcanic 2, but the specific sources could not be determined (Sunahara 2003: 123). Volcanic ash in the paste was regarded as one of the most out standing characteristics of Belize Red (Gifford 1976), and in Sunahara's samples, there were Belize Red sherds grouped into both petrofabric groups that contained volcanic ash (Sunahara 2003: 143). Thus Sunahara also identified two different groups of Belize Red that possibly contain different kinds of volcanic ash. Lower Dover was not included in her study, but Floral Park, a district belong to Lower Dover in my research, was included in her study as a small site. Although the contexts she got her sample from were different from mine, her sample usually includes the three types I have chosen as well, since these types are just prevalent in the whole area. In my results, I could also identify two different compositional groups that almost exclusively produced Belize Red, and this may correspond to Sunahara's result. Maybe there were two groups of potters using different ashes to produce Belize Red. Furthermore, Sunahara noted that the two volcanic groups do not appear in all the sites and proposed that only the bigger sites would have both groups, while smaller sites, like Floral Park, would only have one, because smaller sites had less access to both interregional and intra-regional pottery distribution systems (Sunahara 2003: 143). However, I did not see much difference between the proportions of the two Belize-Red-focused production units at Floral Park or Tutu Uitz Na. Belize Red specimens from Texas only came from one elite house group, and they mostly belong to production unit 1. This may indicate something interesting that will be discussed more under research question 2 that focused on comparison within and between districts. The two production units I identified do not necessarily correspond to the two petrofabric groups that contain volcanic ash Sunahara (2003) found, but if they do, it is possible that the reason she did not see both groups at Floral Park could be a result of her very small sample size (only two pieces of Belize Red from Floral Park).

In her research, the other three types are Calcite 1, Calcite 2 and Granite 1 (Sunahara 2003: 140). Specimens from Floral Park in her study included only Cayo Unslipped that belongs to Calcite 2 group, but in many other sites included in her study, Dolphin Head Red and Cayo Unslipped are grouped into both Calcite groups. My results also correspond to this. There seem to be multiple recipes for making those two types, meaning that the production of those two types was less exclusive. Her Belize Red specimens also fell into both of the Calcite groups sometimes as well, but the numbers of Belize Red specimens in those groups are much smaller than Cayo Unslipped and Dolphin Head Red. My results also correspond to this; most production units produced all three types, including Belize Red, but in small amounts.

To sum up, the degree of specialization in the production of different types varies between types. Only two production units almost exclusively produced Belize Red, and only Belize Red mostly came from those two production units. Those two units might represent two different habits of making the same type, used by different groups of potters, or by limited potters that are specialized in making it. There are no other production units making other types exclusively, except the relatively small production unit 2 that contains mostly Cayo Unslipped. But this is a very small unit so I am not confident in saying that this small unit was a special one that nearly exclusively made this type. Most other units produced different types, so potters could use the same recipe to make different types. It seems they would often have a preference between the two types, but the differences between types were not big enough to say that any of them mostly focused on producing one single type. The degree of specialization will be further discussed when we look at the possible connections between production units and house groups/districts under later research questions.

Similar results could be reached from the perspective of how each type spread across the production units as well. In short, Belize Red is more concentrated in production and mostly comes from two production units, while the other two types were more widespread, Cayo Unslipped seemed to concentrate in fewer groups and Dolphin Head Red spread out across most production units.

Figure 5.3 shows sherds from different production units by type, expressed as proportions of the total number of sherds of that type in the sample analyzed. Each bar represents one unit. For example, the first bar on the left in the first graph means that 43.2% (86 of 199) of all the Belize Red specimens are identified as production unit 1 with error range for different confidence levels. We can see that, the production units that produce Belize Red were rather concentrated. Units 1 and 3 each account for about 40% of Belize Red production, and all the other production units produced very low proportions of Belize Red. The other two types do not have the obvious concentrations of Belize Red but each shows a different pattern. For Cayo Unslipped, there are several production units that produce higher proportions than others (units 6, 10 and 11), while units 2, 4 and 7 produce lower proportions of this type. There are significant differences between the production units that produce a lot and those that produce very little. Several units produced Dolphin Head Red in similar amounts (units 4, 6, 7, 8, and 10). Only unit 11 produced more than others, and unit 9 produced lower proportions of Dolphin Head Red. But unit 9 was also a very small unit. To sum up, the amount of Belize Red produced was the most unbalanced. Two units were almost equally responsible for making about 2/5 of it each; the pattern looks slightly unbalanced for Cayo Unslipped, although in general its production was more spread out than Belize Red; and the pattern looks most even for Dolphin Head Red, since almost all the production unit that produced it were similarly responsible for making it.

One reason for these differences in the patterns of different types may be the function of the vessels usually made from each type. Of the three most prevalent types in the area, two were mostly serving vessels of various sizes and one is mostly medium to large sized storage jars. The typical vessel form of Belize Red was bowls of different sizes, plates and dishes. The typical vessel form for Cayo Unslipped was medium to large sized jars, and the typical vessel form of Dolphin Head Red was small red bowls, dishes and plates (Gifford 1976). People may have more stringent requirements for serving vessels that were going to be on public display than for storage vessels not intended to be seen, so there may need to be more choices in the market. Or perhaps people would prefer making their own serving vessels so that they could make decorations they like, while storage vessels only need to be more durable and useful. They do not need

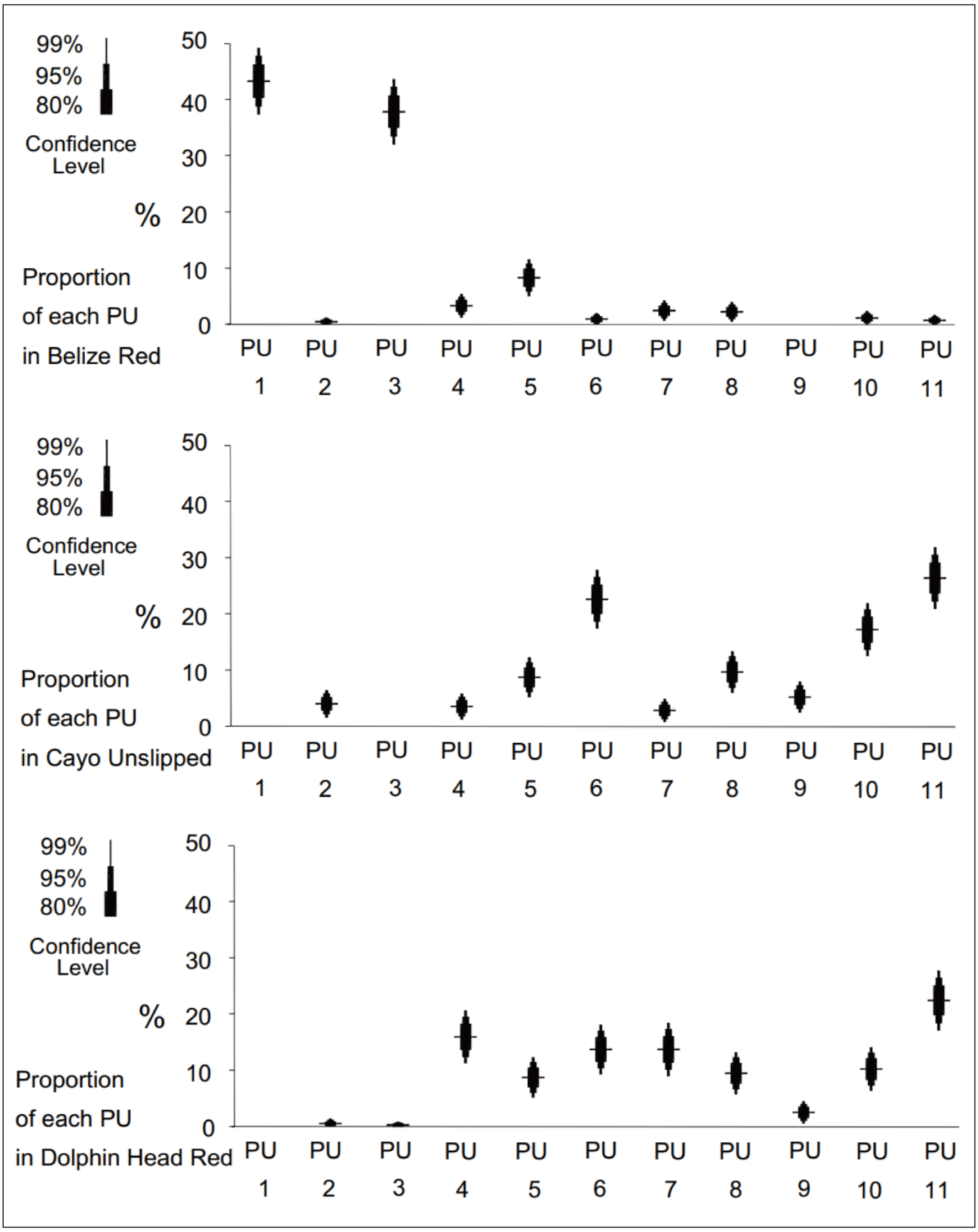

Figure 5.3: Sherds from different production units by type, expressed as proportions of the total number of sherds of that type in the sample analyzed.

complicated design, and anyone could make similar jars. This would explain the different patterns Dolphin Head Red and Cayo unslipped have. Almost all the production units that produced Dolphin Head Red were similarly responsible for making it. It is very interesting that almost all the recipes I identified could be used to make similar amounts of Dolphin Head Red, suggesting that multiple groups of potters made this type. This mainly serving vessel type thus actually had the most varied sources. The production of Cayo Unslipped was more concentrated. Large storage vessels tended to be made at the household level, and the majority of the unslipped jars were exchanged locally, although long distance exchange also occurred (Rice 2009b). Although storage jars tended to be made at the household level, this does not necessarily mean that each household made their own storage jars. Cayo Unslipped was mostly produced by three production units (6, 10 and 11), so only three recipes were mostly chosen to make this type. Although we cannot assume that only three groups of potters were responsible for making these storage jars, the production of large storage jars is actually more difficult and requires more skilled techniques to keep them stable in the process of firing (Lucas and Robb 2021). This maybe another reason that fewer production units were more responsible for producing Cayo Unslipped. Another explanation might be that the knowledge of those three recipes was shared widely, and potters knew to choose those recipes when making storage jars, because those recipes yield the most durable and useful jars.

However, the other type mostly used for serving vessels, Belize Red, may have been exclusively made for different reasons. First, this most concentrated type actually had the largest number of specimens, and the proportion of Belize Red among all pottery types were high in all contexts at Lower Dover (Walden 2021). This type is also super identifiable due to the special ashy paste and would always have been recorded at least as Belize Group even for non-diagnostic sherds, and thus there would appear to be higher proportions of them. It is also prevalent in the whole Belize Valley area (Gifford 1976). The likely production location of this type is Baking Pot (Chase and Chase 2012), another medium sized polity not far away from Lower Dover. I do not have samples from other sites in this research, but my pilot study included Baking Pot and Cahal Pech, two similar size polities nearby, and Belize Red specimens found from those two sites did group together with most Belize Red specimens from Lower Dover as well. Two pieces of Belize Red from Lower Dover in my pilot study fell in a different group including different types, just as some Belize Red specimens do in this research. This suggests that 1) the Belize Red from several polities in the area is quite similar in composition, and 2) there might be different types of Belize Red at Lower Dover. However, this may be strongly affected by the relatively small sample size of my pilot study (also see Chapter 3, Research Question 3).

Baking Pot was also included in Sunahara's (2003) research among some other nearby sites. In her research, also, only two volcanic ash groups were identified, and Belize Red specimens mostly fell in these two groups. She did not identify more different petrofabric groups that contains volcanic ash either. So, it would seem that recipes for making this type are probably very limited in the whole valley. Belize Red is the type that looks most consistent in paste among the three types, and the best effort was made to only collect data from the clay, but it is possible that there are two types of volcanic ash that caused Belize Red to drive into two big production units. No matter who is making this type, locally or exchanged from other sites, such as the possible production location, Baking Pot, as long as volcanic ash is added, the sherds would look very different from other types in composition, and there are probably two types of volcanic ash added to them. We do not know where exactly the volcanic ash comes from (Sunahara 2003; Chase and Chase 2012), and when which kind of ash is added. This does not necessarily mean potters that could get access to the one kind of ash did not have the other kind of ash at the same time; it is very possible that the same group of potters could make Belize Red using both recipes. It is also possible that it is two groups of potters that use each kind of ash separately and people would choose from those at their will. This is further discussed under later research questions. Anyway, the recipes used to make these two types are probably quite limited and all the potters knew they would use these recipes to make Belize Red. There might be some other visible differences like decoration patterns between those that use the two kinds of volcanic ashes, but my research would not be able to tell that since I only chose small sherds that often do not have any slip left.

To sum up, potters seem to have in mind what types they want to make when they chose recipes, especially for Belize Red. Also, different types have different patterns in terms of the work loads of different production units. Belize Red is made by very limited production units, Cayo Unslipped is mostly made by a few units, and Dolphin Head Red is made almost equally by all the units. Again, the relations between production units and households and districts may provide us more thoughts on the degree of specialization of these types, as discussed more under the research questions below.

This research question mainly focuses on the relationship between pottery types and the production units. Because of the mature typology study in the area, one would naturally be curious about whether the different types are different in regard to composition, since this could produce some information about the organization of the local economy. The relatively diverse production of numerous types at a good number of workshops suggests a fairly small-scale local economy whose organization formed bottom-up. I have identified 11 production units just by sampling from 9 house groups of one medium sized polity, this is a lot of production units for a relatively small place, so there is probably a lot of relatively small-scale pottery production. One imagines each production unit supplying a relatively small network of customers with a diversity of pottery types. Belize Red would be the exception though, because the heavy concentration of two production units in making this type and the large proportion of it that comes from just those two production units suggest a more centralized system with possibly more top-down elite involvement. But looking at this more production-related aspect of my results is somewhat ambiguous, so for the remaining research questions, I am going to focus more on consumption since the distribution of production units across different social units like house groups and districts will help us understand the organization of the local economy better.

5.2 Research Question 2

Based on the production units identified, how similar or different were the networks through which house groups within the same district acquired their pottery? How similar *or different were the networks through which districts acquired their pottery as a whole?*

As the basic social unit for production and consumption, the assemblages of remains from different households should reflect the degree of resource control (Hirth 1998). The household is also often the most important place of interaction among the Maya (Freter 2004; Wilk 1988; LeCount and Yaeger 2010; McAnany 2013; Robin 2003; Webster and Gonlin 1988; Yaeger and Canuto 2012). Utilitarian pottery was involved in peoples' daily lives in many ways for all households, and thus provides a lens to look at households of different status or specialization tendencies, with different amounts of wealth or other specialized activities. Although production unit sounds most related to production, the relationship between production units and social units is actually more related to consumption, and patterns in procurement of pottery for daily use can help us interpret ancient economies and possible social organizations. Also, pottery usually makes up the bulk of remains found from each house group, and thus can provide big enough samples to reach higher level of confidence.

Different households may or may not have different daily-use pottery procurement patterns due to several reasons. They could get pottery through different interaction methods or simply have different preferences due to their wealth status. When answering this question, we will only focus on how different house groups vary in regard to the production units represented so as to look for similarities and differences in procurement patterns among house groups. The question of how house groups and districts are represented in different production units involves Research Question 3 (comparison among households regardless of the boundaries of districts) and Research Question 4 (the physical extent of production units).

Figure 5.4 is a map of the research area. According to the excavator of all the house groups mentioned in this research, Lower Dover center is surrounded by a few relatively autonomous districts which would each contain a local center and a set of neighborhoods around the center. The local center is usually the residence of an intermediate elite household and also works as ceremonial center of the district, and each of the neighborhoods around it has a higher status commoner household as the head of the neighborhood (Walden 2021). "Higher status" here is proved by higher proportions

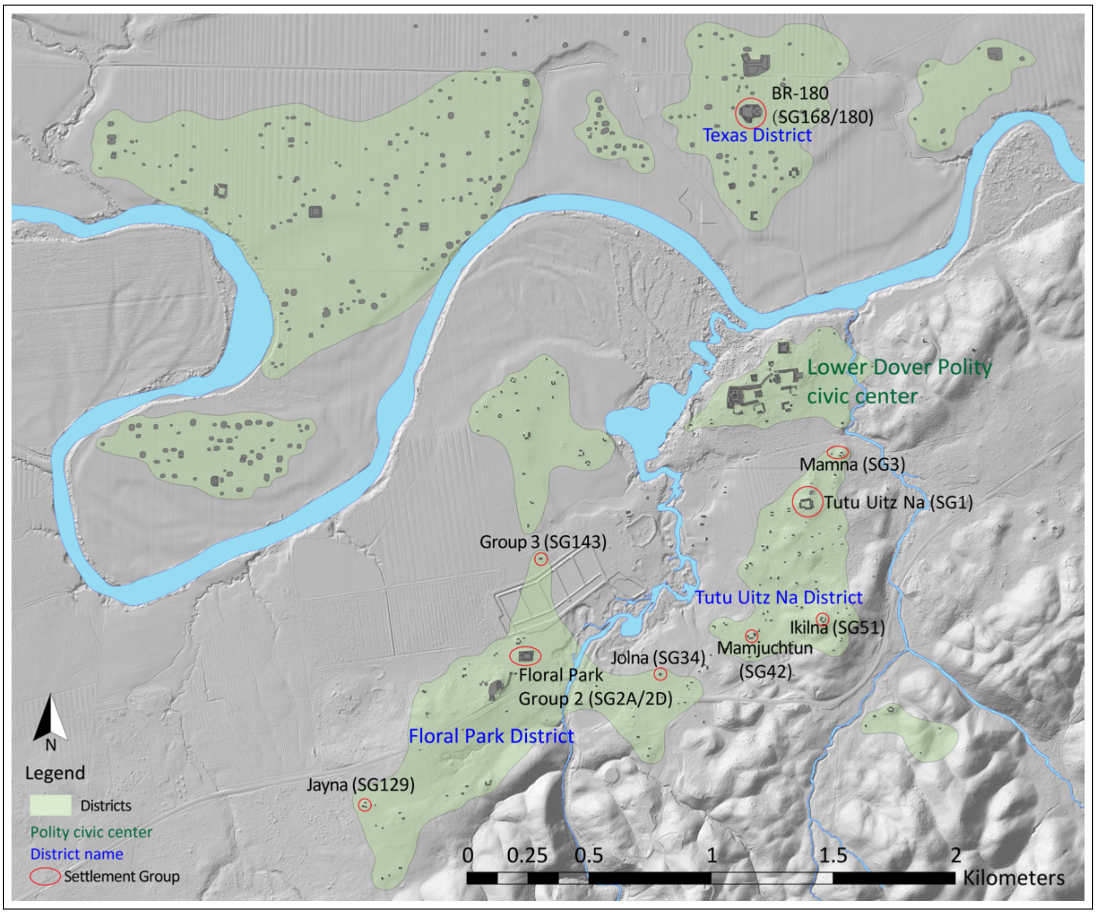

Figure 5.4: Map of Lower Dover (Adapted from Walden 2021 Figure 1.3)

of wealth items. Each district would include around 100 to 300 people while a neighborhood would be much smaller and includes about four to ten house groups (Walden 2021).

As stated in previous chapters (Chapter 2.2 Districts, neighborhoods and settlement groups and Chapter 3.4.1 Sampling strategy), I have selected sherds from nine house groups that belong to three districts. This includes three elite groups from each of the three districts – SG1, Group 2 (Structures 2A&2D), and BR168/180. Most of the remaing house groups are likely to be the heads of the neighborhoods they come from, three from Tutu Uitz Na district (SG3, SG 42 and SG51), and three from Floral Park district (SG 34, SG129 and SG143) (Walden 2021).

Most of them are located on flat areas, except for SG 51 which is located on a low mound. The intermediate elite group of each district is often located at the local center, while the head of each neighborhood are dispersed around. Most of the three districts are located on relatively fertile soil suitable for hand cultivation (Walden 2021: 312, 411, 464) and could provide agricultural self-sufficiency. More detailed information on each house groups is found in Chapter 2.

5.2.1 House groups variations within the same district

Tutu Uitz Na

Figure 5.5 shows production units as proportions of the total sherds analyzed from each house group in Tutu Uitz Na. For example the first red bar in the first row of bars means that in SG1, 17.6% of specimens (29 of 165) are grouped into production unit 1, with error ranges for different confidence levels. The other bars in the first row represent the proportions of specimens from SG1 that correspond to other production units. Putting all the house groups of Tutu Uitz Na district together, we can first see that all the house groups got products from all the production units, except SG1 does not have any products from production unit 2. But unit 2 is a very small one, and it is hard to imagine SG1, as the intermediate elite, had limited access from any production units, so probably it was just not preferred by SG1, or this was just result of sampling. Second, each house group seems to have a few, usually five to six, favored production units. Those units largely overlap from house group to house group, but they are not totally identical. SG1 preferred units 1, 3, 4, 5, 6, and 11; SG3 preferred units 1, 3, 5, 6, 7, 8, and 11; SG42 preferred units 3, 5, 7, 9, and 11; and SG51 preferred units 1, 4, 6, 10, 11. Third, most production units were preferred by at least one house group, except units 2 and 9. Unit 2 was not liked by most house groups; only SG42 choose it slightly more than other house groups. Units 3, 6, and 11 were liked by all the house groups, although to different degrees. Unit 4 was more preferred by SG1 and SG51. Unit 5 was preferred by all the house groups except SG51. Unit 7 was more liked by SG3 and

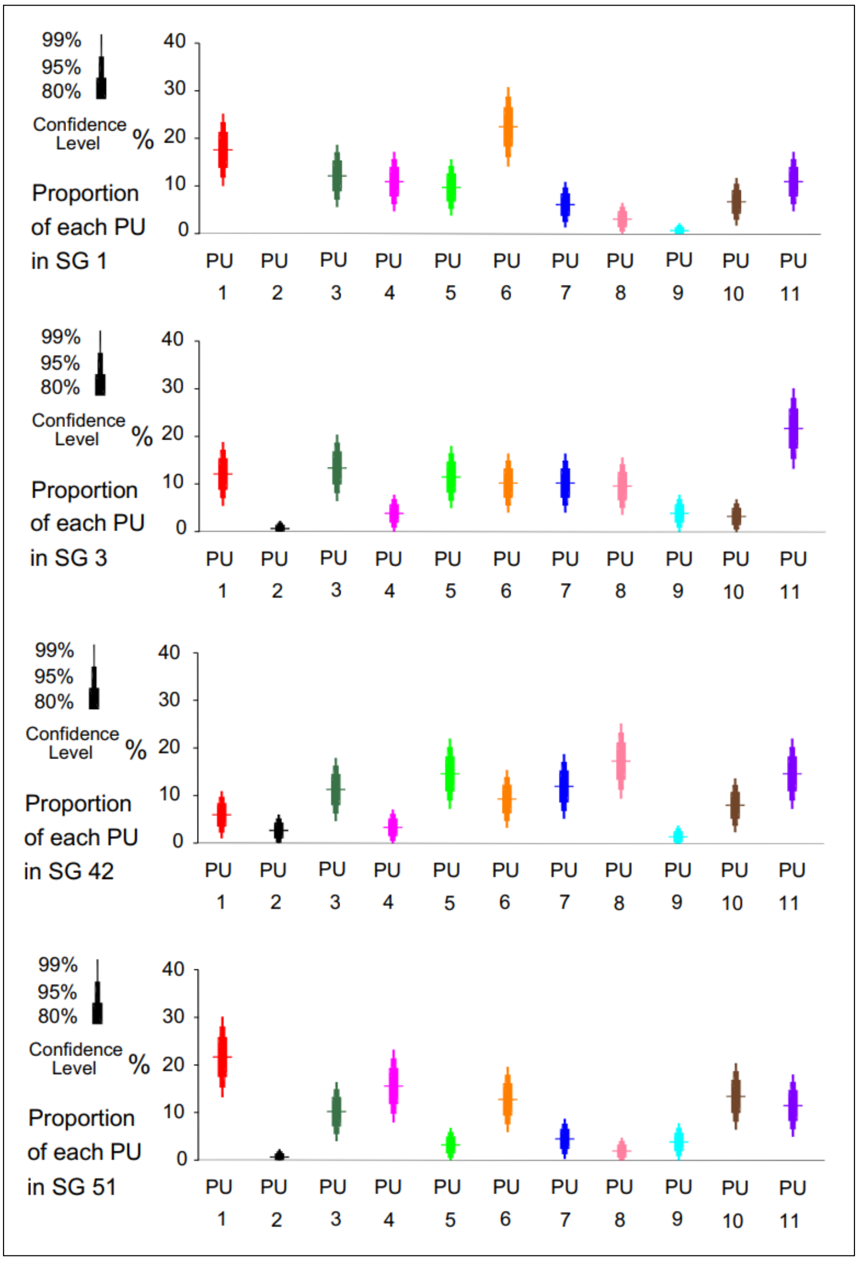

Figure 5.5: production units as proportions of the total sherds analyzed from each house group in Tutu Uitz Na.

SG42 and less so by SG1 and SG7. Unit 8 was much preferred by SG42 and SG3 than SG1 and SG51. Unit 9 was not liked much by any house group, but slightly better than unit 2. Unit 10 was preferred by SG 51 most obviously and not as much as some other production units for the other three house groups. Fourth, the degree of variation among production units in each house group was different. Although for most households, the units they preferred do not seem to have astonishing differences from other units, there is statistical significance in many cases. For example, SG3 seems to have gotten pottery quite similarly from several production units, while SG51 had clearer preferences, and the differences between the preferred and non-preferred units were stronger than in other house groups. We do not know the reason for these differences. SG3 did have some degree of ritual significance as the head of its neighborhood, and could summon labor from other lower status commoners (Walden 2021: 383), but so did SG42 (Walden 2021: 403). SG51 had quite a prominent location on the top of a small hill and had a better viewshed, but the connection between the prominent location and slightly more concentrated choices of production units is unclear.

In general, the pottery procurement patterns of these house groups from Tutu Uitz Na do not seem very different. It is very likely that that they were getting pottery through the same exchange mechanism. The actual scale of the exchange of simple daily-use vessels is very unclear, except that it was most likely local (Rice 2009b). The fact that almost all the house groups procured pottery from all the production units indicates that they did not likely get the pottery directly from producers, which would cause every house group to have a different combination of production units, and not to have products from some units if they had no connections with those producers. Instead, they more likely got their pottery from some more centralized mechanism that created what has often been called “pooling.” Either redistribution or a market could create this pattern. However, on the basis that every house group was getting products from all the production units, but they all still had their own preferences, they more likely got their pottery from a marketplace where all kinds of products were available for everyone, and each house group had a chance to pick and choose instead of being given products randomly though a redistribution system. Some researchers have argued that elite groups would consume utilitarian pottery, but were not likely involved in its production or distribution. Instead, they would more likely be involved in the running of the marketplace (Ball 1993).

Floral Park

The story at Floral Park is similar. Figure 5.6 shows the proportions of each production unit in the pottery collected from each house group in Floral Park. For example, the first red bar in the first row of bars means that in Group 2 (Structures 2A&2D), 17.5% of specimens (29 of 166) are grouped into production unit 1, with error ranges for different confidence levels. The other bars in the first row represent proportions of specimens from SG1 that are grouped to other production units. We can see that, first, all the house groups possessed products from all the production units. Second, they all favored a few production units. Their choices overlapped sometimes, but the number of units they prefer varies from three (SG129) to five (Group 2 [Structure 2A&2D] and SG34), SG143 preferred four units. Third, most of the production units were preferred by at least one house group, sometimes many, sometimes few. Fourth, the degree of variation among production units in the same house group varied. Some had more obvious differences: for example, SG129 clearly preferred units 3, 10 and 11, and for SG143 preferred units 3 and 11, and maybe unit PU6 as well. On the contrary, SG34 had products more evenly distributed across the units it preferred. The reasons for these differences are disused below.

Among the similar-status commoner households in this district, SG34 had some degree of craft productions. It had relatively high proportions of chert tools and debitage and artifact assemblages indicating a range of crafting activities (Walden 2021: 441). It may have produced certain artifacts, and in addition to getting products from a marketplace, residents of SG34 may also have exchanged for daily-use pottery in other ways, maybe directly with some potters. SG129 focused on fewer production units than others, and had more wealth items like polychromes in the Early Classic, although it seems to have lost access to them during the Late Classic (Walden 2021: 451). If its wealth lasted to Late Classic, focusing on fewer production units could potentially mean careful selection of better-quality vessels to suit their position, but since that was not

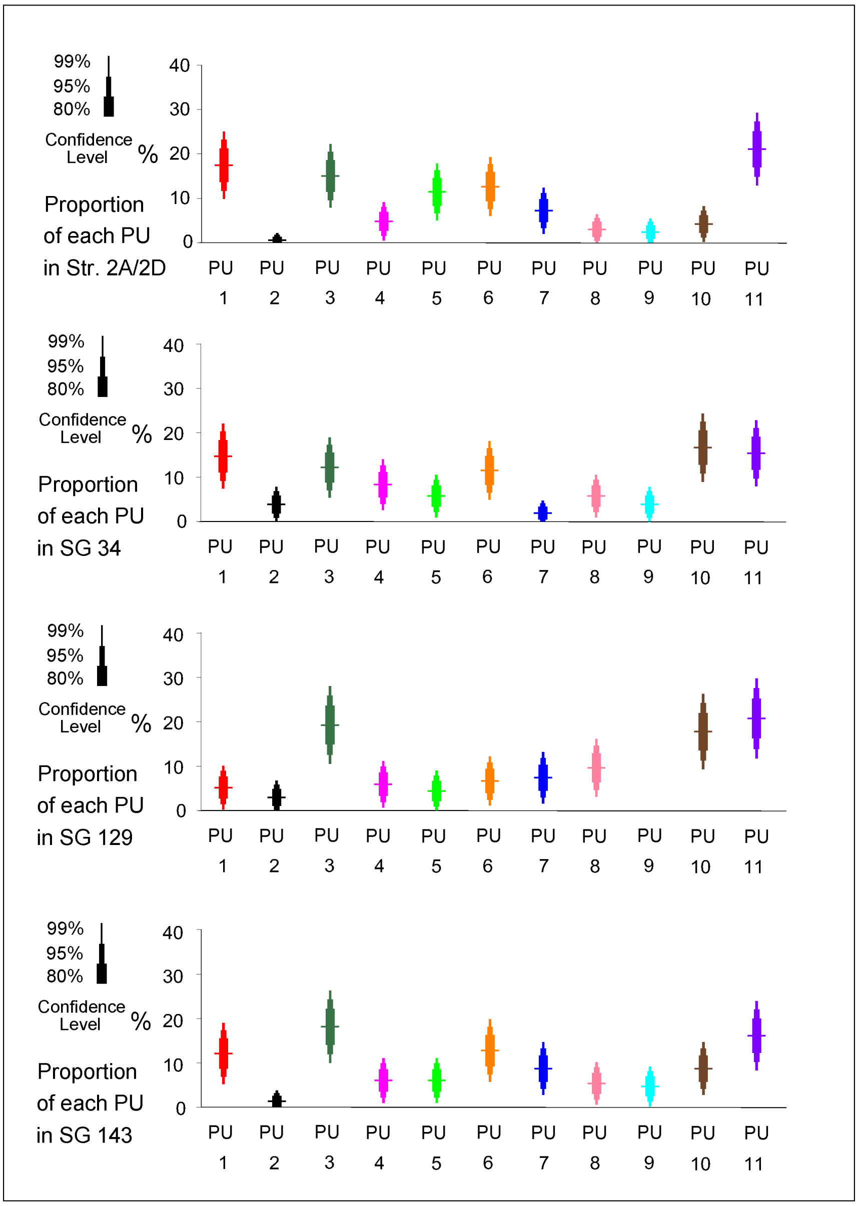

Figure 5.6: production units as proportions of the total sherds analyzed from each house group in Floral Park

the case, there might be other reasons that residents at SG129 favored fewer production units, such as being far away from the Lower Dover center, as discussed under the next research question.

Similar to Tutu Uitz Na, residents at Floral Park had free access to a marketplace where they could choose products they preferred, and usually had rather clear thoughts about which production units they liked, although they did not only get products directly from only a few producers either.

Texas

Texas only has one house group from which only Belize Red sherds were collected, so there are no useful comparison to make in this section. It will be discussed in the comparison among districts in the next section 5.2.2.

Comparison between Tutu Uitz Na and Floral Park

Since house groups from both districts all tended to get utilitarian pottery from a marketplace, we can compare the production units that house groups from different districts preferred to get an idea about whether they used the same market. I think they did. Figure 5.5 and Figure 5.6 show that all the house groups within the two districts all got products from all of the 11 production units identified. In general, despite varied proportions of production units at each house group, the combinations of production units in house groups from the two districts are not too different. The favored units of each house group within the same district did not overlap all the time, and sometimes house groups from different districts shared preferences. However, the production units not favored by residents in Tutu Uitz Na, like 2 and 9 were not preferred by residents of Floral Park either. There might have been limited products from these production units on the market in general, or these products might have just not been liked by consumers. Or the observation could also simply be a result of limited sample size. The similarities in the patterns among house groups from both districts suggest that they all procured their daily-use pottery from the same market, where the products from the same set of production units were provided and each house group could pick and choose the products they liked.

Another thing worth mentioning is that production units 1 and 3 both almost exclusively produced Belize Red, but some house groups clearly had a preference between these two options that looked the same: SG1, SG42, SG51 in Tutu Uitz Na and SG129 and SG143 in Floral Park. Again, this was not really consistent among house groups in the same district, so it is hard to say whether any house groups had less access to one of these production units, or if it was just a matter of preference. Different proportions of these two exclusively Belize Red making units are further discussed below when comparing districts as a whole in section 5.2.2.

To sum up, house groups within the same district likely all procured daily-use pottery from a central market, and house groups from Tutu Uitz Na and Floral Park likely used the same market probably located at the site core, although there might have been several smaller markets located at the center of each district, which might have existed before the rise of Lower Dover in the Late Classic (Walden 2021: 570), and could possibly still have remained in the Late Classic for simple local exchanges. The existence of these marketplaces which may have caused differences in patterns of pottery procurement are not obvious in my results. Furthermore, residents at Floral Park seem to have had slightly clearer ideas about what products they wanted, but not enough to cause great differences from the house groups at Tutu Uitz Na.

5.2.2 Comparison among Tutu Uitz Na, Floral Park and Texas districts.

Comparison within the same district and variations among house groups in the same district has already shown that there was likely a marketplace where residents from Tutu Uitz Na and Floral Park could all go to procure daily-use vessels based on their preferences. Comparing the districts as a whole further verified this. How each district relied on products from each production unit is compared in this section; and how wares from different production units were distributed to different house groups and districts is discussed under Research Question 4.

Figure 5.7 shows different production units as proportions of the total sherds analyzed from each district. For example the first red bar in the first row of bars means that in house groups from Tutu Uitz Na, 14.4% of specimens (91 of 630) correspond to production unit 1, with error range for different confidence levels. Due to the large sample size, the error range even for 99% confidence is not too big for Tutu Uitz Na and Floral Park, so we are quite confident that the patterns in Figure 5.2.4 represent the patterns of utilitarian pottery procurement well in those two districts; less so for Texas due to the limited sample size. Generally speaking, the patterns of Tutu Uitz Na and Floral Park look very similar, almost identical, only the ratios of two Belize Red focused production units (1 and 3) look different. Tutu Uitz Na preferred unit 1 while Floral Park preferred unit 3. Both Tutu Uitz Na and Floral Park had products from all the units. This would very likely be the case for Texas as well if the other two pottery types could also have been collected. Tutu Uitz Na and Floral Park focused on the same few units (1, 3, 6, and 11); and the unit they did not like are the same as well (unit 2 and 9). However, the reason units 1 and 3 are always favored could also be that those two almost exclusively made Belize Red and produced about 80% of Belize Red in total (also seen in Research Question 1). In other words, the production of Belize Red was highly concentrated in units 1 and 3 while the productions of the other two types was more spread, perhaps affecting the importance of units 1 and 3 since the residents had to choose from these two most of the time if they wanted Belize Red vessels.

The preference between these two Belize Red producing units could indicate something interesting. Tutu Uitz Na preferred unit 1 while Floral Park preferred unit 3, although the difference between units 1 and 3 in Tutu Uitz Na was not as strong or statistically significant as in Floral Park. Texas, on the other hand, probably because it only had Belize Red specimens, despite the big error range, clearly preferred unit 1 much more than unit 3, but the data only comes from one elite house group in there. If exchange only happened at the marketplace located at the Lower Dover center, the three districts would still all have had easy access to it. Tutu Uitz Na was located very close to the Lower Dover site core as shown in Figure 5.2.1, and Floral Park was only a little bit further away. Although Texas was on the other side of the Belize River, there are some spots where the river is very shallow and could be easily forded, and setting up bridges at proper places would not have been difficult either. Therefore, residents of all three districts would all have been should all be able to access the marketplace

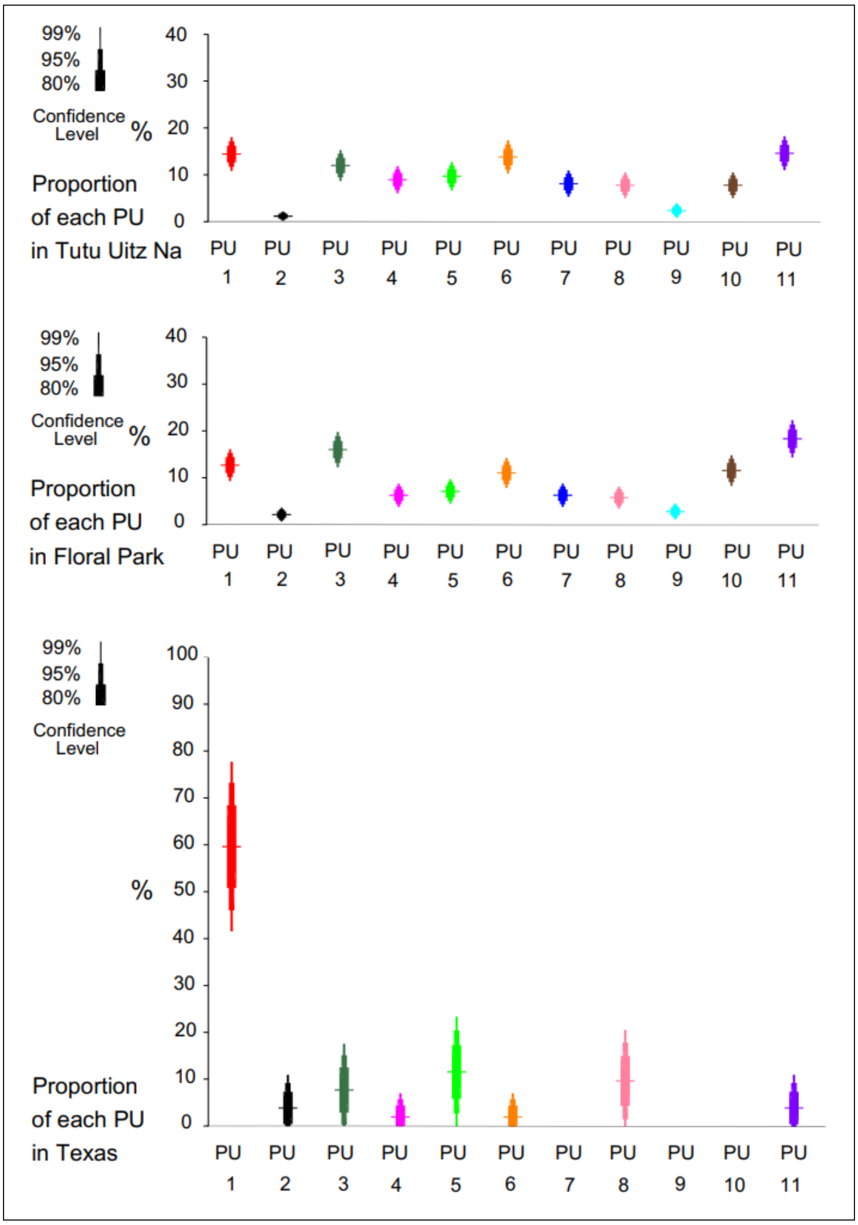

Figure 5.7: Different production units as proportions of the total sherds analyzed from each district.

at the site core easily, if there was one. But still, they all had their own preferences between the two units that produced Belize Red. There might be some other mechanism behind this. Sunahara (2003: 142) proposes that all polities in the Belize Valley had pottery production during the Late to Terminal Classic and local products were exchanged through market economies. She also proposed that there might have been a regional market system used to exchange some special but still utilitarian pottery, like the prevalent type in the valley, Belize Red. She also identified two groups of Belize Red, and smaller sites like Floral Park might not have had access to both groups of Belize Red (Sunahara 2003: 143). But in my results, all three districts had access to both units that produced Belize red, and Tutu Uitz Na and Floral Park had different preferences between these two types of Belize Red, with an even more obvious preference at Texas. My results could not identify the exact place where Belize Red was produced, or the different of the groups of Belize Red, but there is something else worth mentioning. In my pilot study in 2018 (see Chapter 3.3 Pilot study), I picked specimens of different types of pottery from Lower Dover, and two other similar sized polities in the Belize Valley that are not far away, Baking Pot and Cahal Pech. The types I picked were Belize Red, Dolphin Head Red, Garbutt Creek Red and Mount Maloney Black. The sample size was quite small in the pilot study (only seven pieces of Belize Red from each of the three polities). However, it already showed that there might be two varieties of Belize Red in terms of composition. In the result of the pilot study, most Belize Red from all three polities (19 of 21) fell in one group that only had Belize Red specimens. There were only two pieces from Lower Dover that fell in a different group that also included the other three types. Those two pieces were from SG9, which is not included in the sample for this research. But two pieces from SG1 which fell in the same big group of Belize Red with all the other Belize Red specimens from Baking Pot and Cahal Pech in the pilot study are also included in the sample this time, and they both grouped into production unit 1 this time.

It is still unclear what exactly this suggests. There are also two groups of Belize Red in my results this time. Possibly those two Belize Red recipes are popular in different areas. Or possibly they have different production locations? Although only Lower Dover had both types of Belize Red in the pilot study, the other two polities might not have shown two groups could be due to small sample size. Or possibly in addition to the local marketplace where all house groups had similar access, there might have been higher level exchange especially for types like Belize Red. Except for the intermediate elite group of the Texas district that has dramatically more Belize Red from production unit 1 than unit 3, and SG129 with the opposite pattern, all the other house groups had products from both production units not that differently. Maybe only BR168/180 had closer connections with production unit 1 and SG129 had less connection with that source than others. Is it possible that production unit 1 is the recipe Baking Pot produced in large quantity and distributed along the valley through various trading routes as some researches have proposed (Chase and Chase 2012)? The two pieces that fell in production unit 1 this time were grouped together with all the other Belize Red pieces from Baking Pot and Cahal Pech. We do not have enough data on what Belize Red at other locations looked like in terms of composition. Future research might tell us more about the exchange and distribution mechanism of this special type of pottery.

For the other production units that produced a mixture of the types in various proportions, comparing districts makes the differences between units even less obvious than looking at the house groups separately. When looking at house groups separately, although they all seem to favor five to six production units, the ones they favor do not always overlap, and even for the units two house groups both prefer, the proportions of that unit in the two house groups are usually not very close. But when comparing districts as a whole, the general pattern of the proportions each unit takes in Tutu Uitz Na and Floral Park look almost identical. Although each house group made choices separately, the aggregate results for the two districts were not that different because everyone went to the same market where the same set of products were provided. Combining house groups together made the differences between larger social units even weaker, providing another piece of evidence that residents from Tutu Uitz Na and Floral Park likely all got pottery from the same marketplace. Not much more can be said about Texas due to its small sample but it is possible that it behaved like the other two districts.

To sum up, despite possibly different policies of the intermediate elites from the three districts in terms of labor control, rituals and feasting, involvement in production, and degree of wealth compared to commoner house groups in the Late Classic (Walden 2021; also stated in Chapter 2), different districts procured their quotidian pottery in remarkably similar ways. They very likely all got products from the same central market at the polity center. Although located on different soil types, which may affect the degree of self-sufficiency in subsistence production (Walden 2021), and potentially the ability to purchase or exchange for pottery, they showed no obvious differences in my results. It is possible that this conclusion is reached because only elite house groups and relatively wealthy heads of neighborhoods are included in this research. We may or may not see more variations among house groups, and districts if more lower status house groups could be included as well.

5.3 Research Question 3

Based on the production units identified, what other reasons may have caused house groups to have similar or different pottery procurement patterns? Being elite groups or commoner groups? Having different lengths of occupation history? Being located at different distances from the civic center of the Lower Dover polity?

We have compared house groups within the same district as well as different districts as a whole. The results suggest that all the house groups from Tutu Uitz Na and Floral Park, and probably Texas as well, could all go to the same marketplace freely to select daily-use pottery based on their preferences. Since all the house groups selected in this research could potentially all go to the same market and get their vessels through similar mechanisms, I would like to further investigate the possible variations among house groups based on some other obvious differences among them despite the districts they are from, including wealth difference, occupation length difference and distance to the polity center where the marketplace was most likely located, to find out if any of those aspects may or may not have had impacts on the daily-use pottery procurement strategies of different house groups. Since BR168/180 only had Belize Red specimens, it is not included in these comparisons.

5.3.1 Pottery procurement patterns of intermediate elite house groups vs high status commoner house groups

One intermediate elite and three wealthier commoner house groups that have multiple structures of larger size and possess higher proportions of wealth items (Walden 2021) were selected from both the Tutu Uitz Na district and the Floral Park district. Although the elite groups chosen in this research are not the apical ruling ones but the intermediate elite that often act as heads of districts and serve as agents between higher-level rulers and lower-level subjects, they still have clear differences from the commoner groups in terms of wealth. The elite groups had more and larger structures which would have required more labor investment, and usually had special kinds of architecture, like ritual and ancestor-worship-related shrines. Their residences had larger plazas in for rituals or feasting, as indicated by their artifact assemblages (Walden 2021). Also, the elite groups usually had much higher proportions of wealth items including a set of imported and rare products (Walden 2021). Much archaeological, ethnographic and historical research has identified different pottery assemblages at elite and commoner households. Usually the elite would have higher proportions of more valuable pottery like polychromes (Costin 1991; Arnold III 2003; Lucero 1994). However, utilitarian pottery (such as cooking, serving and storage vessels) were expected to be less different among house groups despite differences in wealth level because the major staples people relied on were mostly similar, and each household tended to have similar inventories to carry out these daily life activities. Even so, using pottery of similar function that is seemingly the same on the outside does not necessarily mean the vessels would all come from the same source. There could still be different patterns in the procurement strategies of different social units. Even for utilitarian pottery, the elite groups may have selected a wider range of production units because they had better access to all of them, perhaps through tribute, or patronized production. Or they may have tended to concentrate on a few production units that produced better quality. Although it is hard to identify quality, we could still look for signs of preferences different from these of the commoner groups. Elites may also have showed no obvious difference from commoners, due to the fact that all the house groups did share a set of daily activities that required a similar inventory of pottery and the elites did not have to be different from commoners with respect to daily-use pottery, especially in the case of intermediate elite groups that stand out in each district. The house groups I have selected are also heads of the neighborhoods they belong to and would be relatively wealthy as well (Walden 2021).

Also, the proportions of storage, cooking and serving vessels might be different due to "household size, storage capacity, access to diverse foodstuffs, hosting events, ceremonies and pottery production activities" (Lucero 1994: 18), elites may have more large storage vessels than commoners and more specialized vessels for processing different foods due to a higher diversity of foods (LeCount 1996; Sinopoli 1991: 122). As mentioned in Research Question 1, main vessel forms for two of the three types I have selected are mostly serving vessels like bowls, plates and dishes, and the main vessel form of the third type is usually medium-large storage jars. However, I cannot discuss the proportions of serving vessels or storage vessels in the whole assemblages of those house groups because I choose the same number of specimens of each type from each house group for my sample. I will focus on whether the elite house groups behaved differently in their strategies utilizing production units that focused more on producing serving or storage vessels. As mentioned under research question 1, production units 1 and 3 almost exclusively produced Belize Red, units 4 and 7 focused more on production of Dolphin Head Red, units 2, 6, 9 and 10 focused more on production of Cayo Unslipped, units 8 and 11 produced Dolphin Head Red and Cayo Unslipped in similar amounts, and unit 5 produced all three types in similar amount.

Comparing groups of production units that tended to produce the same type of pottery in regard to how they were favored by house groups helps us find out if there were differences between elite and wealthy commoner groups. Figures 5.8 - 5.12 below are different production units expressed as proportions of the total sherds analyzed from each house group. The figures are organized into groups of production units that tend to produce the same type of pottery, and the house groups are arranged in order of elite groups then commoner groups. BR168/180 is excluded because it only had Belize Red specimens. Each bar represents a house group. For example, the first bar in Figure

5.3.1 indicates that 17.6% of specimens (29 of 165) selected from SG1 correspond to production unit 1, with error ranges for different confidence levels.

Figure 5.8 presents production units that almost exclusively produce Belize Red. The two units were used to different degrees by most house groups. Unit 1 had SG51 as its best customer, followed by the two elite house groups and then SG34, SG3 and SG143. It was not so much liked by SG42 and SG129, while SG129 is one of the best customers of production unit 3. The degree to which people used products of unit 1 varied more strongly than in the case of unit 3. As mentioned above, production units 1 and 3 might have used two types of volcanic ash as temper, one of which might have been harder to access, but we do not know which is which even if there are such differences. In the results of my pilot study, two pieces of Belize Red from Baking Pot that were also picked in this research correspond to unit 1, and it is possible that the variation between house groups in the choice made between these two production units could suggest degree of connection with Baking Pot. BR168/180, the elite house group of the Texas district which is not included in the comparison in this section, actually had mostly Belize Red from unit 1, and it is likely that it had more connection with Baking Pot. Both elite groups included in this research did have larger amounts of unit 1, although they were not its best customer, and production unit 1 is nowhere near exclusively procured by only the elite groups. It is also possible that Belize Red, as the most prevalent type in the area (Gifford 1976), was distributed in other than just through circulation in the local marketplace. However, only a few house groups are included in this research and is hard to reach a clear conclusion about the differences between the two units. More specimens collected from Baking Pot and more house groups at Lower Dover might provide more data in the future. Either way, at this time, SG1 and Group 2 (Structure 2A&2D), as the elite groups of Tutu Uitz Na and Floral Park, seem to have used products from these two Belize Red producing units to a similar degree as other house groups. However, there is nothing special about the elites in terms of choosing between the two units; but some commoner house groups had stronger preferences between these two.

Figure 5.9 shows how much products each house group chose from production units that produced more Dolphin Head Red, which is another serving vessel type. For those

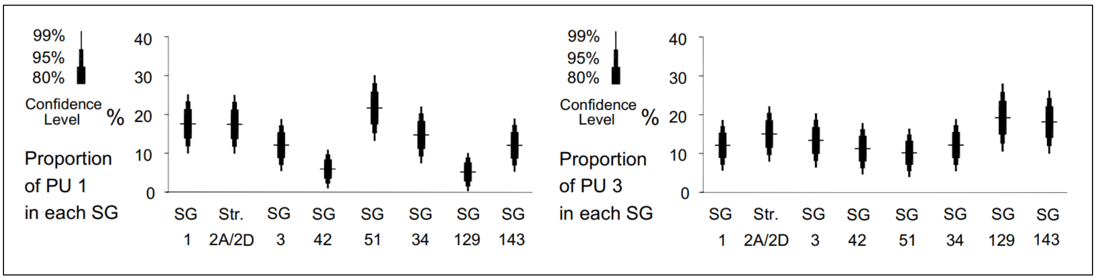

Figure 5.8: production units that produced Belize Red expressed as proportions of the total sherds analyzed from each house group.

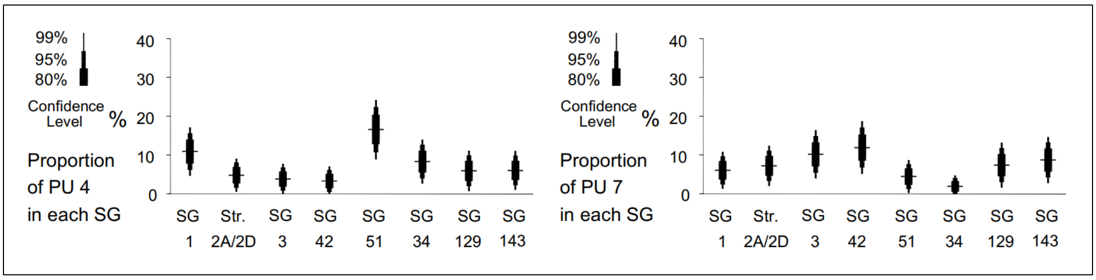

Figure 5.9: production units that produced Dolphin Head Red more expressed as proportions of the total sherds analyzed from each house group.

two units, the patterns are similar to those of Belize Red. SG51 was the best customer of unit 4, SG1 liked it as well, but the other house groups less so. As for unit 7, most house groups liked it except SG51 and SG34. There were obvious differences between commoner groups in both units, but the elite groups did not show any special patterns. Again, there is no way for us to find out which unit produced a better quality of Dolphin Head Red that could help further account for procurement patterns based on preferences between the two units. Thus, from the results we have now, residents of those house groups did not have different patterns in procuring this type of serving vessel either.

Figure 5.10 shows how much products each house group chose from the production units that tended to produce Cayo Unslipped, the only type that consisted mostly of medium to large sized storage jars. Patterns shown in these units are slightly different from those mostly producing serving vessels. Production unit 2 (21 pieces) and unit 9 (32 pieces) had fewer specimens in the sample studied, and all the house groups had fairly similar proportions of these two. For the other two units that produced more Cayo Unslipped, unit 6 apparently had SG1 as its best customer, and all the remaining house groups liked this unit to a similar degree. For unit 10, a few commoner house groups (SG129, SG34 and SG51) were its best customers, and the two elite groups did not like this production unit very much. SG3 did not like this unit very much either. The most obvious special case in these four units was the preference for unit 6 by SG1, while the other elite group did not behave too differently from the commoner groups. It is possible that only SG1 made some choices differently on purpose with the other house groups as the wealthier elite group. Perhaps unit 6 produced larger jars that could provide more storage volume needed by the elites as suggested above, but we could not be sure. Future research might provide more data for further discussion if the rim diameters of the specimens are also measured to represent the volumes of the storage jars. Another thing worth mentioning is that the two most loyal customers of production unit 10, SG129 and SG34 both belonged to Floral Park district. This might indicate some exchange directly between producers and consumers other than through a marketplace.

Figure 5.11 shows the two production units that produced Cayo Unslipped and Dol-

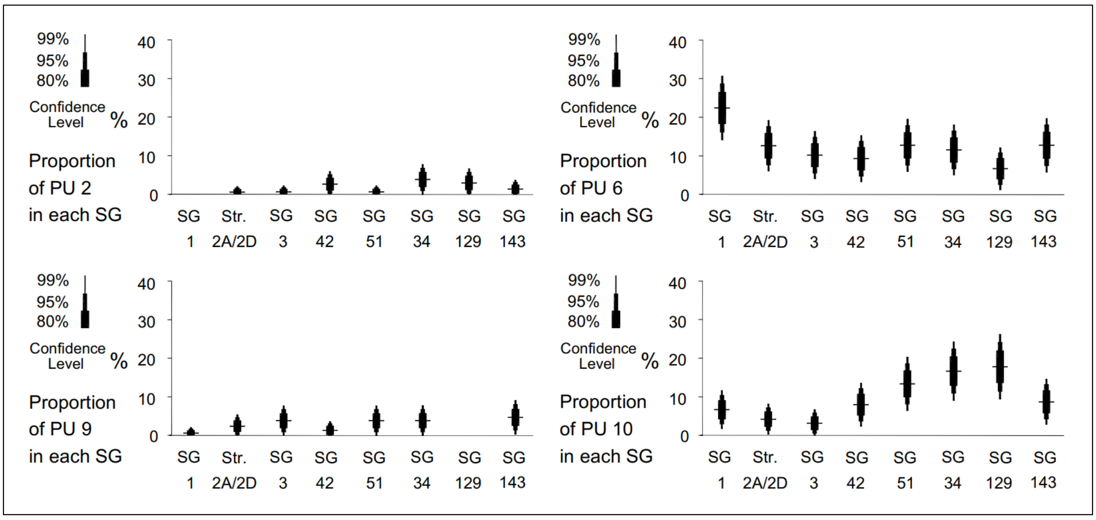

Figure 5.10: production units that produced Cayo Unslipped more expressed as proportions of the total sherds analyzed from each house group.

phin Head Red in similar amounts. For these two units, the variations among commoner groups were quite big and some groups behaved like the elite groups. Both elite groups disliked production unit 8, and SG51 shared this opinion, while SG1 (as well as SG51 again) did not like production unit 11. This is the second time residents at SG1 showed stronger preferences about the products they liked, or rather did not like for some unknow reason. There might be some other traits uncatchable by chemical composition, but more involving the design or decoration patterns that are not recorded in this research.

Lastly, Figure 5.12 shows how much products each house group chose from production unit 5 which produced the three types in similar amounts. Both the elite groups, SG3 and SG42 all were good customers of this unit, while the others had significantly less interest in it. One thing worth mentioning is that the last three bars are the three commoner house groups of the Floral Park district, and their lower interest in this unit was not so clearly shown in the comparison of house groups within the same district above (see in Research Question 2 Figures 5.2.2 and 5.2.3). We do not know the reason

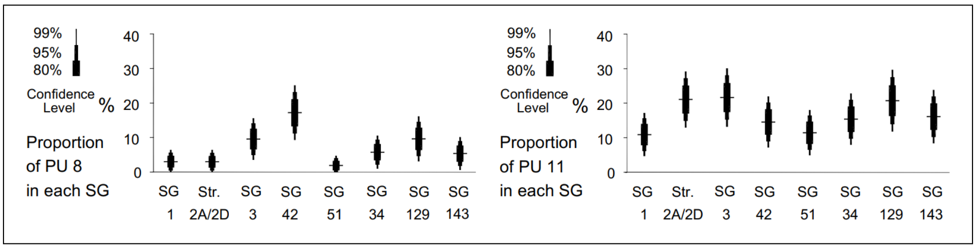

Figure 5.11: production units that produced Cayo Unslipped and Dolphin Head Red in similar amounts expressed as proportions of the total sherds analyzed from each house group.

for this pattern. It may again indicate a small amount of exchange directly between producers and consumers, but in terms of the comparison between the elite groups and the commoner groups, this unit does not show any more unusual behavior of the elite house groups.

To sum up, most of the time, the elite house groups did not behave very differently from the commoner ones. Only SG1 from Tutu Uitz Na sometimes was different by being clearer in its choices of production units that tended to produce the same products. However, the elite group of the Floral Park district did not look too different from the commoners. This might be because the intermediate elite groups of the two districts still had different degrees of wealth during the Late Classic Period. The elite at Tutu Uitz Na had a higher diversity of wealth items and possessed some types of wealth items like jade which the commoners did not have at all. The elite group at Floral Park, on the other hand, shared the same type of wealth items possessed by commoners but had greater amounts of them (Walden 2021). This may explain why Group 2 (Structures 2A&2D) did not look special but SG1 did a little bit sometimes. However, although SG1 did look more special among the house groups, it did not only focuses on fewer sources. Neither were there any production units that only produced products for SG1, irrespective of the type of pottery that unit was more focused on producing. Access to wealth items and differences among house groups in regard to wealth items got smaller during the

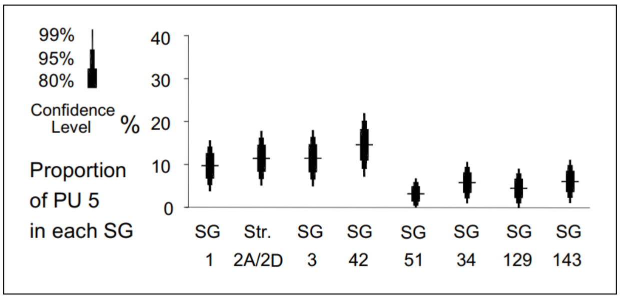

Figure 5.12: production units that produced all three types in similar amounts expressed as proportions of the total sherds analyzed from each house group.

transition from Early Classic to Late Classic (Walden 2021), so the fact that differences in quotidian products seem to be very slight is quite reasonable, especially when the elite groups here were only the heads of districts, and the commoner house groups here were also heads of their neighborhoods. They were usually quite wealthy as well in the first place, so we do not see big differences among those heads of neighborhoods either.

The answer to research question 1 was that utilitarian pottery making had only a low level of specialization in general. The behavior of house groups of different levels of wealth further shows a rather low level of specialization in utilitarian pottery making since even elite groups did not have any products specially made for and provided to them. The combinations of production units the elite groups chose looked very similar to those of the commoner house groups, except that SG1 looked a little bit different sometimes.

5.3.2 Pottery procurement patterns of house groups that have different occupation histories

Occupation history is another obvious difference among house groups. Some house groups have very long histories from the Middle Preclassic period all the way to the Late Classic period, even to Terminal Classic. Some house groups only appeared in Late Classic. Although all the house groups selected in this research were located on relatively more fertile soil for hand cultivation and could easily support themselves in regard to subsistence (Walden 2021), and all also accumulated enough wealth during Late Classic period and left enough remains to provide specimens for this research, they may have had different exchange networks and shown different patterns in daily-use pottery procurement. However, in short, different occupation histories do not seem to have affected residents' procurement strategies.

Table 5.1: Occupation history of each house group.

Period	SG1	SG3	SG34	SG42	SG129	SG51	Str. 2A&2D	SG143
Post Classic AD 900/1000-1521								
Terminal Classic AD 800-900/1000								
Late Classic AD 600-800								
Early Classic AD 300-600								
Terminal Preclassic AD 150-300								
Late Preclassic 300 BC - AD 150								
Middle Preclassic 900-300 BC								
Early Preclassic 1200/1100-900 BC								

Table 5.1 shows the occupation histories of the house groups except BR168/180, which has the same occupation length as SG1. It is not shown here because it is not

included in the comparison below. Two of the three elite house groups I selected all have long histories, except the elite group from Floral Park, for which the starting occupation phase is most likely to be Late Classic. However, the plaza of Floral Park center had quite a long history, starting from Middle Preclassic and lasting untill Late Classic (Brown et al. 1996), so it is very likely that there were elite groups around long before Late Classic, that only moved to this location during the Late Classic along with the rise of Lower Dover (Brown et al. 1996). The commoner households, although they are all heads of the neighborhoods they belong to, do not always have longer occupation histories. Some of those that have longer histories have both larger structures and more prestige remains, like SG3 have *jute* accumulation layers which emulate local elite practices (Walden 2021). SG129, for example, had more polychromes than other commoner households although that was in earlier periods (Walden 2021). The two commoner groups that had relatively short occupation spans, SG51 and SG143, also had outstanding characteristics which made them count as high status commoners. SG51 had quite a prominent location, and, although it did not have many wealth items, it had several large structures which also indicate wealth (Walden 2021). SG143 was a small house group, but did yield wealth items like jade, which was rare. It also had ritual artifacts, was located quite close to the Floral Park center, and was revisited in the Post Classic period (Brown et al. 1996). In other words, all the commoner house groups were quite outstanding at least during the Late Classic period, despite the length of their occupation histories. Probably this is the reason why those that seem to have had longer occupation histories do not seem to have been very different in pottery procurement strategies from those that thrived only in the Late Classic period.

Figure 5.13 is different production units expressed as proportions of the total sherds analyzed from each house group. It shows how each production unit was favored more or less by each house group separately. As above, each bar represents a house group, and the house groups are ordered from the longest to the shortest occupation length. Each bar shows the proportion of each production unit found in that house group. For example the first bar in the graph in the upper left corner means that, 17.6% of specimens (29 of 165) of pottery sherds possessed by residents of SG1 were identified as production unit

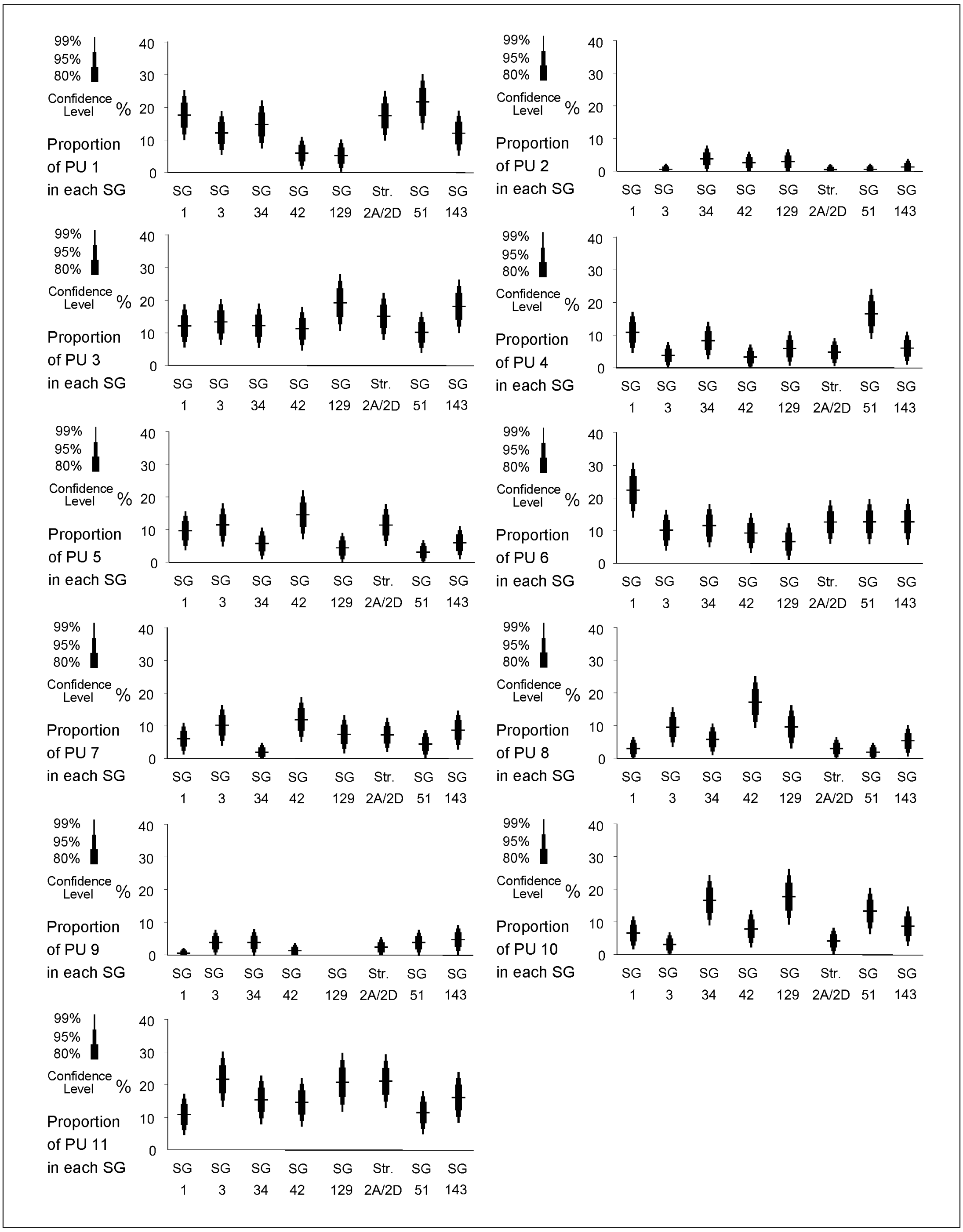

Figure 5.13: Different production units expressed as proportions of the total sherds analyzed from each house group in the order of occupation length.

1, with error ranges at different confidence levels. We can see that there are no obvious differences among house groups that have different occupation histories, regardless of whether we compare all the production units, or all the house groups.

5.3.3 Pottery procurement patterns of house groups that are located at different distances from the civic center of Lower Dover

The trickiest factor that may either have caused differences or encouraged similarities in terms of pottery procurement patterns could be the existence, locations, and scale of marketplaces. Marketplace and market exchange in pre-Hispanic societies has drawn the attention of researchers recently (King 2015a, 2020; Braswell et al. 2010; Cap 2015; Dahlin et al. 2007; Freidel 2020; Jones 1996; Shaw 2012; Wells 2006; West 2002). However, the Classic Maya have mostly been thought to be poorly developed in commercialization (Demarest 1992; Rice 2009b). Marketplaces are hard to identify physically but can be studied through the distribution of goods, which should show telltale patterns if there were marketplaces (Hirth 1998; Chase et al. 2015; Hutson et al. 2016; Masson and Freidel 2012). Market patterns are usually quite different for different kinds of goods (Cap 2020). Plain utilitarian goods are probably less exchanged at the market. However, even for precious goods, despite the existence of large permanent marketplaces, there could be different patterns of distribution due to the degree of centralization of different polities (Hutson 2020), as well as through interactions with many other distribution methods (King 2015a; Dahlin et al. 2010; Stark and Garraty 2010). At Lower Dover, like many other similar scale polities in the area, we do not have any physical remains proving a permanent marketplace (Guerra and Awe 2017). So, if there were marketplaces, they may well have been occasional ones, probably associated with ceremonial activities (Walden 2021).

Although recent research at the civic center did not find strong evidence of marketplaces (Guerra and Awe 2017), Walden (Walden 2021: 567) used a distributional approach to investigate in the possibility of marketplaces by comparing the accessibility of imported/exchanged items between both intermediate elites and commoners at the transition from the Early to Late Classic, and concluded there was a higher degree of commercialized exchange in the Late Classic than the Early Classic that may indicate a central marketplace. However, even if there was a marketplace at the civic center, we are not sure what types of goods were exchanged there. Products like lithic tools which are also quotidian artifacts could possibly have appeared at marketplaces on plazas, leaving evidence in the form of the residues of final retouch sometimes found at possible market stalls (Cap 2015; Cap 2019; Keller et al. 2010: 203). But pottery making does not work this way and pottery products brought to the market would be finished ones. Nonetheless, if there were marketplaces and utilitarian vessels also appeared at the market, the locations of house groups and their distances to the center could potentially cause different patterns in the combination of production units among the house groups. More isolated households could possibly have had fewer preferences if they tended to exchange only with their close neighbors.

Figure 5.14 shows the locations of the house groups, local centers and the site core. The distances of the house groups to the site core are also shown. Since the most likely place for a marketplace at Lower Dover polity is at the site core (Walden 2021: 567), the distance to the site core might make differences. Actually, the straight-line distances between house groups and the site core are all relatively short, only a little bit more than 2 km at the farthest, all easily within walkable ranges (Arnold 1988). The differences between house group distances amount to only a few hundred meters. SG1 and SG3 from Tutu Uitz Na are very close to the site core – within 0.5 km range. SG51 and SG42 from Tutu Uitz Na, Group 2 (Structure 2A&2D), SG34, SG143 from Floral Park and BR168/180 from Texas are all located moderately far away from the site core – about 1km to 1.5km. SG129 is the farthest from the site core, which is a little bit more than 2km away.

Figure 5.15 shows different production units expressed as proportions of the total sherds analyzed from each house group. Each bar represents a house group. For example, the first bar in the graph in the upper left corner means that 17.6% of specimens (29 of 165) of pottery sherds possessed by residents of SG1 are identified as production unit 1, with error ranges at different confidence levels. The house groups are put in the order

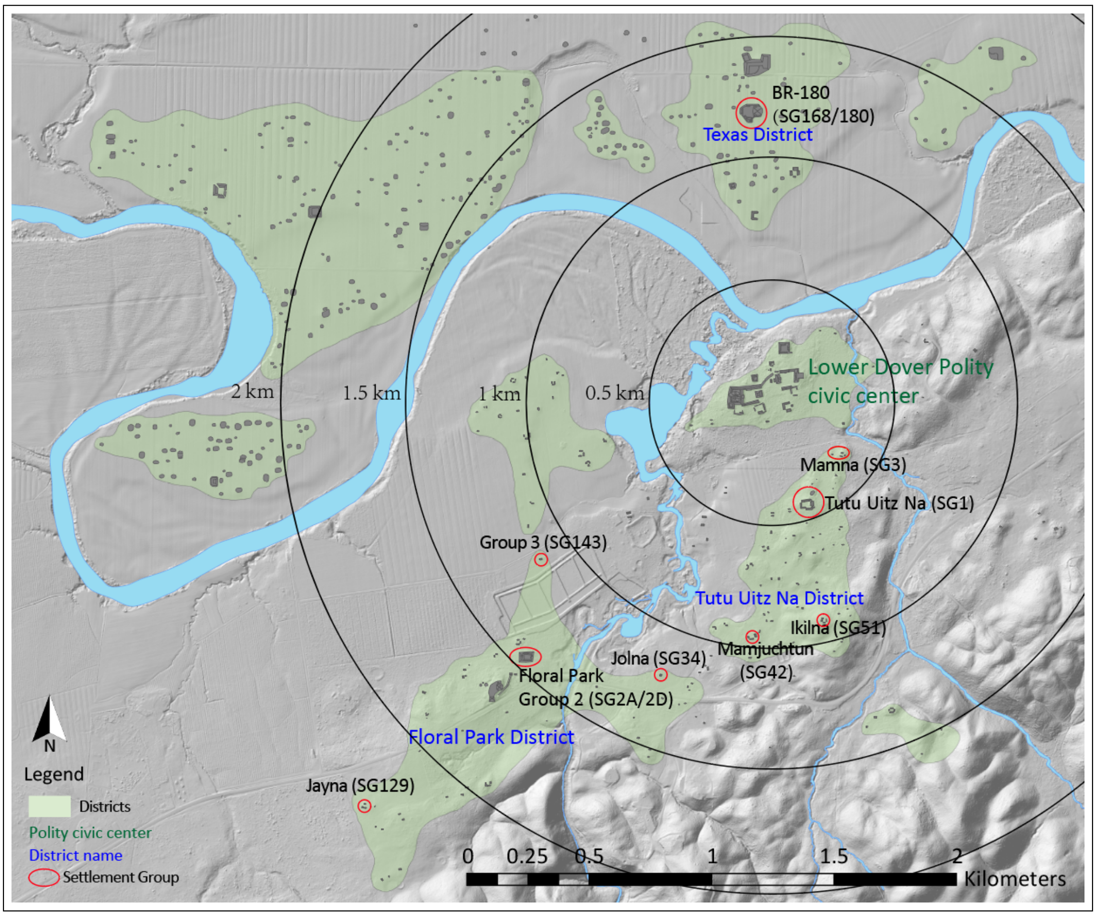

Figure 5.14: Locations of the house groups and centers.

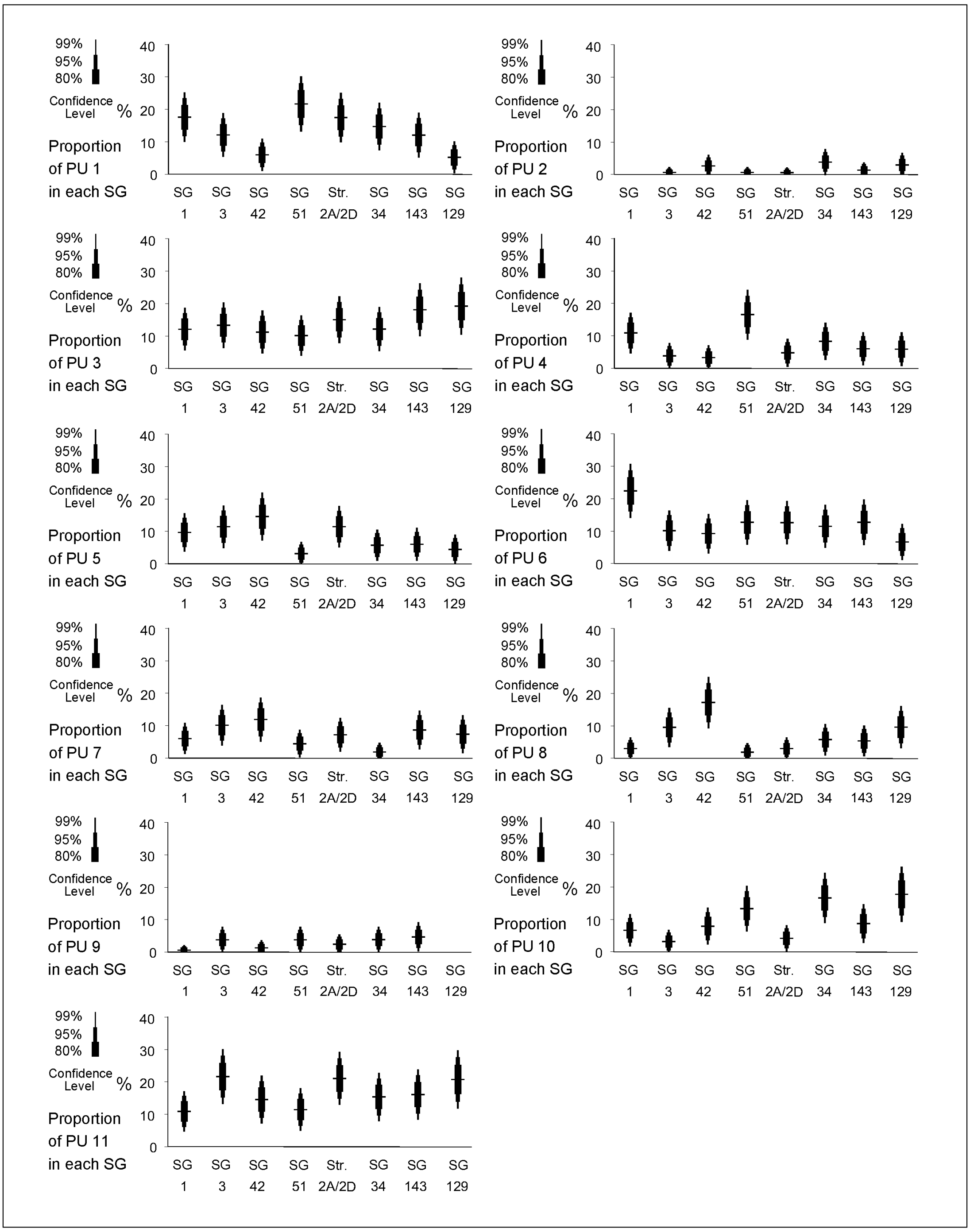

Figure 5.15: Different production units expressed as proportions of the total sherds analyzed from each house group in the order of distance to polity center.

of distance from the site core, not strictly in the order of the closest to the farthest but by approximate ranges, since the exact location of possible marketplace is unknown. We can see that most production units had a few good customers, and some were liked by almost all the house groups, but those good customers did not always overlap. If comparing house groups, they often favored five to six production units, and those units did not overlap either. Only SG129 favored fewer production units, possibly because it had less access to the market at the site core and relied more on the fewer units it could obtain without having to visit the marketplace. But in general, for most of the house groups, distance to the marketplace did not make big differences in choice of products.

To sum up, individual households had similar pottery procurement strategies, just favoring products from a few, usually five to six, main production units. The units house groups favored often overlapped, and none of the units seem to have been inaccessible for anyone. Intermediate elites and higher status commoners did not look different; house groups with different occupation history lengths did not look different; the house group that possibly had low level craft production did not look different from others; and distances to the site core (the potential location of the marketplace) did not make a big difference either. All the house groups seem to have been able to choose pottery from the sources they preferred freely, potentially from a central marketplace. Similar to the conclusion I reached in research question 1, the degree of specialization in utilitarian pottery production at Lower Dover in Late Classic was rather low from the perspective of comparing different house groups.

5.4 Research Question 4

What is the spatial extent of the networks of distribution of pottery from individual production units? Did they usually cover the entire region my research concerns? Or only part of it? To what extent did these networks overlap?

The answers we reached to previous research questions are that all the house groups in the studied area were very likely to have used the same marketplace to procure daily-use pottery based on their preferences. This is a way to look at distribution from the perspective of the consumers. I would also like to look at distribution mechanisms from the perspective of the producers by examining relations between production units and house groups and districts to understand the process that connects production and consumption better.

Production of utilitarian pottery most likely happened at the household level, although not all households had producers (Arnold 1988; Deal 1998; Feinman and Nicholas 2007; Hayden and Cannon 1984; Hirth 2009; Rice 2009b). Although it is often hard to identify the specific location of a production unit, its spatial extent can still tell us a lot about the exchange system. If the spatial extent of distribution from a production unit was restricted to the house group scale (that is, if there were similar numbers of production units and house groups) and if there were cases in which one or a few production units were largely distributed only within the same house group, then probably some house groups produced their own pottery and had little connection with other house groups in terms of pottery production. If the spatial extent of production units often exceeded the house group, then the connections among house groups were closer, since they likely exchanged pottery. If there were production units that only reached a few house groups within the same district, then the distribution from this unit did not cross boundaries of social units like districts. In this case, it is also likely that there was some district level productions, and different districts would show different patterns in terms of the amounts of products from different production units. If there were production units that spread through house groups in different districts, then exchange from those units easily crossed the boundaries of social units like districts, and there was no political power preventing them from doing so. If there were production units that spread across all the house groups selected in this research, then probably the whole polity shared access to those production units, and the scale of distribution might have remained within the polity or the exchange system might have been even larger scale as some other researches have proposed (Sunahara 2003; Chase and Chase 2014).

To evaluate these possibilities, I will look at how pottery produced at each production unit was distributed to different house groups and different districts to further discuss the exchange mechanism of daily-use pottery among the Late Classic Maya people of Lower Dover.

5.4.1 How were products from each production unit distributed to house groups?

From the answers to previous research questions, we already know that there were 11 production units, which is more than the number of house groups whose pottery I have analyzed, and that each house group most likely procured its pottery from the same marketplace rather than exchanging with each other directly. These conclusions came from looking at procurement strategies from the perspective of the house groups. Looking from the perspective of production units will further explore this issue.

Figure 5.16 shows how the pottery produced in each production unit was distributed to house groups. Each bar represents a house group. For example, the first bar in the graph in the upper left corner means that 14.6% (29 of 199) of the pottery sherds identified as production unit 1 were possessed by residents of SG1, with error ranges at different confidence levels. The bars are color coded according to the district they correspond to: green bars represent house groups from Tutu Uitz Na, black bars represent house groups from Floral Park, and the brown bar represents the house group from Texas.

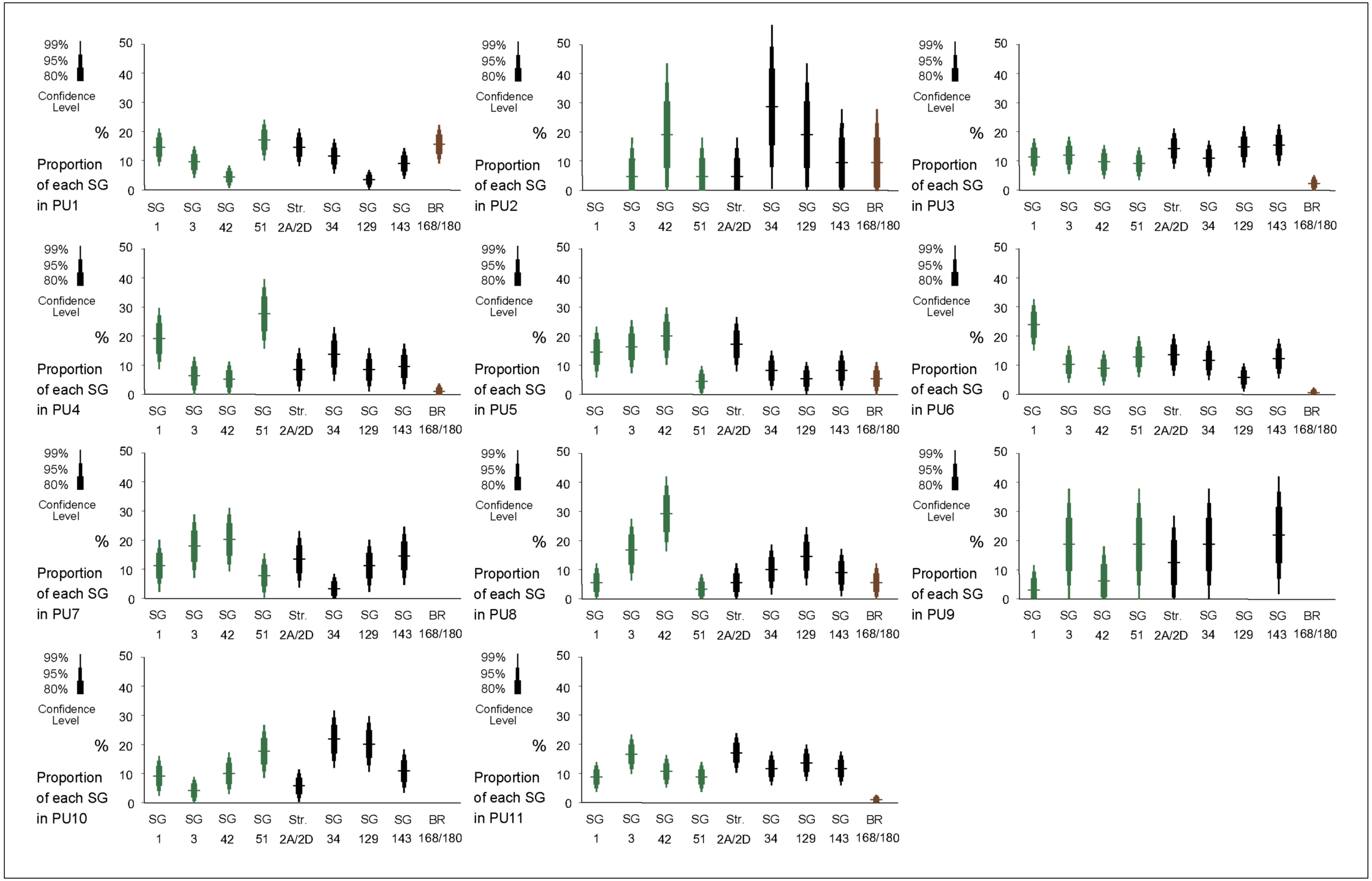

Figure 5.16: Sherds from different house groups expressed as proportions of the total sherds analyzed from each production unit.

First of all, we can see that all the production units were able to reach all the house groups with only few exceptions. In other words, production units were never limited to single or only a few house groups. However, production units did show different degrees of variation in terms of how their products were distributed among the house groups, and there were several patterns among production units. Some units distributed their products to most of the house groups in similar amounts, like units 3, 6 and 11. The products of some units were concentrated more at one house group, like unit 4 in SG51, unit 6 in SG1, and unit 8 in SG42. Those three house groups all were in the Tutu Uitz Na district. If those three house groups are the possible locations of those three production units, then maybe Tutu Uitz Na had more pottery production than other districts. Products of these three units, however, were not limited to Tutu Uitz Na. On the contrary, their products were distributed to house groups in the Floral Park district no less than to those in Tutu Uitz Na. There were also production units whose products were distributed mostly to only a few house groups, and those house groups sometimes were the same district, sometimes not, for example, unit 10 in SG51, 34 and 129 or unit 11 in SG3 and 2A&2D. It is harder to define the possible location of these production units. Perhaps they were potters in a single house group whose products were very popular beyond that location. It is also possible that those production units were potters in different house groups who shared the same recipe and pottery making techniques. Either way, their products were favored by house groups in multiple districts. It is also possible that there were differences among those products in aspects other than composition. According to Arnold (2018), some potters might make different shapes of rims as their signatures when making Cayo Unslipped jars. If this information is also recorded and a larger sample is studied, a clearer picture about the distribution of products from different sources might be reached. One house group, SG34, is believed to have engaged in some other types of low level craft production activities like lithic tool production (Walden 2021; Levin et al. 2020), but it does not seem to be the location of any identified pottery production unit.

In general, it seems most common for production units to have had their products distributed in relatively large amounts to several house groups that did not always belong to the same district, suggesting not only that production units identified in this study could have been distributed to the whole study area, but also that there were no clear differences between the different districts in the area with regard to access to pottery production units. This pattern further suggests the likelihood of a central market in the polity center where products from all the production units were available for selection by residents from all the districts and house groups studied in this research. There were probably no district level markets where daily-use pottery was exchanged, because that would have caused products from production units in that district to be more abundant within it than beyond it.

Since the production units defined seem to have reached all the house groups in this study, it is likely that they reached the entire polity. Only more specimens analyzed from more house groups could help us find out if those units had even broader distribution, or if more complicated exchange mechanisms existed in the valley. We raised the possibility above that Belize Red might have been distributed differently from the other types (research question 2; Sunahara 2003). However, other than this special type, the fact that there were similar groups and types across the whole valley could potentially mean that there were many connections among polities (Gifford 1976; Walden 2021).It is also possible (since transport and exchange at a distance of bulky and fragile pottery would be difficult) that the techniques of manufacture were exchanged instead. There are ethnographic studies showing that Maya potters do learn from each other a lot (Arnold 2008; Deal 1998; Crown and Watson 2007; Hayden and Cannon 1984; Minar and Crown 2001). It is also possible that only visible characteristics like form, color of slip, and decoration patterns were shared (because they are easily learned) while the specific choice of clay and temper still varied among areas. Although the natural resources of the valley are similar and raw materials are often easily accessible, they are still not exactly the same (Jordan et al. 2020). Answering this question will again require more specimens from more contexts.

Research on pottery from a nearby and similar size polity, Baking Pot, also shows that potters shared pottery making information and tended to use similar resources and techniques in pottery production because of easy access to similar resources provided by the same natural environment. There was still, nevertheless, variability in paste recipes, indicating multiple production groups rather than a single source of pottery (Jordan et al. 2020). As for the scale of production and exchange, it still more likely happened at the household level as was the case with many other types of interactions (Freter 2004; LeCount and Yaeger 2010; McAnany et al. 1993; Robin 2003; Webster and Gonlin 1988; Wilk 1988; Wilk 1984; Yaeger and Canuto 2012).

5.4.2 How were products from each production unit distributed to districts?

Figure 5.17 shows sherds from different districts expressed as proportions of the total sherds analyzed from each production unit. The bars are color coded according to districts: green bars represent Tutu Uitz Na, black bars represent Floral Park, and brown bars represent Texas. For example, the first green bar on the left means that 45.7% (91 of 199) of pottery sherds identified as production unit 1 were possessed by residents from Tutu Uitz Na, with error ranges at different confidence levels. Although Texas only had Belize Red specimens from one house group, it is included here because it adds up to 100% together with the other two districts for the production units it has products from, and its presence does not affect the patterns the other two districts show.

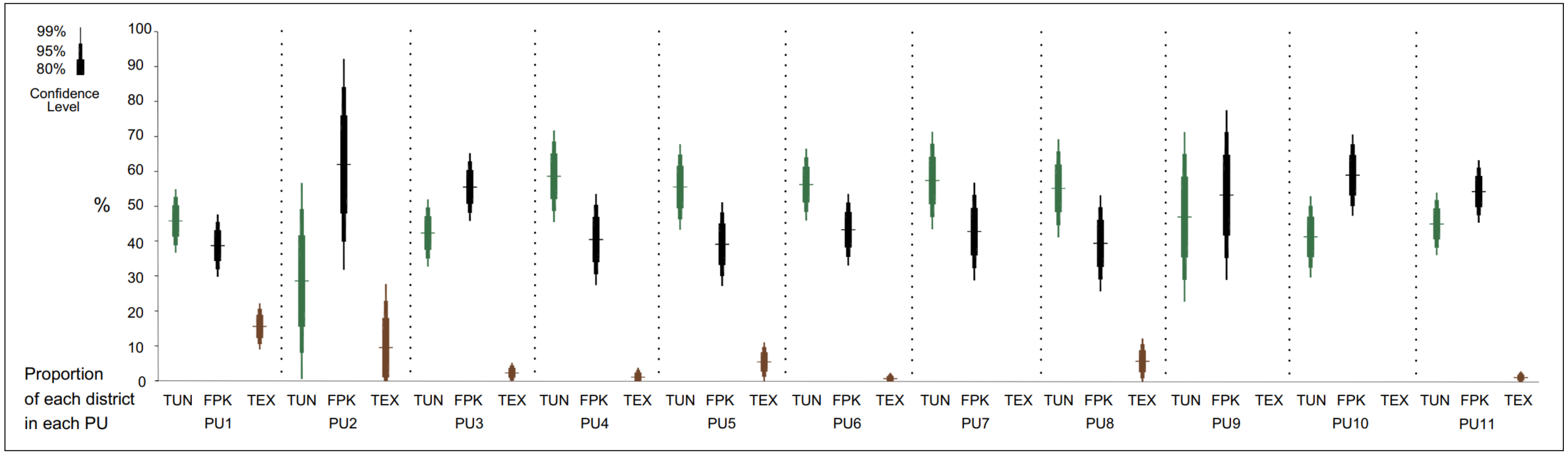

Figure 5.17: Sherds from different districts expressed as proportions of the total sherds analyzed from each production unit.

We can see that, for most production units, the proportions of their products distributed to Tutu Uitz Na and Floral Park were different with statistical significance but little strength, meaning we are very confident that the differences between the two districts were not just random but were also not great.Several production units were more abundant in Tutu Uitz Na (units 1, 4, 5, 6, 7 and 8), and some were more abundant in Floral Park (units 2, 3, 10 and 11), but the other district still always had lots of products from those production units. From comparing the distribution of the production units across house groups in the last section, we have already found that it is hard to identify the locations of the production units. Although products from most units are distributed more in one district than in the other, the differences are not big enough to make a convincing case that any unit was in either specific district.

To sum up, this result leads to a conclusion similar to those of previous sections, which is the existence of a central market at a higher level than a single district, most likely at the polity center, where products of all the production units were provided and residents from all the house groups in this research could all go to freely to select products based on their preferences. No locations of production units identified in the research could be identified, again suggesting a low level of specialization in pottery production since none of the production units seem to represent concentrated production, nor was the distribution of their products limited to particular consumers.

5.5 Discussion

Research on the production and distribution of practical goods used in abundance in the normal course of daily life by an entire population has often been overshadowed in archaeology by attention to elaborate and exotic prestige goods whose production requires considerable investment of highly skilled craft labor and often the acquisition of raw materials (if not finished products) from far away (Drennan 1984). The utilitarian goods of daily life, however, are of much more direct importance to the survival and material well-being of a human population and account for a much greater share of the GDP of a human society. Study of how these latter goods are produced, distributed, and consumed thus provides special insight into the organization of an ancient economy–insight not available from more elaborate prestige goods that are by comparison really quite scarce, despite their ubiquity in the display cases of museums (Freter 2004; McAnany et al. 1993; Masson and Freidel 2002). The large samples of utilitarian goods available for study can also make it possible to discuss the organization of ancient economies in statistical terms, an approach beyond the reach of elaborate prestige goods, which must be scarce to serve their intended function. The research reported here has taken full advantage of the abundance and fundamental economic importance of utilitarian pottery for a geochemical analysis with household consumption as a point of departure for characterizing the organization of production and distribution. It has produced four principal insights.

First, based on the production and distribution patterns of utilitarian pottery, people at Lower Dover had a modest degree of economic interdependence and a moderately integrated local economy in the Late Classic period. The fact that 11 production units using distinguishable recipes could be identified means there was specialization to a certain degree. It is hard to identify any specific house group as the location of any production unit, nor could any district be identified as the possible location of any unit. It is likely that the potters were distributed in multiple house groups but not necessarily in all the house groups, which is usually the case for pottery production (Arnold 1988; Deal 1998; Feinman and Nicholas 2007; Hayden and Cannon 1984; Hirth 2009; Reina and Hill 1978; Rice 2009b). The majority of house groups were dependent on the producing house groups for an essential commodity, which indicates a pretty substantial degree of economic interdependence. Furthermore, all the house groups relied on almost all the production units, and the total number of production units represented in a relatively small population of consumers was also large, so the level of specialization in pottery making was limited, probably what has sometimes been called household production instead of workshop production (Santley et al. 1989; Rice 1987; Rice 2009a; Hirth 2009). It seems likely that even pottery-producing house groups might not have fully abandoned their subsistence pursuits to depend entirely on their pottery craft. Most house groups weree located on good quality soil that could provide agricultural self-sufficiency, so pottery-producing was not likely to be a livelihood. There were often a few production units that a house group relied on more than others, and the units favored by the house groups were not always the same, even for house groups in the same district. The elite groups did not behave differently in any obvious way. They favored similar production units to those favored by commoners. Only the elite group in Tutu Uitz Na sometimes looked slightly different from others. The units they preferred were sometimes substantially more abundant than in other house groups, but this was not always the case. And the elite group in Floral Park showed no difference with other house groups. It is possible that the elite group of Tutu Uitz Na was somehow slightly more differentiated from the commoners, but not to a level at which any products were produced especially for them. Other differences between house groups, like their occupation histories or their specific locations, did not affect their strategies in daily-use pottery consumption either. Although there were house groups that showed traces of low level craft production, there was still no trace of higher level specialization of pottery production based on my results.

There are debates over the power of elites over economic activities. Some argue that rulers had control of both the prestige economy and the subsistence economy (Chase and Chase 1996; Fox et al. 1996). Others argue that they were only concerned with distribution of prestige goods and derived their power mainly from ideology and rituals (Demarest 1992; Demarest 2004; Freidel 1992), while only commoners were more involved in the utilitarian economy (Ball 1993; Blanton et al. 1996; Masson and Freidel 2012; Rice 1987). Other opinions lie in between and suggest that the power of rulers in the economy varied through time and location (Marcus 1993). Lower Dover was a medium sized polity among several similar-sized peer polities in the Belize River Valley in the eastern Lowland Maya. Concentration of power in these polities was not as obvious as other Maya polities located outside the valley (Chase and Garber 2004; Helmke and Awe 2012). This might be the reason that the subsistence economy here looked loosely controlled.

Second, as stated above, all the house groups possessed products from all the production units and usually favored a few of them. The production units favored by house groups overlapped but were not always the same. This indicates that, instead of direct connections to the producers which would have caused more diversity in choice of production units, the house groups more likely got their pottery from some more centralized mechanism that created what has often been called "pooling." Either redistribution or market exchange could have this effect, but if products were given randomly through a distribution system, we should also see more variations between house groups. Instead, the fact that each house group was able to choose from products from all the production units and had its own preferences is more likely to result from a central market. Each house group had its own preferences, but when grouped together as districts, the eleven production units were distributed in almost identical ways in both Tutu Uitz Na and Floral Park, suggesting that residents of both districts got products from the same marketplace. This further suggests a central marketplace at the polity center. In addition, the scale of distribution from all the production units easily covered the whole area in this research, further indicating that all the production units were most likely distributed through a marketplace and all the house groups could choose freely from them.

Identification of marketplaces and commercial exchange has been of interest recently (Braswell et al. 2010; Cap 2015; Dahlin et al. 2007; Freidel 2020; Masson et al. 2020; King 2015b; King 2020; Shaw 2012; Wells 2006; West 2002). Marketplaces have been identified, usually in civic-ceremonial centers, in several polities in the Maya area. How they affected goods distributions was studied at Chunchucmil (Dahlin et al. 2007), Calakmul (Carrasco Vargas and Baqueiro 2012; Martin 2012), Tikal (Jones 1996), Ma'ax Na (Shaw and King 2015), Sayil (Wurtzburg 1991), Motul de San José (Bair and Terry 2012), and Caracol (Chase et al. 2015). There are also cases of marketplaces in the Belize River Valley at Buenavista del Cayo (Cap 2015) and Xunantunich (Cap 2019; Keller et al. 2010). Although there is no physical evidence of marketplace at Lower Dover, the distribution of utilitarian pottery here may provide a little hint, probably on the lower end (Walden 2021) of the spectrum of commercialization – as some have pointed out that commercial development is a continuum of intensity instead of a dichotomy (Masson and Freidel 2012; Smith 2004). The role the elites play is unclear. It is possible that they collected taxes, charged stallholders, or patronized and controlled marketplace exchange (Masson and Freidel 2012). Elite residences were often located close to the plazas in civic centers, so it might have been easy for them to control of the marketplaces (Guderjan 2007). However, based on the fact that the procurement patterns of utilitarian pottery by the elite groups of different districts are not very different, and the improbability of marketplaces at local centers, intermediate elites seem unlikely to have had control of marketplace exchange. More specimens collected from the very civic centers might provide more information on this subject.

Third, since it is hard to identify any specific house group as the location of any production unit, potters comprising the same production unit might have lived in different house groups and shared the same recipes. This would indicate lots of communication among Maya potters, and ethnographic evidence shows this to be the case for modern Maya potters (Arnold 2008; Crown and Watson 2007; Deal 1998; Hayden and Cannon 1984; Minar and Crown 2001). There was probably a relatively high degree of collaboration and cooperation among Maya potters, instead of the harsher kind of competition associated with more intensive specialization in a full-on capitalist economic system.

Fourth, Belize Red truly was a special type. It was more specialized in production, with two production units producing almost all of it, which never happened other pottery types. It was the only type in this research with volcanic ash temper, which must have been imported since there are no local volcanoes, but the specific source remains unknown (Ford and Spera 2007; LeCount 1999). Also, the use context of this pottery type varied in different part of the Belize River Valley. In the upper Belize Valley, at Barton Ramie and Baking Pot, which are very likely to be the production location of Belize Red wares due to the large amounts found there (Gifford 1976; Chase and Chase 2012), it was mostly used in domestic contexts. In the lower Belize River Valley, it was used a lot in both domestic and ritual contexts. And in several large polities outside the Belize River Valley, like Caracol, Belize Red pottery was also used in burial contexts (Chase and Chase 2012). This indicates that there was larger scale exchange of this pottery type in addition to local exchange at the central marketplace as some other researchers have also suggested (Sunahara 2003; Chase and Chase 2012). At Lower

Dover, products of both Belize Red producing units were available at the marketplace, and all the house groups could choose from them, although they often had a preference for one over the other, and there were quite big differences for some house groups. The specific location of the production of this type remains unclear, as does whether the ash temper or the finished products were being moved (Sunahara 2003). The choice between these two units might indicate the degree of connection to the production locations if they were in some other polities. These issues might be resolved by analysis of specimens collected from other polities.

This research only included three pottery types of the Late Classic period from nine house groups at Lower Dover. Research that includes at a larger scale any of the aspects mentioned above could help us understand the production and exchange mechanism of pottery better. Analysis of more types could help us understand the relations between types and compositions better – whether there were actually stronger or weaker connections – and maybe indicate more different or similar patterns between types used primarily for serving vessels or storage vessels. The Late Classic period is the time the Lower Dover polity rose to power and was presumably the period when the rulers' control over the economy was strongest. Studies of earlier periods might see more loosely controlled economic systems and even fewer traces of market exchange and greater self-sufficiency in terms of pottery. Analysis of a sample including more house groups from Lower Dover could definitely help us understand the local domestic economy better, possibly identify locations of production units, and maybe discover other elements that affected the choices each house group made. Sampling from more house groups from other polities could help us the understand larger scale of scale of exchange better. The distribution patterns of other daily-use products could also help evaluate the presence of marketplaces, although exchange systems can be very complicated, and it is hard to distinguish between a low degree of market exchange and vendors, and even gift exchange and redistribution. Evidence of physical remains of marketplaces could make it possible to find out just what was being exchanged at the market. In general, more studies of utilitarian goods could help us understand what was really going on in ancient people's lives varied sampling methods in future research could help fit more and more pieces into the puzzle.

Appendix Electronic Access to Dataset

The geochemical and mineralogical dataset collected in this research is available online in the University of Pittsburgh Comparative Archaeology Database `www.cadb.pitt.edu`. The dataset is in .xls form, it has information on each specimen, inluding which settlement group and district it was collected from, specimen number, type and diagnostic certainty of the sherd, which production unit it has been grouped into, and details on the amount of each element in the sherd. The dataset can be used for comparative purposes or further data analysis for interested research.

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