Use and Utilization of Loose and Commingled Human Dental Remains in Investigations of Ancient Human Populations

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ABSTRACT

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Commingled teeth present a unique opportunity for a novel application of standard methodological approaches commonly utilized in dental anthropological studies. Unfortunately, little research has been conducted on loose or commingled dental assemblages to determine if they are suitable samples for reconstructing bioarchaeological narratives of ancient human populations. The lack of research on commingled dental samples is surprising, given that teeth are highly resistant to post-depositional deterioration and are often some of the only remains left in high deteriorated burials. An experimental analysis of a commingled dental assemblage recovered from four chultuns at Ka'kabish, Belize, was conducted to address this lack of research and provide a real-world example of the potential use and utilization of commingled dental assemblages in investigations of ancient human populations.

Keywords: Dental anthropology, bioarchaeology, Belize, Classic period, Postclassic, Health, Dentition, Commingled, Chultuns

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ABBREVIATIONS

AMTL	Antemortem tooth loss
EH	Enamel hypoplasia
EC	Early Classic
EF	Early Formative
EPC	Early Postclassic
FDI	Federation Dentaire Internationale
KARP	Ka'kabish Archaeological Research Project
KARL	Ka'kabish Archaeological Research Lab
LPC	Late Postclassic
MNI	Minimum number of individuals
SEM	Scanning electron microscopy
SIA	Stable isotope analysis
STN	Site tooth number

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1.0 INTRODUCTION

Human dental remains are remarkably resilient to post-depositional deterioration and are often some of the only recoverable human remains in archaeological contexts. As a result, some burials may present with a select few or several hundred loose and commingled teeth. Despite this, little to no research has been conducted on the use and utilization of loose and commingled dental remains in the reconstruction of ancient human populations and bioarchaeological narratives.

A review of the archaeological literature showed that no standard methodological approaches have been developed to increase the value of loose and commingled dental assemblages in dental anthropological or archaeological research. The reasoning behind why loose and commingled teeth have not been extensively studied and documented is not fully understood. However, it is likely that some researchers lack the technical expertise to evaluate these assemblages and/or do not believe that they assemblages will benefit their larger project goals. It is also possible that the massive amount of work required to process loose and commingled assemblages may not be seen as a good use of valuable time and resources.

To address these issues and misconceptions, this research processed and analyzed 386 loose and commingled teeth. Each tooth was recovered from one of four chultuns (C1, C2, C3, and B2) located at the ancient Maya site of Ka'kabish, Belize. The burials from which the teeth were recovered dated between the Late Formative (400 BC-AD 250) to Postclassic Periods (AD 900-1500) approximately 2,400 to 500 years ago. Most of the teeth analyzed in this study were permanent (n=380) and the rest deciduous (n=6), meaning that this research is applicable to both juvenile and adult populations.

1.1 Research and Objectives

This research aimed to determine if loose dental assemblages are useful in the reconstruction of bioarcheological narratives of ancient human populations. As such it seeks to address two primary objectives:

1. To determine if standard methods of data collection commonly used in bioarchaeological studies of human teeth can be effectively applied to loose dental assemblages.
2. To show, through a real-world example, why and how dental anthropologists and bioarcheologists should process and collect data from loose teeth recovered from archaeological contexts.

1.2 Significance

Dental anthropological and bioarchaeological research has typically focused on teeth that are still in-occlusion (i.e., still articulated with a mandible or maxilla). However, it is common knowledge to archaeologists that teeth preserve well conditions that are not conducive to the preservation of bone. As such, it is common for loose dental remains to be present in a burial that is absent of oft other well-preserved or identifiable skeletal remains. It appears that these "left-over" teeth have often been avoided in the study of ancient human populations and the subsequent development of bioarchaeological narratives. This is, in my opinion, a grave oversight that has not be addressed in archaeological literature. This thesis is the first large scale study that has used a large commingled dental assemblage to assess the viability and potential use of commingled loose and commingled skeletal remains in both dental anthropological and bioarchaeological research. Additionally, this research will show why and how anthropologists and archaeologists can process and utilize information generated from loose and commingled dental assemblages to inform or address research questions that may not have otherwise been addressed in the absence of non-dental human skeletal remains.

1.3 Thesis Outline

This thesis consists of six chapters and two appendices. The outline of those chapters is as follows:

Chapter 2 provides an introduction to dental anthropology and bioarchaeology within Maya populations. Further, Chapter 2 provides a brief overview of the Maya people, regions, and chronology. Additionally, the chapter reviews common types of dental assemblages including standard and commingled assemblages. The chapter concludes with brief overviews of common areas of study in dental anthropological research: dental wear, dental modifications, dental pathologies, and dental calculus.

Chapter 3 “Site and Sample” first presents general information on the site the samples used in the thesis was sourced from: Ka’kabish. Chapter 3 then presents the information on the concentration and locations from which the dental assemblage was excavated.

Chapter 4 provides an in-depth review of the methods implemented in this thesis to collect, record, and assess dental data. Chapter 4 also presents a summary of the primary data collected and processed in this thesis.

Chapter 5 provides an in-depth analysis and discussion of the usefulness of the methods and subsequent data generated through the implementation of the methods discussed in Chapter 4. The primary purpose of this chapter is to show the reader why and how the study of loose and commingled dental assemblages is beneficial to the fields of dental anthropology and bioarchaeology.

Chapter 6 concludes the thesis. In addition to summarizing the primary findings of the research explored in this thesis. Chapter 6 also presents the major limitations of using commingled dental assemblages, potential areas of future study in the area of loose and commingled dental assemblages and presents other explanations as to why researchers should process their commingled and loose dental samples.

2.0 DENTAL ANTHROPOLOGY

2.1 Introduction

To an individual unfamiliar with the field of dental anthropology, it may, at first glance, seem of little relevance to the general study of the human life courses, culture, and population health and demographics. However, this is not the case. Teeth, when compared to human bone, are remarkably resilient to post-depositional destruction and taphonomic processes and, as such, are often some of the only human remains which archaeologists can recover during excavations (Kendall et al. 2018: 24; Ogden 2007). Given that teeth are so resistant to deterioration, it is no surprise that over the last 70+ years, anthropologists have developed advanced methodological approaches to generating biographical data which can be used to address anthropological questions (Hillson 2001; Scott 2015; Thomas et al. 2005).

The questions asked by dental anthropologists vary depending on the time period and population they study. Some dental anthropologists study the evolutionary history of human dentition, some the impact that agricultural development had on the structuring of the oral cavity, and others investigate the relationships between culture and oral/dental health (Hovorakova et al. 2018; Kawamura et al. 2001; Tayles et al. 2010). The questions that can be addressed using dental anthropology are limited by the data sets available to the researchers studying human teeth.

Of crucial importance in the study of dental anthropology is the availability of comparative data sets. In order to study changes in human dentition and oral health, it is vital to have samples with related cultural and contextual information, as contextual information allows researchers to study change under varying circumstances (Larsen 2015). Unfortunately, large data sets of population-specific dental assemblages, particularly in Mesoamerica, are few and far between. In some cases, this can significantly limit the focus of potential research questions by limiting the availability of comparative data sets (Luna 2016). The availability of comparative dental assemblages is such a prominent issue that the Dental Anthropology Association (DAA), the official organization representing researchers within the field of dental anthropology, strongly encourages researchers to make their data sets easily accessible to facilitate large-scale comparative studies (http://www.dentalanthropology.org/).

2.1.1 Bioarchaeology and Loose Tooth Assemblages

Human bioarchaeology is the in-depth study of human remains contained within the archaeological record (Martin et al. 2013:1-2). Bioarchaeology utilizes human skeletal remains to answer questions pertaining to cultural practices/events and changing environmental conditions (Martin et al. 2013: 1-2). The use of human remains in archaeological studies is highly dependent on the amount of contextual information available to the bioarcheologist (e.g., population, time, geographic location of a sample) and the degree to which the remains being studied have been preserved (Martin et al. 2013: 60-61). For example, more information can be generated from a well-preserved articulated skeleton than a poorly preserved commingled assemblage of remains. Within the bioarchaeology field, dental anthropology specialists use teeth as a tool for addressing questions related to the oral cavity and dental health.

Dental anthropologists specifically use dentition to address questions related to human health and culture in past populations. The research projects conducted by dental anthropologists are varied, but of significant interest is the use of dental remains in the study of nutrition, population demographics, and stress. An extensive amount of study has been conducted within the field of dental anthropology in various locations around the globe such as Southeast Asia (Lukacs 2019; Newton and Domett 2017; Oxenham and Matsumura 2014; Willis and Oxenham 2013;), Europe (Bolhofner 2017; Freeth 2000; Karsten et al. 2017; Petersone-Gordina and Gerhards 2011), Africa (Carter and Irish 2019; Dlamini et al. 2016; Forshaw 2009; Grimoud et al. 2012), and throughout the Americas (Cucina, Atoche, and Chatters 2019; Cucina and Tiesler 2003; de Oliveira et al. 2021; Nagaoka et al. 2021; Rose and Burke 2009; Scott et al. 2020).

Despite the vast amount of research conducted within dental anthropology, relatively few studies use large loose or commingled (teeth that are no longer contained within a mandible or maxilla) dental assemblages. Instead, researchers typically use dental samples from assemblages with established MNIs with strong contextual information which better facilitates comparative studies (Luna 2016: 5-6). The lack of research on lose or commingled dental assemblages is likely a result of various factors, including lack of contextual relevance, difficulty with methodological approaches, and the time-consuming nature of processing such collections. However, research by Beck and Smith (2019) has shown commingled dental assemblages can be used to generate new and valuable information about past populations. Their research showed that commingled dental assemblages could be used to study tooth wear and provide estimates of age for subadults contained in the assemblage (Beck and Smith 2019: 2-3) Working with commingled and loose dental assemblages presents a unique and challenging set of challenges. However, loose teeth may often be the only remains left in specific burial contexts due to taphonomic processes, environmental degradation, and cultural practice. Therefore, they should not be overlooked, as has been the case at some Mesoamerican archaeological sites, specifically those occupied by the Maya.

2.2 The Maya People

The term Maya refers to a group of people who have occupied eastern portions of Mesoamerica (Central America), including Belize, Mexico, Guatemala, Honduras, and El Salvador, for several thousands of years (McKillop 2004:3-4). It is important to note that although the Maya are portrayed in popular literature and media as an extinct and ancient civilization, large populations of modern Maya people still live throughout Central America today. Additionally, the term "Maya" does not refer to a distinct homogeneous cultural group, but instead, identifies a regionally and culturally diverse group with a common Mayan language family (Houston and Inomata 2009: 6-7). The Maya cultural region is divided into several geographical "zones" (see Fig. 2.1) spanning approximately 324,000 km^2, including the Northern and Southern Lowlands, the Highlands, and the Pacific coastal plains (Reyes-Foster 2014: 4710-4711). The Southern

Lowlands are of particular importance, in regard to this thesis, as the source location of the dental assemblage, Ka'kabish, is located in this region.

2.2.1 Maya Regions

The Northern Lowlands are spread throughout three regions commonly referred to as the Yucatan Peninsula, Campeche, and Quintana Roo, Mexico (Fedick et al. 2004: 207). The region is arid with low shrub-like vegetation, small amounts of rainfall, and a wet/rainy season between June and December (Houston and Inomata 2009: 4-5; McKillop 2004: 29-30). The arid environment of the Northern Lowlands may appear to be a limiting factor in the development of agricultural systems and trade networks as a lack of accessible water-ways would limit trade routes to only those navigable by foot. However, the Maya of the region were highly adaptable and took advantage of the aridness to grow cotton crops used to manufacture textiles for trade (Ardern 2000: 349).

The Southern Lowlands cover portions of modern-day Belize, Guatemala, and parts of Mexico (Cowgill 1962). The region's environmental stability, vast river networks, consistent rainfall, and nutrient-rich soil allowed the Maya to develop a large and complex agricultural system (Lucero 2006: 281-284). The expansiveness of agrarian production and the diverse resource availability in the region supported the development of monumental cities such as Tikal, Calakmul, and Lamanai. As a result, this region became one of the most densely populated in all of Mesoamerican (Scherer 2007; Webster 2018).

Finally, the Highlands are situated in modern-day Mexico, Guatemala, El Salvador, and Honduras. This region varies significantly geologically and environmentally from the Lowlands and comprises vast mountain ranges, a cool temperate climate, and diverse animal and plant life. The Highlands are scattered with volcanic mountain ranges, which produced obsidian- an important economic resource of the region (Sidrys 1976).

Despite being drastically different geographically and environmentally, the Maya of the Northern Lowlands, Southern Lowlands, and Highlands adapted to varying constraints to prosper and grow as cultural groups. The Maya of the Northern Lowlands overcame drought with innovative forms of water storage. The Maya of the Southern Lowlands grew vast crops and traded long distances due to the prevalence of water which facilitated the use of boats for trade. The Highland Maya populations capitalized on a valuable resource, obsidian.

Figure 2.1: Map of the Maya Cultural Area. Adapted from Sharer and Traxler (2006).

2.2.2 Chronology

Maya history can be roughly divided into three periods: the Formative, Classic, and Postclassic periods (see Table 1.0). Each of these periods is characterized by unique characteristics that can distinguish or identify periods in the archaeological record. The temporal ranges of these periods are based on changes observed by modern archaeologists and may not be consistent for all sites. Nevertheless, this timeline serves as a generic template for interpreting the archaeological record.

Maya Timeline		
Postclassic	*Late- Contact*	AD 1200-1500
	Early	AD 900-1220
Classic	*Terminal*	AD 830-900
	Late	AD 600-830
	Early	AD 250-600
Formative	*Late*	400 BC-AD 250
	Middle	1000 BC-400 BC
	Early	2000 BC- 1000 BC

Table 1.0 *Maya Timeline.*

The Formative Period (2000 BC-AD 250) is when archaeologists can first identify early Maya populations in the archaeological record in the Mesoamerica Lowlands (Schele and Matthews 1998: 16-17). Pole and thatched residential structures dating to the Formative Period, likely belonging to multi-member familial groups, were identified in the Eastern portions of the Maya Lowlands (Schele and Matthews 1998: 17). The Classic Period (AD 250- AD 900) is perhaps the most significant and extensively studied time in Maya history. Maya civilizations rapidly expanded during the Classic Period, economies flourished, warfare increased, and ideology became highly complex (Houston and Inomata 2009). Monumental cities of the Classic Period such as Tikal, Copan, and Palenque, were distinct but equal in their architectural, artistic, and political proliferation.

The decline (see Iannone 2014), of Classic Period Maya civilizations, at the end of the Terminal Classic, leading into the Postclassic is manifested at many sites in the northern Yucatan peninsula (Andrews et al. 2003). Sites, such as those along the Caribbean coast and in the Peten exhibit far less evidence of socio-political change or decline. These populations remained relatively stable during a time that must have been filled with great uncertainty for much of Mesoamerica (Andrews et al. 2003: 151). After a short hiatus or pause in development, activities resumed in the Postclassic Period with a marked revival of some Maya states in the north (Van Voorst 2013: 36-37). This Period lasted until the arrival of the Spanish.

The arrival of the Spanish conquistadors in Mesoamerica in the early 1500s marked the beginning of the Contact period (Rice and Rice 2018). Hernan Cortes (a leader of the invading Spanish) traveled throughout Mesoamerica searching for gold (Graham et al. 1989). His presence in the region would leave the first scars of colonization in Mesoamerica. In 1521, Cortes led an assault that would result in the destruction of the Aztec empire in central Mexico (Hughes 2000:1-3). A short twenty-one years later, in 1542, the Spanish presence had extended into the far reaches of the Maya cultural region (Graham et al. 1989: 246). Thus, in less than three decades, the Spanish had conquered much of Central America.

2.3 Maya Dental Anthropology

Maya populations have been the subject of extensive archaeological studies, with excavation work being conducted on sites dating from the pre-Formative Period (Rice 1976; Hammond et al. 1992) to the Contact Period (Rice et al. 2018; Rice and Rice 2018). As a result of the proliferative excavations, extensive collections of human remains, including teeth, have been identified and studied (Plumer 2017; Whittington and Reed 1997). The study of human teeth within Mesoamerica, particularly from Maya populations, has extensively focused on the cultural practice of dental modification due to the frequent occurrence of the practice within the region (see section 2.7). However, research on general oral health, human migration (Ebert et al. 2021; Rand et al. 2021; Suzuki et al. 2020), and other cultural practices pertaining to teeth (e.g., tooth caching) has also been conducted (Saul and Hammond 1974; Schnell and Scherer 2021).

Maya oral health follows similar trends seen in agrarian cultures around the globe (Weyrich 2021: 96-97). Specifically, caries, commonly known as cavities, are often seen in the Maya dental record and are likely the result of a reliance on a high carbohydrate diet or an individual's social class (Cucina and Tiesler 2003; Cucina et al. 2011; Lukacs 2008). Primary factors contributing to variability in oral health among Maya people (e.g., dental caries and antemortem tooth loss [AMTL]) include social status (Cucina and Tiesler 2003), biological sex (White 2005), age (Vega Lizama and Cucina 2014), diet, methods of food preparation (Cucina et al. 2011) and overall health. Social status impacts general trends commonly seen in Maya teeth. However, a social status does not necessarily result in "better" dental health than another (Cucina and Tiesler 2003). Instead, individuals of the lower class have higher rates of dental caries, while higher status individuals typically have significantly higher rates of AMTL (Cucina and Tiesler 2003).

A notable difference in dental health is evident when comparing individuals of different sexes. Biologically sexed females, regardless of their social status, typically experienced dental caries in greater frequencies than genetically sexed males (Cucina and Tiesler 2003). Variations in diet between sexes likely caused this trend; female sexed individuals probably consumed more cariogenic processed maize than male sexed individuals who had diets with higher ratios of meat-based protein (Cucina and Tiesler 2003: 6-7).

Age also impacted the overall dental and oral health of ancient Maya populations (which is consistent with trends in oral health around the globe [Cucina and Tiesler 2003; Lovejoy 1985; Novak 2015]), particularly in the case of rates of attrition/wear. This trend is most likely a result of the increased amount of time (age) resulting in the more dramatic deterioration of the occlusal surfaces of teeth (Mays et al. 1995). However, factors such as diet (Watson 2008), preexisting conditions (overcompensation or preferential mastication on a specific side of the mouth due to constant or increased oral discomfort and tooth loss [Lovejoy 1985:48]), or occupation (Willman et al. 2020: 256-257) could also impact rates of dental wear. Regardless, age is a factor to consider when investigating any population's dental health, the Maya included (see section 2.5 and 2.7 for more information on dental wear and pathologies).

2.4 Dental Assemblage Types

For this thesis, two primary types of dental assemblages must be considered. First is what I refer to as a "standard" dental assemblage. The second type of assemblage discussed in this thesis is a loose or commingled dental assemblage. Both types can provide information on dental health; however, a loose assemblage is greatly limited in the amount of interpretation drawn due to the contextual nature of these assemblages.

2.4.1 Standard Assemblages

A standard dental assemblage is any dental assemblage used in a study where specific teeth can be affiliated with particular individuals. In the case of a standard dental assemblage, the contextual information and osteobiographical data (age, sex, health, etc.) contribute a more significant amount of data used in archaeological interpretations/narratives. The quality of the interpretations resulting from the contextual information of standard dental assemblages makes them, what I believe to be, the preferred type of assemblages for archaeological research. This type of assemblage is also the most used in dental anthropological studies of Mesoamerican populations (Hosek and Robb 2020; Williams and White 2006; Jacobi 1996) .

2.4.2 Loose Assemblages

Loose or commingled dental assemblages contain teeth that are not affiliated or easily associated with specific sets of human remains. These assemblages can provide the same general data seen in a standard assemblage, however, they are hindered by a lack of other osteobiographical data. Significant studies using large scale (n=100+ teeth) loose dental assemblages are uncommon in the archaeological literature and, in the case of the Maya, are not present in the literature. The exceptions to this are rare dental caches (see section 2.4.3.2) (Pendergast et al. 1968: 638) and a study by Olivia Munzo (2017) which reviewed several hundred teeth that were not directly associated with their alveoli, however, this study did not present an in-depth methodological approach to utilizing loose/commingled skeletal remains; further the assemblage used by Munzo (2017) contained a proportionate number of fragmented alveoli within maxillae and mandibles meaning the teeth were not fully isolated as is the case for the sample utilized in this study. Consequently, a thorough understanding of how common loose dental assemblages are within the Maya region, or globally, is not completely understood.

2.4.3 Causes of Loose Assemblages

A review of the bioarchaeological literature from Mesoamerica yielded few results on loose or commingled Maya dental assemblages. The only two examples found in the Maya area were both documented as tooth "caches": one from Labaantun, Belize (Saul and Hammond 1974) and a second was also from Yakalche, Belize (Pendergast 1968). However, given that the sample used in this thesis (see Chapter 3 for sample information) primarily consists of many loose teeth, I believe it is essential to present two probable explanations of how these types of dental assemblages come to be. The first explanation (see section 2.4.3.1) is concerned with taphonomic processes and the preservation of teeth in the archaeological record. The second explanation considers that loose dental assemblages may result from cultural practices, such as tooth caching.

2.4.3.1 Taphonomic Processes

In Mesoamerica, specifically in the areas surrounding modern-day Belize (see figure 2.1), seasonal changes in humidity levels and the prevalence of rain result in the poor preservation of human remains, not well protected from the elements. The cyclical process of introducing water (the medium in which most chemical reactions occur) and then having it evaporate during the dry season results in highly deteriorated and fragile bones (Turner-Walker 2008: 11-13). Due to this, even minor disturbances could destroy already fragile bones, such as facial bones. If this were to occur, it is likely that the teeth, which are remarkably resistant to weathering and taphonomic processes, would be the only well-preserved component of the remains left behind. In the case of burials in chultuns, burials could be damaged due to falling capstones or material from the ceiling. This could result in a sudden and forceful impact on the highly fragile skeletal remains, resulting in the presence of loose teeth that cannot be associated with specific sets of skeletal remains. Dispersal of the teeth throughout chultuns in irregular patterns can be accounted for by considering the natural shifting of soil caused by rainfall, animals inhabiting the chultuns, or during excavation when a dark environment may make the difficult to see. Additionally, large animals, bioturbation, looting, and secondary burials/internments may also impact the overall preservation of the skeletal remains contained within burials.

2.4.3.2 Caching

A cache is “a collection of items of the same type stored in a hidden or inaccessible place" (Kunen et al. 2003:198). In an archaeological context, a cache can be diverse in terms of the type, variety, or number of items that it contains. For example, although extremely rare, dental caches (the intentional and/or ritual depositing of teeth in the Maya area) have been identified at only two sites (Saul and Hammond 1974: 123; Pendergast et al. 1968): Labaantun, Belize (Saul and

Hammond 1974), and Yakalche (Pendergast et al. 1968: 637-638). The latter of which is the only documented case of a deposit consisting only of teeth.

Chronological trends of dental caches are not yet fully understood. However, the practice is generally believed to be primarily contained to the Early and Middle Classic Periods, although the Yakalche dental cache dates to the Late Postclassic (Pendergast 1968). Additionally, both known Maya examples of tooth caching come from what is now Belize suggesting that the practice may be a regional phenomenon (Pendergast 1968; Saul and Hammond 1974). Interestingly, the composition of the dental cache from Yakalche (containing 379 teeth) has a one-to-three ratio of deciduous and permanent dentition (26.6% deciduous:73.3% permanent) meaning teeth contained in the cache came from both adults and adolescents. Further, a notable proportion of the teeth from the Yakalche dental cache are molars (Pendergast et al. 1968: 638-639). Finally, it is essential to note that neither of the known examples of Maya dental caches were associated with other skeletal remains as was the case with the loose/commingled dental assemblage recovered from the chultuns at Ka'kabish.

2.5 Studying Loose Tooth Assemblages

Despite the challenges and difficulties associated with studying loose tooth dental assemblages (most of which relate to generating information about the dental health of specific individuals), the data generated from these types of deposits is, I believe, highly valuable. Loose dental assemblages present a unique opportunity for dental data to be reviewed in an isolated context. The data generated in that analysis can be used in comparative studies in dental trends both regionally and globally. Further, these assemblages can be used to refine the skills required to be a well-rounded dental anthropologist; this is particularly true as the analysis of large loose dental assemblages depends on the researcher's ability to identify tooth type without the aid of the teeth being “in situ”. Additionally, the types of data generated from the analysis of loose tooth assemblages are markedly similar to that which can be generated from teeth still present in their original anatomical position: dental wear, dental modifications, oral health and pathologies, and dental calculus can all be identified and scored on teeth in loose dental assemblages.

2.6 Dental Wear

Dental wear can be subdivided into two primary types. The first is known as attrition, which is wear caused by tooth-to-tooth contact, including teeth located beside each other resulting in interproximal wear facets (IWF). Attrition also can be caused by contact between two or more teeth, such as when the maxillary and mandibular teeth come into contact (Hillson 1996: 231). The second type of wear is abrasion, which results from introducing foreign materials to the teeth (e.g., foodstuffs, pipes, chewing tobacco, etc.) (Hillson 1996). These two types of wear are present visually, in different ways; attrition results in clearly defined wear/polished facet shaped surfaces; abrasion appears more generally on the entire exterior surface of the tooth (Hillson 1996). Both types of dental wear are important to the study of dental anthropology. Attrition is beneficial to the analysis of tooth positioning with a mandible or maxilla and identifying specific teeth. Abrasion is more valuable, however, in studies related to broader trends such as diet (Hillson 1996).

Dental wear studies have been conducted around the world with extensive amounts of research focusing on an array of topics from the evolution of the structural and functional studies of the human jaw resulting from evolutionary pressures and cultural change (Kaifu et al. 2003; Kurniawan et al. 2022; Watson and Schmidt 2020); the use of dental wear in the reconstruction of ancient diet has provided insights into the impact of agricultural intensification and dietary change in ancient human populations (Fiorenza 2015:11-12; Fiorenza et al 2018; Rodrigues et al. 2021); dental wear analysis has also been used extensively to estimate the developmental ages of individuals recovered from archaeological excavations around the globe (Domett et al 2011; Faillace et al. 2017; Lovejoy 1985; Newton et al. 2013:3-4; Romero et al. 2019). The global prevalence and variation in the design, implementation, and uses of dental wear studies showcases the importance of dental wear analysis and its subsequent contributions to our understanding of a diverse range of ancient human populations.

Dental wear studies have also been conducted in many regions of Central/Mesoamerica; these studies have primarily focused on intentional wear resulting from the prevalence intentional dental modifications within Mesoamerican populations (Spence and Pereira 2007; Tiesler 2010; Verdugo et al. 2020) (see section 2.7). However, dental wear has been considered as it relates to diet in some studies (Seidemann and McKillop 2007).

Within Belize, as with much of Mesoamerica, dental wear studies have disproportionality focused on the assessment and recording of intentional wear/dental modifications (see section 2.7). The lack of research on dental wear, in relation to diet and aging, in Belize (when compared to the abundance of research in other regions of the world) may be a result of several factors including a lack of dental wear in some site-specific populations (Seidemann and McKillop 2007) or due to the prevalence poorly persevered remains and "the normal post-mortem fall [of teeth] from the sockets" (Cucina et al. 2015). There are also no currently identifiable examples of dental wear studies within Mesoamerica, including Belize, which have utilized loose or commingled dental assemblages in the study of dental wear.

2.6.1 Macroscopic Wear

There are two primary areas for studying wear on the dentition: macroscopically and microscopically. As suggested in the name, macroscopic wear involves the analysis of "larger" patterns of attrition and abrasion on the tooth which are visible without specialized equipment. Microscopic wear involves the use of magnifying technology to study patterns embedded in the dental enamel which are too small to see with the naked eye. This thesis focuses on the use of macroscopic wear.

2.6.1.1 Anterior vs. Posterior Dentition

Several factors can impact variations in the severity or extent of dental wear that can occur between the anterior and posterior dentition (Kaidonis et al 2012). One of the primary physiological factors that impact anterior vs. posterior dental wear is known as "anterior guidance" (Thornton 1990). In a physiologically normal jaw, anterior guidance prevents continuous non-lateral force from being placed on the posterior teeth because of the natural positioning of the anterior teeth (i.e., it makes it more difficult, although not impossible, to grind the posterior dentition) (Thornton 1990). Other factors that can impact the rates of wear between anterior and posterior dentition include missing teeth, dental pathologies, and injuries which may result in overcompensation in chewing in one area of the mouth, which results in significantly higher rates of wear in a specific area of the mouth (Hillson 1996)

2.6.1.2 Diet

The types of food commonly consumed by a specific population have a visible impact on the degree and location of the observed wear. For example, agriculturalist societies tend to present with much less anterior tooth attrition than in hunter-gatherer populations (Hillson 1996: 237). This is caused by a notable difference in diet, with hunter-gatherers consuming more abrasive and tough foods while agriculturalists relied more heavily upon less abrasive cereal grains (Hillson 1996).

Interestingly, food processing methods also impact the severity of wear observed in agriculturalist populations. In the case of the Maya, stone metates (a ground stone tool used to grind corn) were often made from abrasive porous stones. While grinding the maize, small amounts of the stone from the metate could be incorporated into the final product, resulting in a much more abrasive dough that can increase tooth wear.

2.6.1.3 Age

Dental wear also is used for determining age in studies (Jeon et al. 2020; Lovejoy 1985; Prince et al. 2008). This method analyses the amount of enamel present on a tooth as well as dentin exposure. Once the teeth have been scored (see Chapter 4.0), they can be compared to the standard expectation for four broadly divided age groups (Brothwell 1963; Hillson 1996: 239). Dental wear is used in estimating age, particularly in cases where few bones are available, for other methodological approaches to aging (e.g., epiphyseal fusion) (Ubelaker and Khosrowshahi 2019). Although teeth from loose tooth assemblages can be scored for wear, they are unable to help in the establishment of accurate age estimates as more than one tooth is required, and the teeth must be in occlusion to estimate an age.

2.6.1.4 Other Causes of Dental Wear

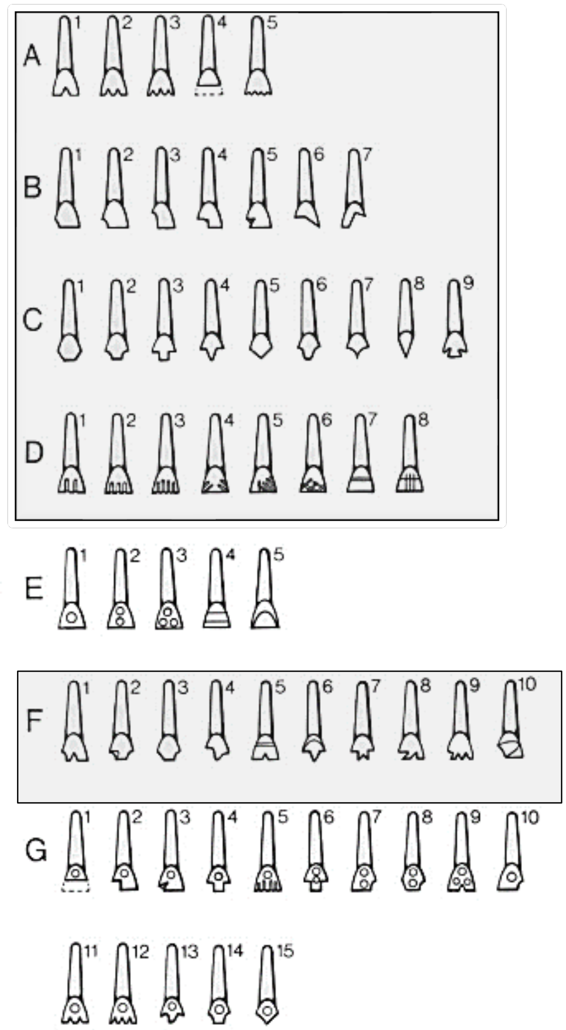
Other causes of tooth wear are related to occupation and cultural practices. Teeth from archaeological contexts with unique wear patterns have been linked to occupation patterns. For instance, some fishing populations have well-rounded semi-circular grooves in their teeth that result from the repetitive pulling of fishing lines between the teeth (Waters-Rist et al. 2010). Additionally, pipe notches in teeth are commonly seen in individuals in Western Europe because of the constant biting of a pipe stem (Carroll and Inskip 206). Cultural factors, such as intentional dental modifications, can also be observed in several populations worldwide, including the Maya (Burnett and Irish 2017; Williams and White 2006).

2.7 Dental Modifications

Dental modifications (the practice of intentionally altering the dentition) are seen in several populations around the world in both ancient and modern populations (White and Williams 2006; Verdugo et al. 2020; Estrella 2021; Bhatia et al. 2015). The differences in modifications, however, are distinct in both the styles and the methods used to produce modifications. Within the Americas, dental modifications are primarily seen in Central America (Mesoamerica), but also can be identified in populations much farther north at sites like Cahokia, Illinois (Meadman et al. 2017). However, the practice is more commonly seen in Maya populations (Tiesler et al. 2017). Over the years several explanations have been presented in the literature to explain the function that modified teeth served in ancient Maya populations (Tiesler et al. 2017; Verdugo et al. 2020). Suggestions include social status, familial affiliation, political affiliation, and cosmetic appearance as possible explanation for the varying styles and frequencies of modifications seen in Maya populations (Verdugo et al. 2020). Dental modifications are important to consider when working with loose tooth assemblages as they may provide insight into the status and identity of the individuals whose teeth make up an assemblage.

Modifications can be achieved in several ways. Most commonly in Maya populations, the desired modification results were achieved by filing (Burnett and Irish 2017). The process of filing teeth was likely done by a specialized trades person, as removing too much of the crown could expose the pulp chamber increasing tooth sensitivity and the potential for infection (Ramirez-Salomon et al. 2018). This process resulted in an array of styles and forms (see Figure 2.2) and their meanings are still being investigated.

In addition to the practice of dental filing, Maya populations also used dental inlays. Dental inlays consisted of many materials, but pieces of jade or pyrite were most common (Fastlicht 1962: 399-400; Verdugo et al. 2020: 1-2). These materials would be affixed to the labial surface of the anterior dentition using a specialized bonding agent (Tiesler 2011). Evidence suggests that inlays were likely placed by highly skilled individuals to prevent over drilling as the process could result in pulp pathosis if not properly performed (Ramierez-Salomon 2018). Due to the sourcing of materials for dental inlays and the amount of specialized training required to add the inlays to teeth, it is likely that this practice was reserved for more elite or wealthy individuals (Serafin et al. 2021).



Dental modifications are an important aspect of dental anthropological research on loose tooth assemblages in Maya populations as the presence of modified teeth may elucidate some of the information about individuals and the population that is missing due to the absence of affiliated skeletal remains.

2.8 Oral Health and Pathologies

The adoption of agriculture around the globe is almost always affiliated with an increased prevalence of certain oral pathologies, particularly dental caries, and dramatic changes in overall oral health (Cheung et al. 2019; Tayles et al. 2010: 68-69; Temple and Larsen 2007; Turner 1978). In addition to the changes in oral health caused by the shift to agriculture and an increased reliance on carbohydrates there are also strong indicators of developmental stress, known as enamel hypoplasia (EH) in the dental record. Each of these indicators of dental and oral health (i.e., caries and EH) provide important and unique information on both individual and population health. As previously mentioned, dental caries was one of the most common afflictions in Maya oral health (Cucina et al 2011), however, EH is also relatively common.

2.8.1 Dental Caries

The formation of dental caries is relatively complex, and the function of this section is to clarify the relationship between the transition to a maize based diet and dental caries. Caries form when demineralization of the tooth's outer surfaces results in small cervices in which organic material can be deposited (Hillson 1996: 269). When organic materials, especially soft and sticky carbohydrates, become embedded in these crevices salivary, bacteria begin to consume the sugars that make up a carb-based deposit; the byproduct of the bacterial metabolism are organic acids that eat away at the mineralized component of the teeth (Gibbons and van Houte 1975: 122-123). The proliferation of the bacterial colonies can eventually result in the destruction or penetration of the dentine layer and the eventual exposure of the internal pulp chamber; exposure of the pulp chamber can result in the development of an internal infection of the tooth and the dental pulp (pulp pathosis) and dental abscesses (Li et al. 2018: 441-442). As human became more reliant on cereal grains and processed carbs (e.g., maize) the amount of readily available sugars for salivary bacteria also increased. The continued presence of acidic bacteria in the oral microbiome resulted in dental caries becoming one of the most common pathologies in both ancient and modern populations (Gibbons and van Houte 1975: 123; Kezler et al. 1990; Koruyucu and Erdal 2021; Lanfranco and Eggers 2012; Li et al. 2018). Due to the complex relationship between dental caries, population health, and agricultural intensification many studies around the world, in Mesoamerica, and more specifically in Belize have focused on these dental pathologies.

Around the world caries have been studied in numerous populations and for varying reasons. As mentioned, the rise of agriculture was associated with changes in prior trends seen in human oral health (i.e., the prevalence of dental caries) (Cheung et al. 2019). Interestingly, the extensive research on the relationship between an increased dependence on carbohydrates and the prevalence of dental caries is not globally applicable; some populations, such as those in Southeast Asia, farmed and consumed large amounts of rice (Tayles et al. 2000) which is far less cariogenic than other crops and cereal grains. In fact, there are no positive correlations between chronological time periods in Southeast Asia (i.e., the transition to agriculture) and the overall frequency of dental caries observed in ancient populations in the region (Halcrow et al. 2013). This is important to note as it provides some clarity to questions surrounding the increased frequency of dental caries in ancient populations; simply put- it was not always agricultural intensification that resulted in the increased prevalence of dental caries but the cultivates being grown and consumed by specific populations that had a notable impact on changes in the prevalence of dental caries.

In the case of Mesoamerican populations caries can be positively correlated with agricultural intensification (Boulware 2001; Marquez et al. 2002:334-345). This is because one of the staple crops of Mesoamerican populations was maize which is, when processed, highly cariogenic (Larsen 1983; Cucina et al. 2011:562). Although maize consumption is associated with an increased prevalence of carious lesions in Mesoamerican populations attributing the prevalence of caries to diet alone has been note by some authors as an oversimplification (Cucina et al. 2011). Other factors such a sex-based differences in diet (Lukacs and Thompson 2008), socioeconomic status, and site-specific functions (Cucina et al. 2011:560-561) can also impact the prevalence of dental caries within a population.

Within Belize large studies of Maya dental health are somewhat limited. However, research has considered the relationship between the prevalence of cariogenic foods (i.e., maize), dental wear, and overall presence of carious lesions. A study of a Postclassic Maya population on Wild Cane Caye, Belize found that the significance of occlusal dental wear reduced the overall prevalence of dental caries in the study population (Seidemann and McKillop 2007:307-308). Further, this study found that, relative to mainland populations, the overall oral health of the individuals on Wild Cane Caye was much better; this was likely a result of a diet more consistent with island Caribbean populations (i.e., less reliance on maize and a more reliance on marine resources) which reduced the overall prevalence of cariogenic foods within the populations diet (Delgado-Darias et al. 2005: 565; Seidemann and McKillop 2007).Other studies that document the presence of dental caries among Maya populations in Belize typically consider the overall prevalence of caries without in-depth considerations for causative factors (e.g., social status, sex, occupations) extending beyond diet (Harmon 2018). Within Mesoamerican bioarchaeological research no samples or studies could be identified which implemented loose or commingled dental assemblages in the investigation of the prevalence of dental caries despite the likely presence of these types of assemblages at many archaeological sites. However, one study of dental caries (in relation to agricultural intensification) in prehistoric Ukraine did include a small sub-sample (n=34) of loose teeth in their study and noted that although caries could be identified on loose teeth the causative etiology of those caries could not be determined due to their loose nature (Karsten et al. 2015).

2.8.2 Enamel Hypoplasia

Enamel hypoplasia (EH) are defects in the dental enamel that are caused by disruptions in the enamel matrix secretion (EMS) process (Hillson 1996: 165-166). EMS occurs during tooth development when epithelial (skin) cells, known as ameloblasts, secret the enamel matrix resulting in what later turns into the dental enamel (Hakkinen et al. 2019: 2-3). Disruptions during the development of enamel can result in EH. These disruptions are typically caused by increased levels of dietary stress during adolescent maturation. As the process of EMS is retarded thinner layers of the enamel matrix are deposited resulting in intermittent layers or “stacked” circular rings or pitted indents on the teeth where the enamel matrix was not properly deposited. These “rings” can be measured and used to estimate the age at which the dietary stress occurred during development.

Extensive studies of enamel hypoplasia both through time and around the globe has been used to increase our overall understanding of how improved nutritional conditions contribute to a decrease in the occurrence rates of EH (El-Najjar et al. 1978). Further, the advancement of studies pertaining to EH has shown that although a singular causative factor of EH cannot be isolated in archaeological samples the pathology is still useful in the identification of developmental stress in ancient human populations (El-Najjar et al. 2978; Miszkiewicz 2012). Enamel hypoplasia has been identified in a multitude of osteological collections from around the world at varying times and as such is a critical tool which can and should be utilized to increase our understanding of childhood in ancient human populations (Mays et al. 2017; Miszkiewicz 2012; Towle and Irish 2020). Many studies concerning the presence of EH have considered the pathology within the context of 'weaning stress' model (Mays et al 2017) however, other causative factors such as viral and bacterial infections, physiological trauma sustained to the enamel during tooth development, premature birth, and malnutrition are often considered as potential differential diagnoses. The addition to incremental stable isotope analysis to studies evaluating EH can be used to more accurately confirm that EH resulted during the weaning process (Mays et al. 2017). In addition, measurements of EH can be compared to those from previous studies to determine to determine if they are consistent with expected weaning ages.

Within Mesoamerica several studies have considered the presence of EH in relation to sociopolitical, economic, and subsequent dietary changes; one such study was significant in increasing our general understanding of life of Maya children between the cessation of weaning and adulthood (Cucina 2013); this work determined that only individuals who experienced extreme levels of developmental stress (indicated by eight incidences or more of EH) were at risk of dying before adulthood (Cucina 2013). Within the Maya geopolitical sphere rates of EH have also been found to remain consistent during the Early, Late, and Postclassic periods (Wright 1998). Additionally, a more recent comparative study of EH at three Maya sites (Colha, La Milpa, and Dos Hombres) confirmed that rates of EH formation are temporally consistent throughout the Maya chronology however, peak population increases at sites during the Classic Period are associated with a noteworthy decrease in the identified incidences of EH (Riegert 2018:52). Despite the abundance of research on EH most studies of the pathology use teeth which are still present in occlusion and have overlooked the potential for the use of teeth with EH from loose and commingled dental assemblages; a singular paper was identified during the literature review for this thesis which considered loose teeth in the reconstruction of dietary trends but no incidences of EH were identified in the sample (Pfeiffer et al. 2020)

The observation and recording of dental caries and EH is critical to our understanding of any given populations dental/oral health. This is particularly true in the further development of bioarchaeological reconstructions of childhood in ancient human populations. Observations of caries and EH, however, are not always possible. This is particularly true when large build ups of dental calculus (dental plaque) prevent observation of a tooth's exterior surface. The above sections have showed a small sample of work which depicts the invaluable information that can be obtained from the observation of dental pathologies in remains originating from archaeological sites however, almost all archaeological studies have overlooked the use of loose and commingled dental assemblages in paleopathological investigations of ancient human populations and, in my opinion, have ignored both a valuable and likely plentiful sample pool.

2.9 Dental Calculus

Dental calculus is mineralized dental plaque that is present on the outside surfaces of many teeth as well as sub-gingival area (Waldron 2021: 315). Dental calculus is primarily formed of calcium phosphate ($Ca_3[PO_4]_2$) which precipitates from minerals found in saliva (Waldron 2021). There is a strong correlation between poor oral hygiene and the prevalence of dental calculus, particularly on the lingual surfaces of teeth where calculus is most likely to from due to the increased presence of saliva and higher rate or precipitation (Nasution and Amatanesia 2018: 2-3).

Deposits of calculus are commonly found in dental assemblages around the world and were originally believed to be of little research value; in the earliest days of dental anthropological research the deposits were often removed and discarded in order to facilitate closer observation of the actual tooth itself (Scott and Turner 1988). However, today dental calculus is seen as one of the most valuable resources for reconstructing the diet, health, and environment of past human population (Power et al. 2014; Warriner et al. 2014). Calculus, like teeth, is remarkably resilient to taphonomic processes and as such preserves considerably better than most other biological materials in the archaeological record (Warriner et al. 2014: 1).

Calculus forms over time, much like soil matrix, with consecutive layers being deposited on top of each other over and over again. Between these layers, organic and inorganic material is both preserved and protected from outside forces that would otherwise contaminate or destroy a sample. In fact, calculus is such a remarkable medium for preservation that archaeologists specializing in genetics and proteomics now use the material as a source location as it contains some of the oldest and most well-preserved genetic samples that can be recovered. Since the 1970s, observation of dental calculus deposits under a scanning electron microscope (SEM) has revealed preserved organic materials such as starches and phytoliths which can be used to reconstruct trends in paleodiet (Hardy et al. 2016). More recently, multiple pathways of inclusion have been identified, such as non-deliberate consumption, breathing, and illness (Hardy et al. 2016: 73-76).

The observation and analysis of dental calculus in the study of loose dental assemblages is critical as the organic and inorganic materials contained within the calculus matrix can be used to reconstruct a vast amount of the information lost due to the depositional nature of the loose tooth assemblages. For example, a singular tooth out of context is of little value for understanding a person's environment, health, and diet; however, genetic, proteomic, and microscopic analysis of the calculus contained on a singular tooth can provided information on environmental conditions (Hardy et al. 2016), the presence of disease and pathogens in a population (Warriner et al 2014), and specific information about diet (e.g., what species of cultivates were being consumed) (Henry et al. 2010).

2.10 Conclusion

Teeth provide an opportunity to study ancient populations particularly in the case of a large loose dental assemblage. Limited research has been conducted in Mesoamerica, and around the world, on loose dental assemblages. It is not yet fully understood what types of data sets can be generated from loose tooth assemblages and if they are of any use in the reconstruction of bioarchaeological narratives. It is likely that this is due to the lack of human skeletal data associated with the assemblages which may limit the interpretations and question that a researcher can ask. It seems that this type of research has generally been avoided resulting in the archaeological significance of loose tooth assemblages not being fully understood.

Although human skeletal data is not readily available in the case of a loose tooth assemblage, most of the common areas of research conducted in dental anthropology such as dental wear, pathological observation, and calculus analysis are still applicable in loose tooth assemblages. Further, many of the scoring systems already used within the field consider teeth in an individual context and not as a part of a full set. Consequently, the process of cataloging a loose tooth assemblage may directly benefit the field of dental anthropology by providing a large comparative data set which can be used in future studies.

Ancient Maya populations present a unique opportunity to investigate the applicability of loose tooth assemblages in relation to modern bioarchaeological research questions for two primary reasons. First, it has been shown that intentional deposits of cached teeth are present in Maya populations and could be future sources of study. Second, the study of loose tooth assemblages in the Maya region may provide new bioarchaeological data which has been overlooked due to the complex nature and extensive work associate with processing such assemblages. I will test the validity of loose dental assemblages in the development of bioarchaeological narratives, and the progression of comparative dental anthropological research, through the study of a large dental assemblage (n=509) recovered from four chultuns at the Formative-Postclassic site of Ka'kabish, Belize.

3.0 SITE AND BURIAL CONTEXT

3.1 Ka'kabish

The dental sample used in this thesis was collected over multiple field seasons from Ka'kabish, Belize. The site is in the north-central region of Belize and is approximately 10km from the more extensively excavated site of Lamanai (Graham 2004). Occupation of the area likely began in the Middle Formative Period (800 BC), with final habitation estimated around the end of the Late Postclassic Period (AD 1500) (Haines 2019). Several villages surround modern-day Ka'kabish; Indian Church provides food, housing, and excavation assistance to the staff at the Ka'kabish Archaeological Research Project (KARP).

Twenty-seven structures have been identified thus far within the core center of Ka'kabish. However, several factors limit a complete reconstruction of the site. First, Ka'kabish has been extensively looted, and multiple looters' trenches are present through several primary structures (Tremain 2011). Additionally, fast-paced agricultural expansion in the area surrounding Ka'kabish has resulted in irreparable damage and loss of archaeological materials over the last two decades. Other factors impacting the preservation of the site and its materials include the construction of roads and quarrying.

Before discussing the burial context of the chultuns, it is essential to note that the Ka'kabish Archaeological Research Project (KARP) uses a unique methodological approach when excavating structures to subdivide archaeological strata. In addition to using a standard "level", KARP has implemented the use of lot numbers. The term "level" describes variations in the archaeological strata that identify separate naturally occurring or cultural layers in stratigraphy (Moore 2021: 54-55). Lots, however, are used to identify unique or isolated clusters or assemblages within any given level. While a level most often has a single lot assigned, a level containing two features such as multiple burials could have two lots.

3.2 Burial Context

Chultuns can be difficult to locate, are often small and structurally unsound, and can contain biological materials, such as bat guano, that pose serious health risks to excavators. The difficulties associated with excavating chultuns and interpreting the data collected from them are further exacerbated at Ka'kabish by the presence of complex and commingled skeletal/dental assemblages. Unfortunately, the human remains buried in the chultuns at Ka'kabish were not excavated by archaeologists with specialized knowledge in skeletal anatomy or bioarchaeological methods. As a result, much of the initial contextual information that could have been used in this thesis was lost. To remediate the lack of burial information, field notes, excavation data, and extensive osteological analysis were used to reconstruct the deposition and burial context of the remains. The in-lab burial reconstruction was invaluable in elucidating the nature of the dental assemblage and the potentially affiliated human remains. The primary purpose of this chapter is to describe the depositional context of the loose dental assemblage recovered from four chultuns at Ka'kabish and show how the loose teeth have been affiliated with specific clusters of skeletal remains.

The identified MNI within the burial schematics was derived from a secondary osteological assessment that was conducted separately from this thesis research. The MNI established using an osteological assessment does not always corroborate with the number of teeth present in any given level; for example chultun C-3, Level 2 contains 117 teeth and an identified MNI of three (n=3), however, the maximum number of teeth that would be present in a burial containing three individuals is 96; this means the number of teeth present in the level exceeds the number of teeth that could have originated from the identified MNI. At first glance this may appear as an issue, however, when the materials from the upper level of the chultun are added to Level 2 the MNI becomes four (n=4) which could be represented by a total of 128 teeth. It is likely that the discrepancy between the frequency of teeth present in Level 2 and the established MNI is simply a result of more extensive commingling between the levels of the chultun which may have occurred from natural post-depositional disruption of during the excavation process; it should be noted that overall, the number of teeth present within any of the chultuns never exceeds the number of teeth that could have been produced by the total MNI of the entire burial chamber.

3.2.1 Chultun C-1

3.2.1 Chutlun-C1 Depositional Description

Chultun C-1 consists of ten levels and thirteen lots dated using ceramic seriation and radiocarbon dating to between AD 1058-EPC (Early Postclassic) ND 1439-epc. Seven levels contained human/dental remains (2, 4, 5, 6, 7, 8, and 9). Level 2 has an established MNI of 1 and contains four teeth. Levels 4, 5, and 6 (TER/EPC) have been combined; a loss of contextual information occurred during and post-excavation.

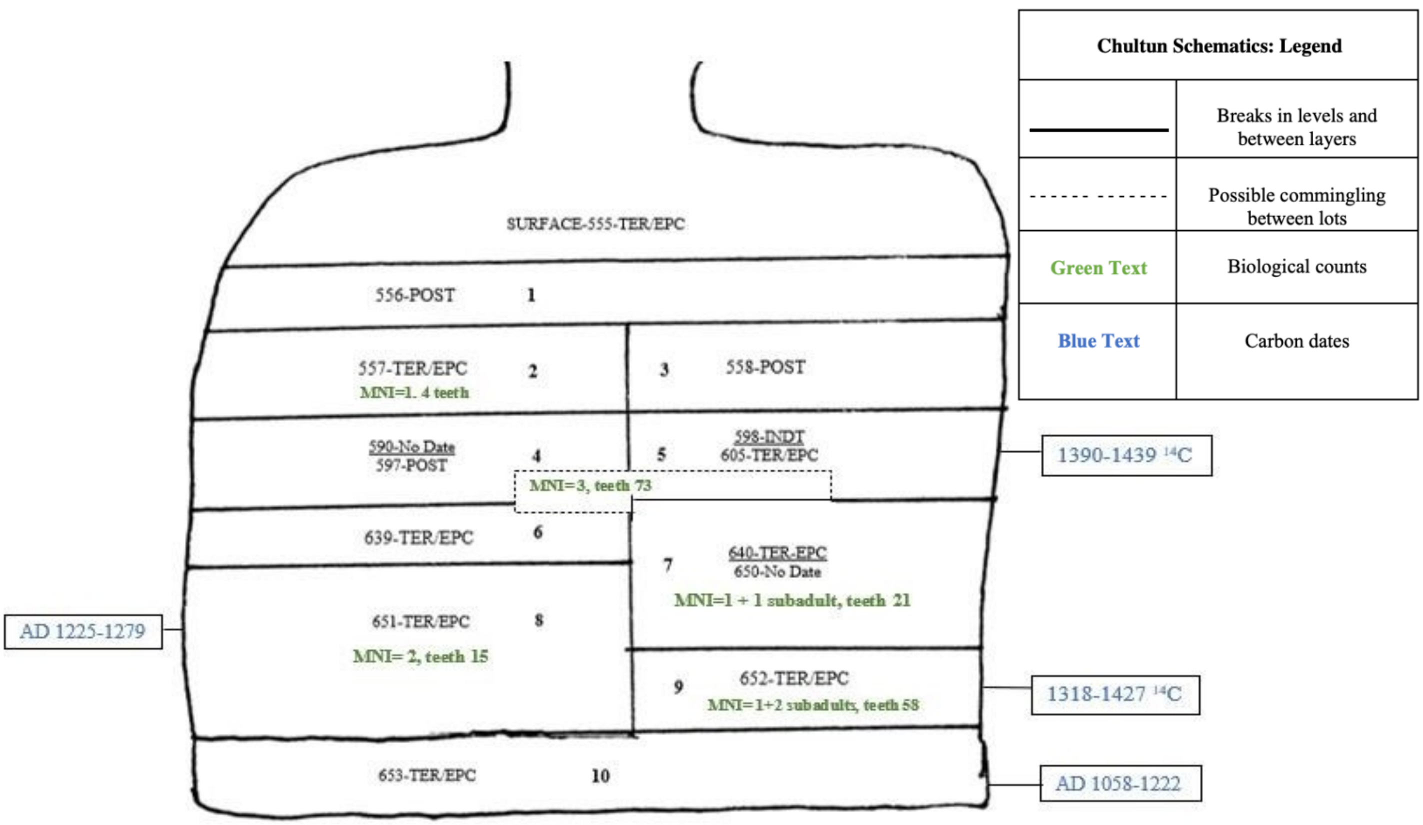


Figure 3.1: Schematic of Chultun C-1 at Ka'Kabish, Belize. Items in green indicate MNI (Minimum Number of Individuals) and the number of teeth per Lot. Items in blue indicate Lots with established ^{14}C radio-carbon dates.

Because of the loss of associated information, the loose teeth cannot be affiliated with specific skeletal remains (MNI=3, seventy-three teeth). Therefore, they must be considered a comingled assemblage as it is impossible to determine if the teeth contained in these neighboring levels were combined post-deposition. The remains of two individuals (1 adult and one subadult) and twenty-one teeth were identified in the lower portion of Level 7 (TER/EPC). Level 8 contained the remains of two individuals and 15 teeth and was separated from Level 7 by a compact layer of soil. Finally, Level 9 had multiple individuals (MNI=1+2subadults) and fifty-eight teeth (see Figure 3.1).

Chultun C-1				
Level	***Lot***	***Date***	***MNI***	***# Of Teeth***
2	557	TER/EPC	1	4
4,5,6	590, 597, 598, 605, 639	TER/EPC	3	73
7	640/650	TER/EPC	1+1*	21
8	651	TER/EPC	2	15
9	652	TER/EPC	1+2*	58
		Total:	***8+3****	***171***

Table 1.1: Depositional summary of levels within Chultun C-1 containing human remains. Asterisk (*) indicates subadults.

3.2.2 Chultun C-2

3.2.2.1 Chultun C-2 Depositional Description

Chultun C-2 (see Figure 3.2) dates from the Late Formative to Early Post Classic Periods. The upper levels of the chultun (surface to Level 5) do not contain human remains. Levels 7 (MNI=2, 15 teeth), 6 (MNI=1), and 9 (MNI=2) have a minimum of five individuals and 15 loose teeth. The lots associated with each of the identified levels were securely separated using ceramic seriation, meaning that the chance of post-depositional comingling of the remains is low.

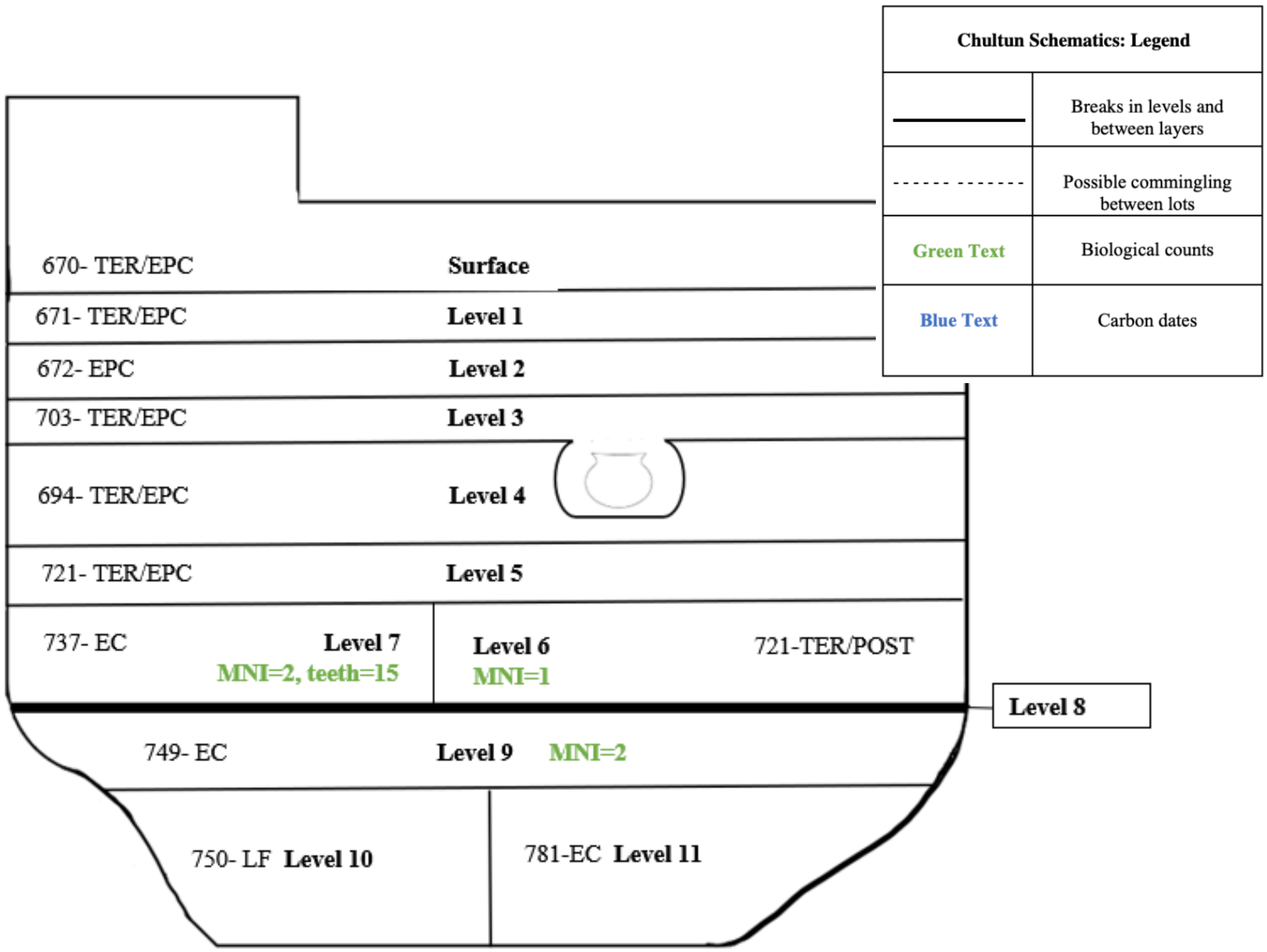


Figure 3.2: Schematic of Chultun C-2 at Ka'Kabish, Belize. Items in green indicate MNI (Minimum Number of Individuals) and the number of teeth per Lot..

Chultun C-2				
Level	***Lot***	***Date***	***MNI***	***# Of Teeth***
6	721	TER/POST	1	0
7	737	EC	2	15
9	749	EC	2	0
		Total:	***5***	***15***

Table 1.2: Depositional summary of levels within Chultun C-2 containing human remains.

3.2.3 Chultun C-3

3.2.3.1 Chultun C-3 Description

The surface level of Chultun C-3 contains seven identified, loose teeth but does not have other skeletal remains. However, Level 1 has an established MNI of one and includes three teeth; the individual contained in Level 1 was interred close to the surface level and the seven unaffiliated teeth in the surface level likely belonged to this individual and were disturbed post depositionally. Level 2 (MNI=3) contained the highest frequency of teeth (n=117).

Chultun Schematics: Legend	
———	Breaks in levels and between layers
------ -------	Possible commingling between lots
Green Text	Biological counts
Blue Text	Carbon dates

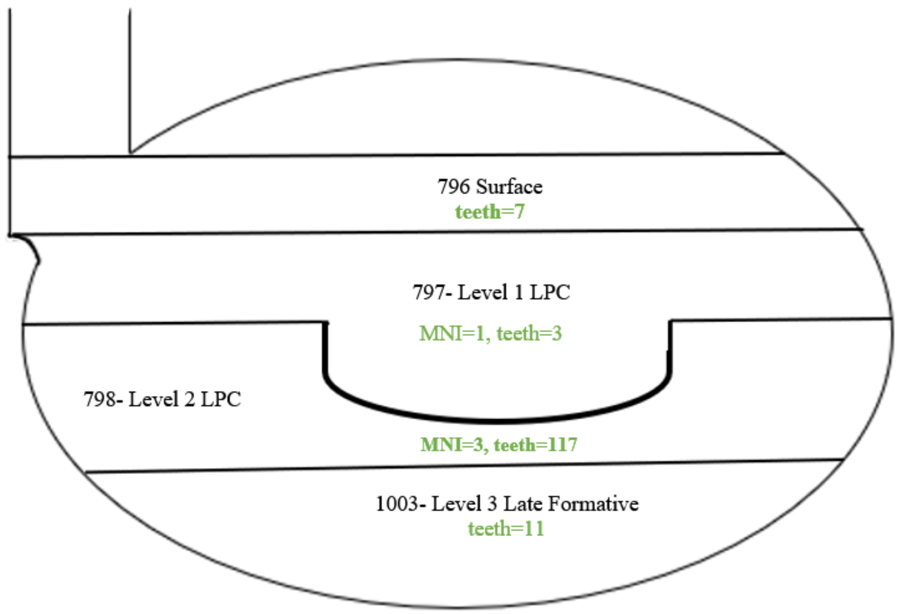


Figure 3.3: Schematic of Chultun C-3 at Ka'Kabish, Belize. Items in green indicate MNI (Minimum Number of Individuals) and the number of teeth per Lot.

Finally, Level 3 had highly deteriorated bone fragments and 11 identified teeth. Overall, Chultun C-3 contained 128 loose teeth with an MNI of 5; the number of teeth overall does not exceed the possible number of teeth expected of five individuals.

Chultun C-3				
Level	***Lot***	***Date***	***MNI***	***# Of Teeth***
SURFACE	796	LPC	?	7
1	797	LPC	1	3
2	798	LPC	3	117
3	1001	LF	1	11
		Total:	***5***	***138***

Table 1.3: Depositional summary of levels within Chultun C-3 containing human remains. ? indicates possible individual.

3.2.4 Chultun B-2

3.2.4.1 Chultun B-2 Description

Chultun B-2 dates from the Terminal Classic to Post Classic periods. The surface level of Chultun B-2 contained a singular tooth with no other skeletal remains. Level 2 (MNI=1) also has a singular loose tooth that is associated with the skeletal remains. Level 3 (MNI=1) contained twenty loose teeth. Levels 4 and 5 could not be easily separated and thus have been combined to represent, what is likely, a singular individual with two loose teeth identified near the remains (Level 3, 4, and 5 may represent a comingled group of individuals since levels 3 and 4 are side-by-side).

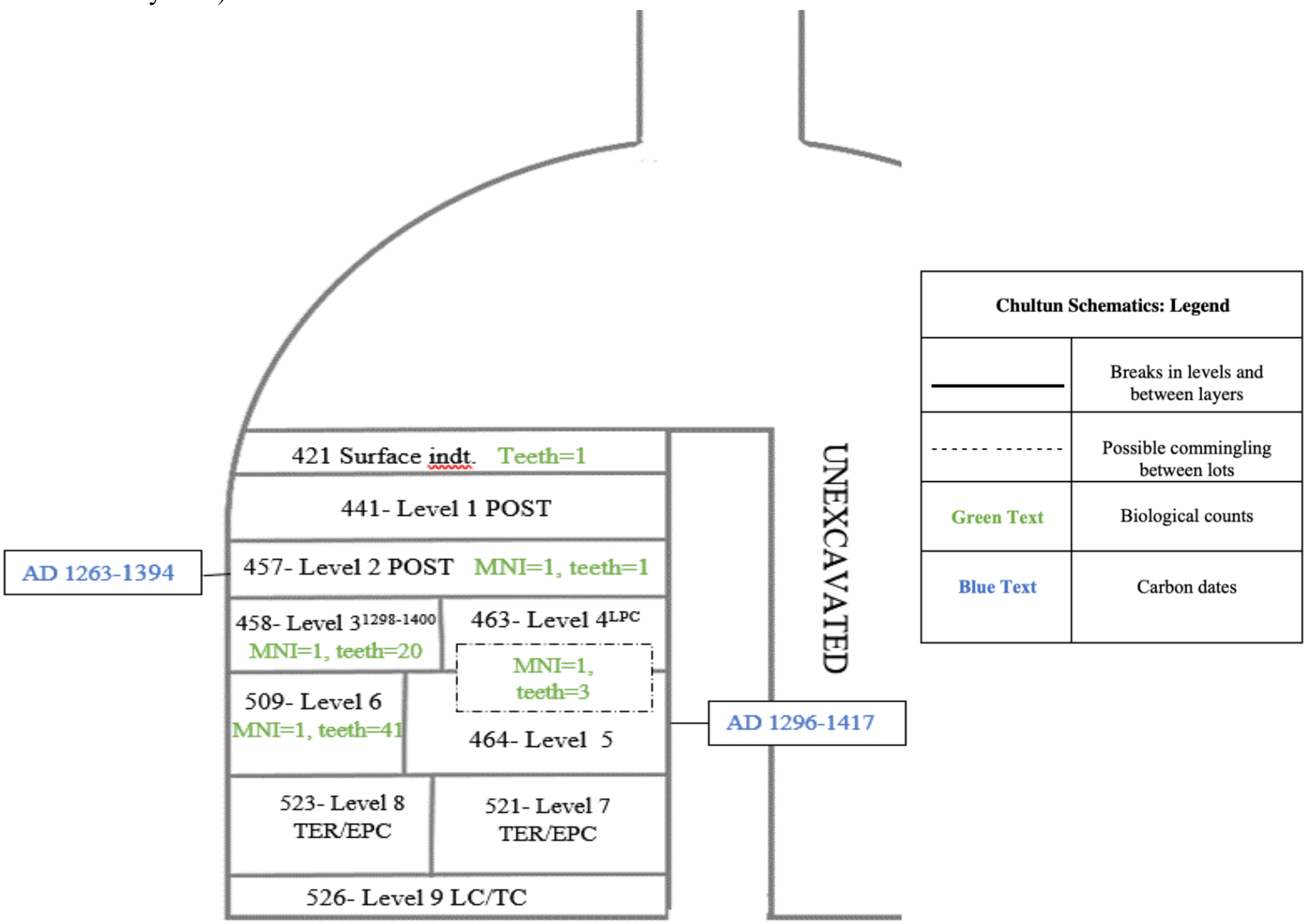


Figure 3.4: Schematic of Chultun B-2 at Ka'Kabish, Belize. Items in green indicate MNI (Minimum Number of Individuals) and the number of teeth per Lot. Dates in blue indicate Lots with established ^{14}C radio-carbon dates.

Finally, Level 6 is believed to contain the remains of a singular individual and held the highest frequency of teeth (n=41). Overall, Chultun B-2 includes the remains of at least four individuals and sixty-five (65) teeth.

Chultun B-2				
Level	***Lot***	***Date***	***MNI***	***# Of Teeth***
SURFACE	421	INDT	N/A	1
Level 2	457	AD 1263-1349	1	1
Level 3	458	AD 1298-1400	1	20
Level 4, 5	462/464	LPC (AD 1296-1417)	1	2
Level 6	509	AD 1290-1396	1	41
		Total:	***4***	***65***

Table 1.4: Depositional summary of levels within Chultun B-2 containing human remains.

3.3 Conclusion

The purpose of this chapter was two-fold. First, it gave a brief overview of the site, Ka'kabish, Belize, from which the dental assemblage used in this thesis was sourced. Second, and more importantly, this chapter described the chultuns' burial contexts and depositional nature and their stratigraphy. This information will allow the reader, and future researchers, to better understand how the dental assemblage was divided and how teeth were associated with specific clusters of skeletal remains.

4.0 METHODS AND DATA

Chapter 2 provided a general background on dental anthropology and the types of data generated through the study of human teeth while Chapter 3 presented the contextual background on the site and origins of the sample used in this thesis. As noted, the information used in dental anthropological studies is acquired and recorded using standard methodological approaches. The use of standardized methods allows for both consistency and accuracy when researching dental assemblages and allows researchers to produce data sets that are more easily used in comparative studies.

The purpose of this chapter is two-fold. First, it will describe, in detail, the methodological approaches taken to develop the data set used in this thesis (see Appendix A). Second, this chapter will summarize the data generated using each of the discussed methods. Methodological approaches and a summary of the data from the initial processing of the dental assemblage (i.e., sample procurement, tooth identification, and the ascription of an STN) will be presented first. I will then review the methods used in the pathological scoring of the dentition (i.e., tooth presence, wear, caries, calculus deposits, and enamel hypoplasia) and the data generated using each method, respectively. Finally, this chapter will conclude with an in-depth review of the methods used in the sampling, preparation, processing, and final imaging of the SEM samples discussed later in this thesis.

4.1 Initial Sample Processing

The initial processing of the dental assemblage recovered from the chultuns was conducted during an early bioarchaeological investigation of stable isotopes and diet at Ka'kabish (see Smith 2020). After the importation of the human remains from Belize was complete, the dental sample was broadly divided into two primary sub-categories: permanent and deciduous dentition (Smith 2020: 72-73). The loose teeth were then further divided into clusters of tooth types (e.g., maxillary molars, mandibular molars, incisors, premolars, etc.) within each excavation level

(Smith 2020). The preliminary sorting of the teeth by Smith (2020) was not specific enough to facilitate further scoring, so I conducted a secondary analysis to identify each individual tooth.

4.2.1 Tooth Identification

In the case of this thesis, the identification of specific teeth was completed through a process of elimination. Teeth had previously been divided into broad categories: permanent vs. deciduous, mandibular vs maxillary, and molar vs. non-molar (Smith 2020). However, further analysis, by myself was conducted to assign an FDI number (see section 4.2.1) by observing the form of tooth crown morphology, root number, and wear facets following the methods described by White and Folkens (2005).

4.2.1.1Dental Notation

Dental notation involves ascribing a series of numbers and letters to each specific tooth to associate information with those teeth. This thesis used the Fédération Dentaire Internationale or the World Dental Federation notation system, commonly referred to as FDI. The FDI system is the most utilized notation system in dental research. It is used in most countries, excluding the United States of America where they use the Universal Numbering System (UNS).

	Quadrant Codes		***Tooth Codes***
1	Upper right permanent dentition	***1***	Central Incisors
2	Upper left permanent dentition	***2***	Lateral Incisors
3	Lowe left permanent dentition	***3***	Canines
4	Lower right permanent dentition	***4***	1st Premolars (permanent) 1st Molar (deciduous)
5	Upper right deciduous dentition	***5***	2nd Premolars (permanent) 2nd Molar (deciduous)
6	Upper left deciduous dentition	***6***	1st Molars (permanent dentition)
7	Lower left deciduous dentition	***7***	2nd Molars (permanent dentition)
8	Lower right deciduous dentition	***8***	3rd Molars (permanent dentition)

Table 4.2: FDI scoring notation codes

The FDI system divides the dental arches into four quadrants: upper left maxillary quadrant, upper right maxillary quadrant, lower left mandibular quadrant, and lower right mandibular quadrant. Each quadrant contains eight teeth: a central and lateral incisor, a canine, the two premolars, and the three molars. Each quadrant is given a code (see Table 4.1) and each tooth (see Table 4.2); the combination of these two codes produces the FDI number. For example, lower right permanent teeth are coded as a "4," and canines are coded as a "3," so a lower right permanent canine would be a 43 in FDI notation (for more information on FDI notation, please consult the World Dental Federation's website www.fdiworlddental.org).

4.2.1.2 Site Tooth Number

In addition to using FDI notation, each tooth from the Ka'kabish dental assemblage has been assigned a site tooth number (STN). The use of an STN is multifunctional: Primarily, the STN allows for easier management and tracking of teeth, which may be temporarily removed from the assemblage for additional study or testing. By having a unique numeric identifier, each tooth can easily be cross-referenced with the master database and reassociated with other samples and contextual information (e.g., burial location, lot number, excavation level, other skeletal remains). Additionally, accessing samples via an STN does not require technical expertise in dental analysis, and an individual would not need an understanding of dental notation to do so. Site tooth numbers were assigned sequentially to analyze the teeth (i.e., the first tooth observed was STN1, and the last tooth observed was STN509).

4.2.2 Tooth Type, Frequency, and Presence

The number of teeth contained in each chultun varies proportionally to the established MNI (see Chapter 3). The tooth type (identified by FDI numbers) and frequency for each chultun was recorded during the initial analysis (see Figure 4.1). The data contained in Figure 4.1 summarizes the teeth that were securely identified and excludes those that, due to varying reasons, could not be given a secure FDI number (see Appendix A for a complete summary of FDI numbers).

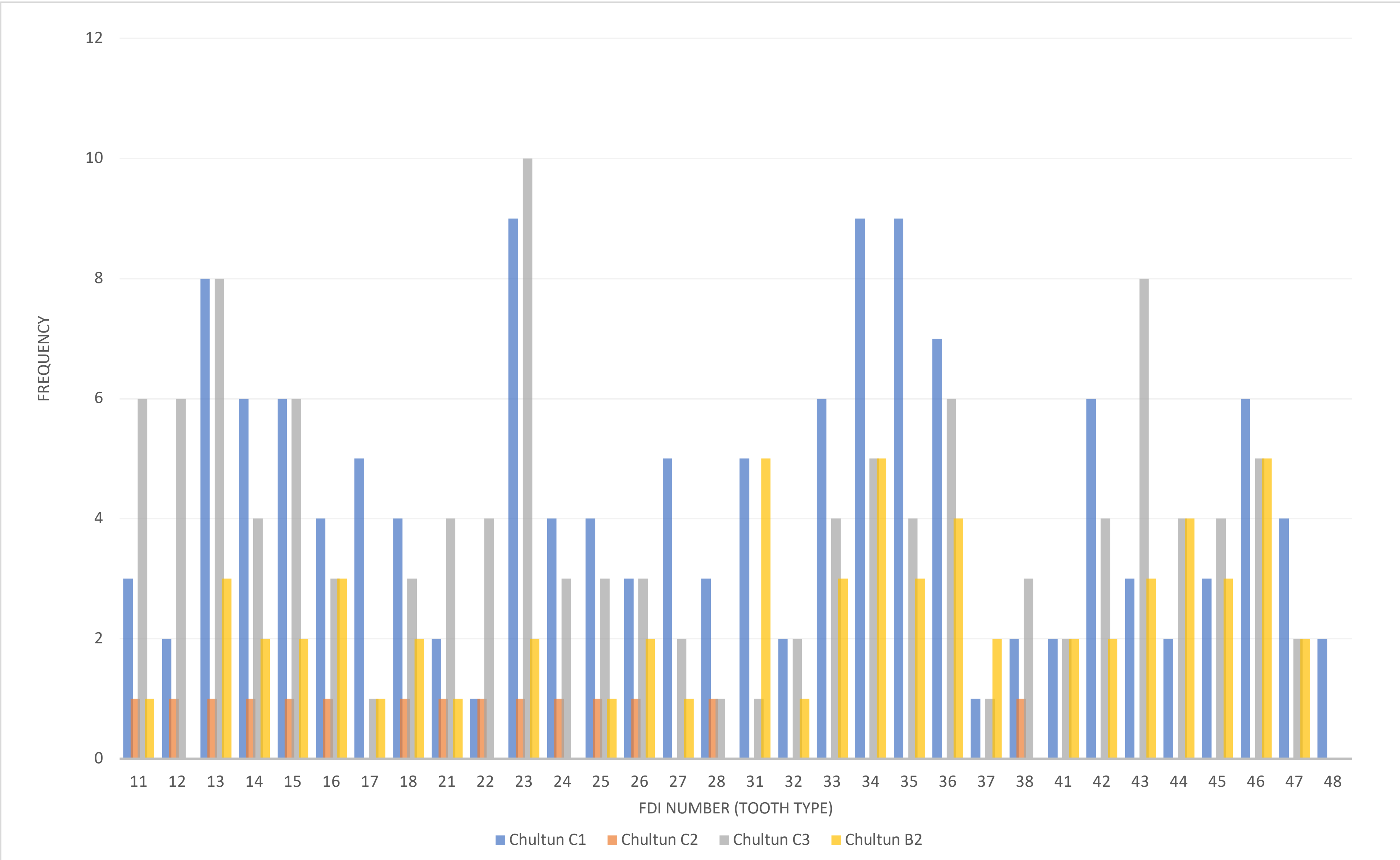


Figure 4.1: A breakdown of tooth type (FDI) of securely identified teeth by chultun.

4.2.2.1 Tooth Presence

Tooth presence refers to the completeness of the teeth contained within the commingled dental assemblage; "completeness" of teeth refers to how much of the loose tooth remains (i.e., is it complete, only a root is present, only a crown is present, etc.). Scoring of tooth presence was completed using an altered version of the "Inventory Categories for Recording the Dentition" from Buikstra and Ubelaker's *Standards for Data Collection from Human Skeletal Remains* (1994: 49). The system used by Buikstra and Ubelaker does not have a score for teeth that are both "present, but not in occlusion" and intentionally modified, so a score of 10 was added to alter their system to include teeth with both traits. Given that the sample used in this thesis is comprised of loose teeth, most of the sample was given a score of 1 (*present, but not in occlusion*), 7 (*present, damage renders measurement impossible, other observations are recorded*), or 10 *(present, but not in occlusion and intentionally modified)*.

The presence score for the teeth in the Ka'kabish commingled dental assemblage varied. By far, the majority of the teeth (n=354) were scored as a 1, representing 91% of the assemblage. However, a score of 7 was given to 3 teeth (0.8% of the commingled assemblage); each only had a crown and no root. Additionally, 22 teeth, representing 5.9% of the assemblage, could not be assessed due to intentional dental modifications. It should also be noted that seven teeth could not be scored for presence (see Table 4.3 for tooth presence summary). No score for presence has been provided after “1” given that all tooth roots that were observable were fully developed.

Tooth Presence		
Score	**#**	**%**
1	354	91.7
7	3	0.8
10	22	5.7
Unknown	7	1.8
Total:	*386*	100

Table 4.3: Summary of Tooth Presence Scores: Ka’kabish Commingled Dental assemblage

4.3 Dental Wear

Wear in this study was recorded using two different methods. First, the wear on the anterior dentition (incisors, canines, and premolars) was recorded using a modified version of Smith's anterior wear scoring system (Buikstra and Ubelaker 1994:52). The posterior dentition (molars) was scored using the "Scott system for scoring surface wear on molars" (Scott 1979:214; Buikstra and Ubelaker 1994:53). Buikstra and Ubelaker (1994) recommend that the two separate systems be used to score dental wear as Smith System fails to differentiate between moderate-to-low wear rates (Buikstra and Ubelaker 1994:52-53).

Wear data was recorded for each individual tooth, posterior and anterior, and recorded in the master excel database (see Appendix A). In addition, data on the average rates of wear by burial, date, and excavation level, for both the anterior (Avrg.Non Mol) and posterior (Avrg.Mol) was also generated (see Tables 4.4 to 4.7).

Chultun C1 Wear Scores				
Time Period	**Date**	**Level**	**Avrg. Mol**	**Avrg. Non Mol**
Postclassic	ND	1	/	/
	ND	2	/	5.5
	ND	3	/	/
	ND	4	/	/
Terminal-EPC	1390-1439	5	3.5	3
	ND	6		
	ND	7	3.4	3.4
	AD 1225-1279	8	/	2.8
	AD 1318-1427	9	3.5	2.9
	AD 1058-1222	10	/	/

Table 4.4: Average Wear Scores of Loose Dentition Recovered from Chultun C1, Ka'kabish

Chultun C2 Wear Scores				
Time Period	**Date**	**Level**	**Avrg. Mol**	**Avrg. Non Mol**
Early Classic	ND	7	3.8	3.2

Table 4.5: Average Wear Scores of Loose Dentition Recovered from Chultun C2, Ka'kabish

Chultun C3 Wear Scores				
Time Period	**Date**	**Level**	**Avrg. Mol**	**Avrg. Non Mol**
	ND	Surface	/	3
Late Postclassic	ND	1	2.5	2.6
	ND	2	3.6	2.7
Late Formative	ND	3	3.8	3.4

Table 4.6: Average Wear Scores of Loose Dentition Recovered from Chultun C3, Ka'kabish

Chultun B2 Wear Scores				
Time Period	**Date**	**Level**	**Avrg. Mol**	**Avrg. Non Mol**
Indeterminant	ND	Surface	1	/
	AD 1298-1400	3	2.5	1.9
Middle to	ND	4	/	/
Late Classic	AD 1296-1417	5	/	/
	AD 1290-1396	6	2.61	2

Table 4.7: Average Wear Scores of Loose Dentition Recovered from Chultun B2, Ka'kabish

4.4 Caries

Several methodological approaches have been developed over the years to assist in identifying and recording dental caries in bioarchaeological human remains (Buikstra and Ubelaker 1994; Hillson 2001; Moore and Corbett 1971). This thesis implemented the methods developed by Buikstra and Ubelaker (1994: 54-55), adapted from the approach developed by Moore and Corbett (1971). This methodological approach scores caries on a scale of 1 to 7. However, the numerical score does not represent the extent of the carious lesions but instead indicates the surface on which the caries were located (see Table 4.8). This method relies on the visual observation of the tooth surface to identify caries; visual observation has been shown to reduce interobserver bias in scoring caries and produces more accurate data on rates of dental caries in any given study (Buikstra and Ubelaker 1994: 54).

	Dental Caries Scores
0	***No lesion present***
1	***Occlusal Surface:*** *any contact surface between mandibular and maxillary teeth*
2	***Interproximal Surfaces:*** *mesial and distal regions*
3	***Smooth surfaces:*** *buccal and lingual*
4	***Cervical Caries:*** *originating at the cementoenamel junction (excludes interproximal areas)*
5	***Root Caries:*** *below the cementoenamel junction*
6	***Large Caries:*** *no discernible location of origin due to the size of the caries*
7	***Noncarious Pulp Exposure:*** *appear as caries but are not*

Table 4.8: Dental caries scoring system adapted from Buikstra and Ubelaker (1994: 55)

4.4.1 Dental Caries Data

Within the commingled dental assemblage from Ka'kabish, some teeth (n=26) presented with caries, of which several (n=6) had more than one. Each of these caries was recorded to the methods outlined above. In addition, the caries data set includes information on the burial, potential individual, level, and lot (for provenience), FDI number, and STN for ease of analysis. A completed summary of the dental caries data can be found below (see Table 4).

Dental Caries: Ka'kabish Dental Assemblage								
Burial	***Individual(s)***	***Level***	***Lot***	***FDI***	***STN***	***Caries***		
<u>Chultun C-1</u>								
Chultun C-1	C1/8	7	650	13/23	351	⁊	-	-
Chultun C-1	C1/8	7	650	13/23	353	⁊	-	-
Chultun C-1	C1/8	7	650	28/18	355	3	-	-
Chultun C-1	C1/2	4	597	46	252	4	⁊	1
Chultun C-1	C1/2	4	597	Mandibular Premolar	259	6	-	-
Chultun C-1	C1/2	4	597	27	263	⁊	-	-
Chultun C-1	C1/3	5	605	17/27	196	⁊	-	-
Chultun C-1	C1/3	5	605	17	199	1	1	-
Chultun C-1	C1/3	5	605	17/27	200	1	-	-
Chultun C-1	C1/3	5	605	?	202	1	-	-
Chultun C-1	C1/3	5	605	16	204	⁊	-	-
Chultun C-1	C1/3	5	605	23	222	3	-	-
Chultun C-1	C1/11	9	652	48	402	1	-	-
Chultun C-1	C1/11	9	652	36	399	6	-	-
Chultun C-1	C1/11	9	652	31	394	1	-	-
<u>Chultun C-2</u>								
Chultun C-2	C2/3	7	737	14/15	454	⁊	-	-
<u>Chultun B-2</u>								
Chultun B-2	B2/1	6	509	36	5	6	4	-
Chultun B-2	B2/1	6	509	37	7	2	-	-
Chultun B-2	B2/1	6	509	43	26	5	-	-
Chultun B-2	B2/1	6	509	13	23	4	-	-
Chultun B-2	B2/1	6	509	26	38	4	-	-
Chultun B-2	B2/2	3	458	46	48	⁊	-	-
Chultun B-2	B2/2	3	458	27	57	3	4	-
<u>Chultun C-3</u>								
Chultun C3	C3/3	3	1003	43	463	6	-	-
Chultun C3	C3/3	3	1003	14	466	⁊	-	-
Chultun C3	C3/2	1	796	46	186	⁊	-	-
Chultun C3	C3/4,5,6	2	798	16	134	⁊	-	-
Chultun C3	C3/4,5,6	2	798	13	172	1	-	-
Chultun C3	C3/4,5,6	2	798	14/15	150	⁊	-	-
Chultun C3	C3/4,5,6	2	798	14/15	149	4	2	6
Chultun C3	C3/4,5,6	2	798	46	69	⁊	⁊	-
Chultun C3	C3/4,5,6	2	798	36	78	4	1	-
Chultun C3	C3/4,5,6	2	798	38	77	1	-	-
Chultun C3	C3/4,5,6	2	798	38	74	1	-	-
Chultun C3	C3/4,5,6	2	798	36/38	73	1	⁊	-
Chultun C3	C3/4,5,6	2	798	Premolar	86	⁊	-	-
Chultun C3	C3/4,5,6	2	798	14/15	82	4	-	-
Chultun C3	C3/4,5,6	2	798	43	110	6	-	-

Table 4.9: A summary of the data pertaining to frequency and types of caries recorded in the Ka'kabish commingled dental assemblage. Note "⁊" indicates noncarious pulp exposures which should not be used in analysis of caries prevalence/frequency. Three columns are present under "Caries" to accommodate teeth that may present with more than one carie. Individuals recorded as Burial/individual number [e.g., C1(chultun C1)/Individuals (1,2,3 etc.)].

4.5 Enamel Hypoplasia

Linear enamel hypoplasia was identified on some of the teeth from the assemblage. The EH was recorded using methods for estimating the age at which the EH (Goodman et al. 1980). Electronic calipers were used to measure the EH's maximum height to the CEJ (cementoenamel junction). Multiple instances of EH on singular teeth were all measured and documented. Nine (n=9) teeth presented with linear enamel hypoplasia within the commingled dental assemblage. Of the recorded nine teeth with EH, four (n=4) presented with two separate EH lines (see Table 4.10 for a summary of EH data).

Enamel Hypoplasia Measurements					
Burial	**Individual**	**Lot**	**FDI**	**STN**	**EH Measurement (mm)**
Chultun C-1	C1/2	4	47	248	3mm and 4mm
Chultun C-1	C1/11	9	12	377	4.5mm and 3mm
Chultun C-2	C2/3	7	28	458	3mm and 1.5mm
Chultun C-2	C2/3	7	14/15	454	3mm
Chultun C3	C3/3	3	43	464	7mm and 2.5mm
Chultun C3	C3/2	1	46	186	1.75mm
Chultun C3	C3/4,5,6	2	12	159	6.5mm
Chultun C3	C3/4,5,6	2	12	155	7mm
Chultun C3	C3/4,5,6	2	33	114	4.5mm

Table 4.10: A summary of the EH measurements from the Ka'kabish commingled dental assemblage.

The collected EH measurements were then calibrated to an American population using the regression equations developed Wright (1997) (see Table 4.11). This was done to ensure the ages at formation were more specific to an America population and not a European population which the system was originally calibrated for.

Tooth	Development Age CEJ	Regression Equation[1]	Minimum Scorable Age
Maxillary			
1	4.5	-0.307x+4.5	2.5
2	4.5	-0.238x+4.5	3.0
3	6.0	-0.313x+6.0	3.5
4	6.0	-0.357x+6.0	4.0
5	6.0	-0.338x+6.0	4.0
6	3.5	-0.342x+3.5	2.0
7	7.5	-0.480x+7.5	5.0
Mandibular			
1	4.0	-0.304x+4.0	2.5
2	4.0	-0.308x+4.0	2.5
3	4.5	-0.258x+4.5	2.5
4	6.0	-0.483x+6.0	3.5
5	7.0	-0.524x+7.0	4.5
6	3.5	-0.325x+3.5	2.0
7	7.0	-0.400x+7.0	5.5

Table 4.11 : Regression equations for the estimation of age formation of enamel hypoplasia in a population from the Americas. Adapted from Wright (1997:239).
[1] *Where x equals the recorded EH measurement from the cementoenamel junction.*

4.6 Dental Calculus

Dental calculus was recorded for each tooth when present and scored using the standards set out by Buikstra and Ubelaker (1994: 56). Visual observation of the tooth's surface was implemented to identify calculus deposits. The scoring system is based on a 0-3 scale with a 0 indicating no calculus, 1 representing a small amount of calculus, a 2 indicates a moderate deposit, and a 3 representing a large deposit (see Figure 28 [Buikstra and Ubelaker 1994: 56] for a visual representation of varying calculus scores.

Within the assemblage, 138 (or 35.8%) of the loose teeth had at least some dental calculus. The average calculus score within the entire assemblage was 1.4 (small-moderate amount). Ninety-seven (70%) of the teeth that had calculus were scored as a "1" (small amount of calculus). An additional 34 teeth (24%) were scored as a 2 (moderate amount of calculus). Finally, eight teeth (6%) had a calculus score of 3 (a large amount of calculus). The identified calculus deposits were most often located on the lingual surface of the teeth, with several deposits also present on the labial surfaces of some teeth. However, many of the teeth, primarily those scored as a 1, had a thin layer of calculus covering the entire non-occlusal surface of the tooth, and no specific surface was identifiable (see Appendix C for dental calculus data).

4.7 Scanning Electron Microscopy

Dental calculus samples were imaged using scanning electron microscopy (SEM) at The University of Guelph's Molecular and Cellular Imaging Facility (MCIF). The SEM imaging was conducted under the supervision of Dr. Elyse Roach (Ph.D., Molecular and Cellular Imaging). Ten (n=10) teeth with dental calculus were imaged using SEM for this pilot project.

Two samples (n=2) were initially sent to MCIF and processed by Dr. Roach to determine the viability of imaging calculus samples from the Ka'kabish commingled dental assemblage. Dr. Roach ran the initial test samples. The test samples yielded positive results and the dental calculus samples were deemed viable for further SEM analysis. After the success of the test samples, eight (n=8) more teeth were selected for study (additional information on sample selection can be found in section 4.7.1).

4.7.1 SEM Sample Selection

Stratified sampling was used to select the eight (n=8) other teeth/dental calculus deposits imaged in this study. Three primary factors impacted the selection process:

1. The dental calculus score of the tooth was used to assess the viability of a calculus sample for imaging. Teeth with higher calculus scores (e.g., 2 or 3) were given preference over a score of 1 to maximize the amount of the sample available to image.
2. The location of the teeth was also considered, with at least two (n=2) samples originating from each of the identified chultuns.
3. Teeth associated with secure C14 dates were prioritized to facilitate the viability of the SEM imaging over time.

These three criteria were used whenever possible. However, in some cases, they could not be followed. For example, all teeth within Chultun C-2 that presented with dental calculus received a score of 1 excluding a single tooth (score of 3), so one tooth with a score of 1 was used due to sampling availability (see Table 4.11 for sample information.

SEM Samples				
Chultun	***Lot***	***Tooth***	***Score***	***Date***
B-2	458	Mandibular Molar	3	AD 1298-1400*
B-2	458	Maxillary Molar	3	AD 1298-1400*
B-2	458	33	3	AD 1298-1400*
B-2	509	32	2	AD 1290-1396*
C-1	605	Maxillary Premolar	3	AD 1390-1439*
C-1	652	43	2	AD 1318-1472*
C-2	738	16	2	56 BC-AD 124*
C-2	727	24	1	TERM/POST
C-3	1003	43	2	Late Formative (cer)
C-3	798	Mandibular Premolar	2	AD 1249-1453*

Table 4.12: Summary of Samples Used in SEM Analysis. “*” indicates samples dates using C14, “(cer)” indicates samples dated using ceramic seriation.

4.7.2 SEM Sample Preparation and Imaging

Samples were prepared for scanning electron microscopy by mounting on aluminum stubs with double-sided carbon adhesive and conductive aluminum-based tape. They were then sputter-coated with a gold-palladium coating for 90 s at 20 mA using a Denton Desk V TSC. Samples were then imaged using an FEI Quanta FEG 250 SEM operated at 20 kV under high vacuum (Roach 2021). This methodological approach used whole tooth samples (calculus was not removed from the tooth for imaging) for imaging (see Image 4.1).

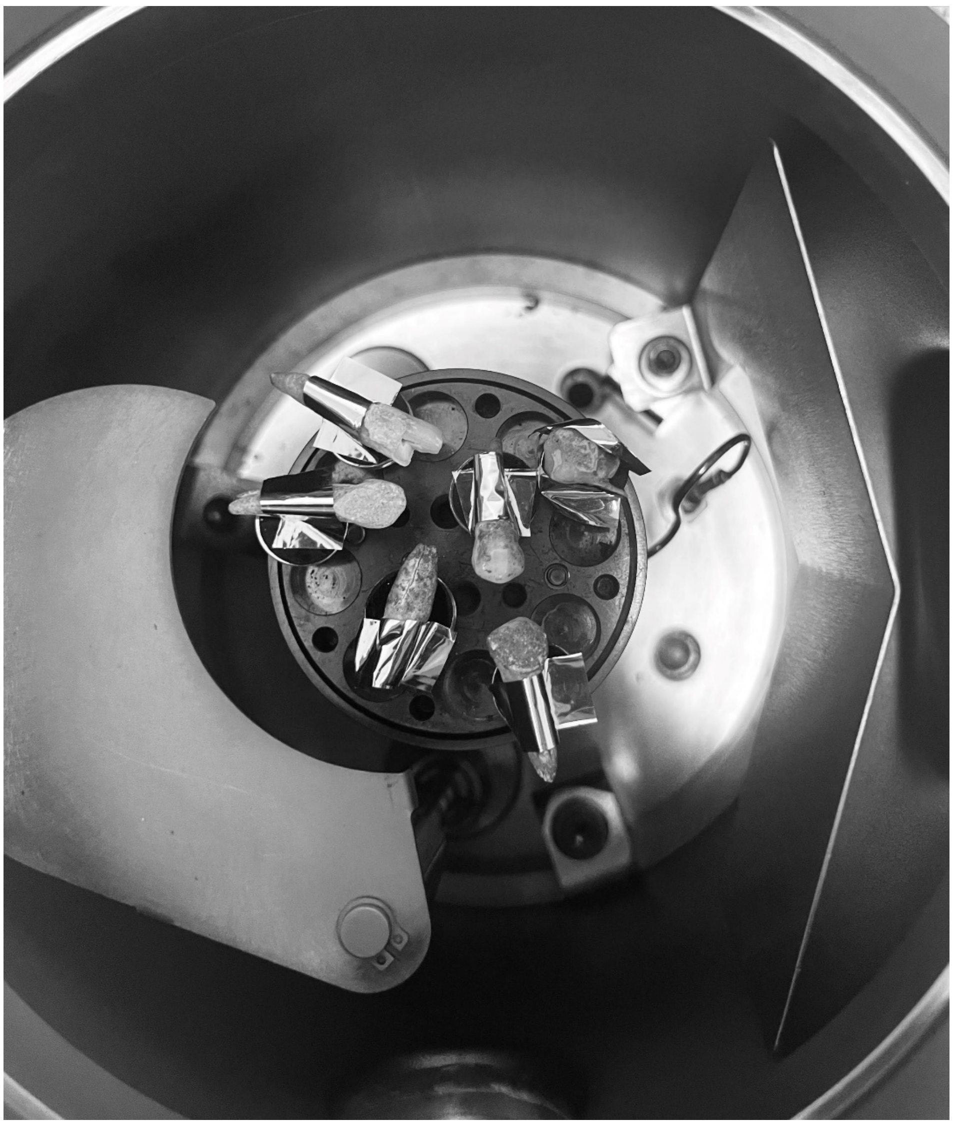


Image 4.1: Dental SEM samples loaded into the microscope prior to imaging.

4.7.3 Initial Results

Overall, the SEM imaging of the dental calculus samples was successful. The number of images generated was limited due to time and monetary constraints. However, over seventy-five (n=75) pictures were taken between the ten samples. The images produced were clear with a maximum magnification peaking at 200,000x; any attempt to further magnify specimens beyond 200,000x resulted in distorted images. A complete compilation of the generated images can be found in Appendix B (see Images 4.2, 4.3, and 4.4 for examples of SEM imaging results).

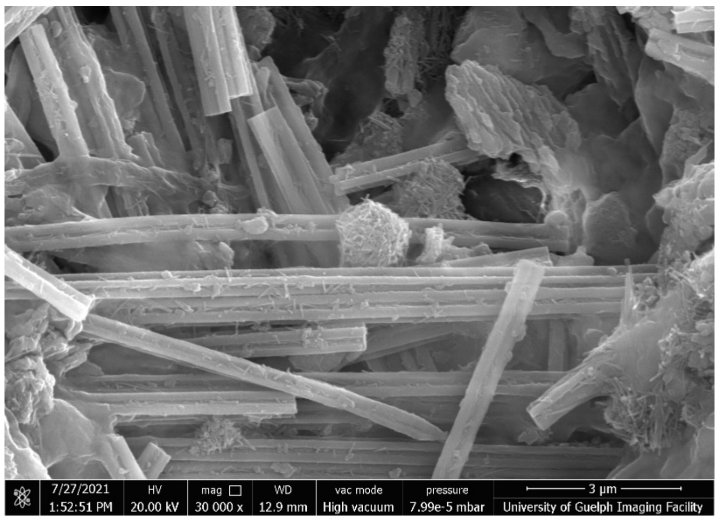


Image 4.2: Sample 1, Image 15 (30,000x magnification)

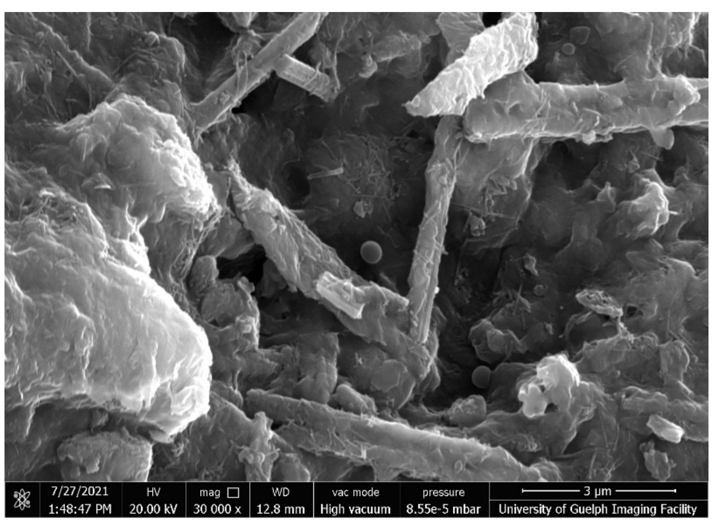


Image 4.3: Sample 1, Image 13 (30,000x magnification)

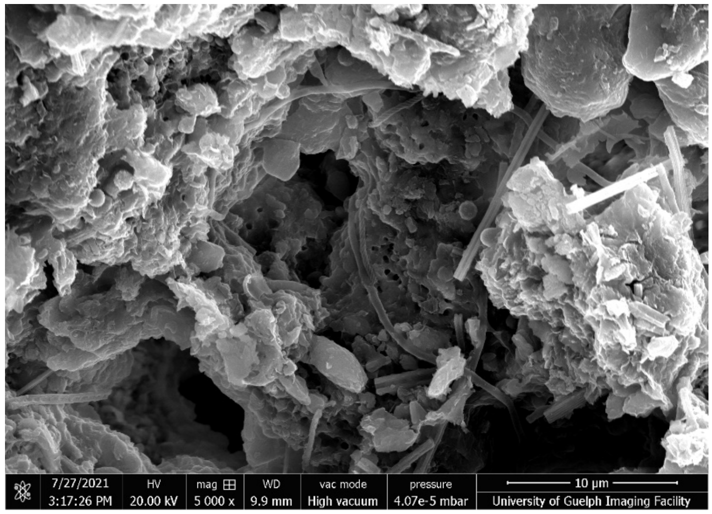


Image 4.4: Sample 6, Image 3 (5,000x magnification)

4.8 Conclusion

The primary function of this chapter was twofold. First, it served to present the methodological approaches used to generate the primary data set used in this thesis. Methodological overviews were provided for the initial sampling process, tooth identification, dental wear recording, caries identification, recording of enamel hypoplasia, and scoring of dental calculus deposits. Additionally, this chapter reviewed the methods used in the sample selection, preparation, and SEM imaging of dental calculus deposits.

In addition to reviewing methods used in this thesis, the chapter also presented a brief overview of the data generated through the implementation of the above-mentioned methodological approaches. The data, and relevant tables, serve to inform the reader of the types and general trends of data recorded/observed. The succeeding chapter will discuss the analysis and interpretations of the data and its potential use in the investigation of commingled dental assemblages.

5.0 ANALYSIS and DISCUSSION

Chapter four provided an overview of the methodological approaches used in this thesis and the data generated through their implementation. Primary topics covered in Chapter 4 included: tooth identification (including type, frequency, and presence), dental wear, dental pathologies (i.e., caries and enamel hypoplasia), dental calculus, and electron microscopy. The data collected using the various methodologies outlined in Chapter 4 will be analyzed in this chapter to explore the viability of commingled dental assemblages as a tool for producing data sets that can be used to examine ancient human populations. This chapter will then discuss how, and if, the data generated using standard methodological approaches within the context of loose tooth assemblages, can be used to develop bioarchaeological narratives.

The chapter will then make suggestions regarding standardizing an approach to processing, recording, and cataloging commingled dental assemblages to maximize their contributions to bioarchaeological investigations of ancient human populations on an inter-site and regional scale. Chapter 5 will conclude with some suggestions for potential future research questions concerning the use of loose dental assemblages in the investigation of ancient human populations; specific suggestions for future research on the commingled assemblage from Ka'kabish will also be provided. The chapter will conclude with a summary the primary research findings and an explanation as to why commingled dental assemblages should not be overlooked in bioarchaeological research.

5.1 Tooth Frequency, Type, and Presence

5.1.1 Tooth Frequency and Time Periods

A total of 386 loose teeth were present in the Ka'kabish commingled dental assemblage. These teeth were divided between four chultuns (C-1, C-2, C-3, and B-2) (see Chapter 3 for burial details). Chultun C-1 contained the highest frequency of teeth (n=171), all dated to the Terminal Classic to Early Postclassic periods. Most of the teeth recovered from Chultun C-1 were identified as permanent adult teeth, with only three of the teeth (n=3) identified as deciduous.

Chultun C-3 contained the second highest frequency of teeth (n=138). Most of the teeth from chultun C-3 were dated to the Late Postclassic period (n=127). However, eleven (n=11) teeth were dated to the Late Formative Period. The commingled dental sample from Chultun C-3 was primarily composed of permanent dentition. Only three (n=3) of the teeth recovered were deciduous and were dated to the Late Postclassic period.

Chultun B-2 contained sixty-five teeth (n=65). All the teeth identified in this chultun were dated between the Late Classic and Postclassic periods. However, one (n=1) was present in the surface level and could not be associated with a date. The entirety of the commingled dental sample from Chultun B-2 was comprised of permanent dentition. It should be noted that only half of the B-2 chultun was excavated when this thesis was written. As such, the frequency and type of teeth may change once the unit excavation has been completed.

Finally, Chultun C-2 contained the fewest number of commingled teeth (n=15). The commingled teeth from Chultun C-2 dated to the Early Classic period, and each of the 15 teeth present in the chultun were permanent adult teeth.

The frequency of teeth and the dates associated with them suggest all the chultuns from Ka'kabish, from which the dental assemblage in this thesis originated, were used as burial locations throughout the Late to Postclassic Periods. This is consistent with research conducted into the use and functions of chultuns conducted by Carlos (2019), which showed the most frequent final function of a chultun was burial space.

In the case of the teeth dated to the Late Formative period from Chultun C-3 (level3), three possible explanations for the deviation in date are possible. First, it may be that the teeth were incorporated during a burial that took place at a much earlier date; for example, an individual may have been buried in this chultun and the space was reused as a burial space during the Late Postclassic (Chase and Chase 1996). The teeth may also have been incorporated into the lower strata via taphonomic processes or bioturbation and animal activity which could have resulted in the dentition being mis associated with the lower level of the chultun (Armour-Chelu and Andrews 1994). Finally, the date of the level may not be accurate; however, this scenario is unlikely due to the level of experience and specialization of the site's ceramicist who dated the strata and affiliated materials.

5.1.2 Tooth Type

As mentioned in the previous section, most of the teeth in the commingled dental assemblage from Ka'kabish were permanent teeth. Collectively, only six (n=6) of the 386 teeth were deciduous teeth. Given that the dental assemblage is commingled, it is impossible to determine if these teeth were from a juvenile/adolescent individual, or if the teeth were incorporated into the strata by other means (e.g., tooth caching or intentional ritual deposition). However, each of the chultuns that contained deciduous teeth did have subadult skeletal remains within the burial, so it is likely that the deciduous teeth originated from those individuals.

The breakdown of tooth by type, as identified by the FDI number (see Figure 4.1), is relatively consistent within all the chultuns. The teeth from chultuns C-1, C-2, and C-3 have a proportional distribution between the maxillary and mandibular arches as well as the posterior and anterior dentition. Only Chultun B-2 deviates from this trend; the teeth are proportionally distributed between the posterior and anterior dentition, however, there is a greater frequency of mandibular teeth (n=44) than maxillary teeth (n=21).

The proportional patterning in the frequency of tooth types between the mandibular and maxillary arches and between the posterior and anterior dentition suggests that each of the depositions of teeth represents the remains of interred individuals and likely did not result as a tooth cache. This is further supported by other skeletal remains present within the chultuns, which are not included in known examples of tooth caches. The two documented cases of tooth caching from the Maya region contained teeth and no other human skeletal remains expect for small fragments of skull bones (Pendergast et al. 1968; Saul and Hammond 1974). Additionally, both known cases of tooth caching from the Maya region were affiliated with structures and no tooth caches have been identified in chultuns to date.

The increased frequency of mandibular teeth compared to maxillary in Chultun B-2 may be due to pathologies resulting in tooth loss. Maxillary teeth are more susceptible to periodontal disease, commonly known as gum disease, which is an infection of the gums which, if left untreated, can result in the destruction of the tooth roots which leads to subsequent tooth loss (Upadhyaya 2009). Consequently, maxillary teeth are far more susceptible to antemortem tooth loss (Upadhyaya and Humagain 2009). Therefore, it may be possible that if an individual in Chultun B-2 had severe periodontal disease, they may have experienced higher rates antemortem maxillary tooth loss. This would manifest as a higher frequency of mandibular teeth in the archaeological record as there would be fewer maxillary teeth present.

5.1.3 Tooth Presence

Trends in tooth presence were reviewed for the entire commingled dental assemblage (see Table 4.3 for a breakdown of tooth presence). Most of the teeth in the commingled dental assemblage from Ka'kabish were completely intact (n=354); others (n=22) were also intact but intentionally modified. Of the entire commingled dental assemblage, only fourteen teeth were damaged beyond identification or unidentifiable due to large calculus deposits. The recording of the tooth presence scores from the Ka'kabish dental assemblage can tell us several things. First, modified teeth in the chultuns may elucidate some information about the individuals buried in the chultuns. Second, the lack of teeth with antemortem tooth damage may provide insight into Maya dental practices.

The presence of intentionally modified teeth within the commingled dental assemblage might help us better infer the sociopolitical status of at least some of the individuals in the chultuns. The practice of intentional dental modification is a well-documented and widespread phenomenon amongst the Maya (Serafin et al. 2021:117-118). However, the reasoning behind the practice is not entirely understood. Explanations for the practice have ranged from expressions of gender identity (Serafin et al. 2021:117) or as a display of beautification (Havill et al. 1997). The practice appears to be primarily associated with female members of the social elite living in urban centers (Tiesler et al. 2017). Further, the rate of modifications amongst men decreased significantly during the Postclassic period (Tiesler et al. 2017:280-281). Variations in the rates of intentional dental modification between male and female populations were corroborated through genetic analysis of modified teeth at the Midnight Terror Cave site which concluded that 60% of the identified modified teeth were from females with the remaining 40% being from males (Verdugo et al. 2020). Reasonings for the variations in the rates of dental modifications between males and females are varied; it is possible that the rates of modification seen in the archaeological record, in relation to sex, may be direct evidence of one sex engaging in modification more frequently than another (Tiesler et al, 2017). However, it has also been suggested that the noted variations in sexed based trends in intentional dental modifications may be a result of other external factors such as males being taken during conflict as prisoners (Verdugo et al. 2020). Iconographic images depicting male prisoners have been found throughout the Maya cultural sphere (Burdick 2016). The depictions of prisoners often involve torture of the individuals prior to their deaths; it is possible that teeth may have been extracted during torture, especially if the modified teeth are indeed associated with status or political affiliations (Burdick 20116).

The reported trends in dental modifications throughout the Maya geopolitical sphere in the Postclassic period suggests that the modified teeth recovered from the chultuns are more likely to belong to early-to-middle-aged women from an upper-level social class however, there is not enough physical evidence within the assemblage to confidently corroborate that claim and it should instead be interpreted as a potential explanation. The Ka'kabish commingled dental assemblage had a limited number of modified teeth, which makes it difficult to determine the significance of the presence of modifications and styles at the site. However, it is possible that advanced methods, such as dentin and pulp DNA analysis, could be used on commingled dental assemblages to determine the sex of the individuals the modified teeth originated from which would greatly increase our understanding of causative factors of dental modifications in samples of teeth from commingled assemblages (Zapico and Douglas 2013).

Dental modifications are not the only trend in tooth presence in the dental assemblage. The initial observation of the fourteen (n=14) teeth that could not be assigned an FDI number all appear to have been damaged after their deposition in the chultuns. The post-depositional damage to these teeth makes it impossible to establish and FDI or determine if the teeth were modified; this is especially true in cases where the tooth crown has been obliterated beyond the potential for reconstruction. Studies considering tooth presence analyze teeth that are in occlusion as it is necessary to understand teeth in relation to one another in order to determine which are more susceptible to antemortem loss and why (Forshaw 2014:531). This is not possible with loose teeth as the causative factors resulting in antemortem tooth loss are primarily visible in the boney portion (maxillae and mandible) of the dental arch.

5.1.4 Summary

The recording of tooth frequency, type, and presence tells us several things about the commingled dental assemblage from Ka'kabish and the population it represents. First, as shown by the even frequency of tooth type between the maxillary and mandibular arches and the posterior and anterior dentition, the assemblage likely originated from the primary interment of human remains. Additionally, recording frequency by time shows that the vast majority of the dental assemblage dates to the Late Classic to Postclassic periods. Finally, the tooth presence scores show that intentional modification was practiced at the site and there were some modifications performed at Ka'kabish in the form of tooth filing (Becker 1973:400-401); the study of dental modifications from both loose and in occlusion assemblages can inform us of a wide variety of trends including temporal trends in dental modifications, preferences for modification styles, and the socio-cultural factors that influence the presence of dental modifications in a given populations. For this reason, the observation and recording of modified dentition from loose and commingled dental assemblages should not be overlooked. The observation and recording of tooth frequency, type, and presence can be useful in the reconstruction of a broad bioarchaeological narratives for each chultun (i.e., MNI, time period, potential social class). However, those same observations are not directly useful in developing individually specific bioarchaeological narratives due the loose nature of the assemblage as supporting evidence from skeletal material is typically used to address specific research questions pertaining to individuals (Forshaw 2014).

5.2 Dental Wear

The dentition present in each chultun level was divided into posterior (i.e., premolars and true molars) and anterior (i.e., incisors and canines) subgroups. The average wear scores by chultun, level, and date were recorded for both categories. Overall, the rates of wear were comparable between the posterior and anterior dentition within each chultun; posterior teeth presented with an average wear score of μ=3.02 and anterior teeth had an average score of μ=3.03. The maximum range in wear scores between molars in the commingled dental assemblage was 2.8. Comparatively, the non-molars had an average wear score of μ=3.03 and a range of 3.6. Generally, the wear scores for the teeth in the commingled dental assemblage can be described as "mild to moderate" (Buikstra and Ubelaker 1994: 52-53). The most extensively worn teeth were from Chultun C-3 with a maximum average score of 5.5 (FDI 18) and a minimum of 2.9 (FDI 14). The rates and averages of wear associated with the loose tooth assemblage may not be useful in the reconstruction of bioarchaeological narratives, but may be useful in larger inter-regional or global studies looking at broad factors impacting dental wear such as agricultural intensification, environmental and climactic changes, and potential genetic factors resulting in abnormalities in the types of tooth wear scene in the archaeological record (e.g., dental agenesis and abnormal jaw formation/articulation).

As detailed in the background section of this thesis, dental wear studies are a vital tool within the field of dental anthropology for investigating bioarchaeological questions related to age, diet, and tooth positioning. However, studies that have investigated these questions have typically focused on samples where the dentition is still in occlusion and not commingled or loose teeth (Cucina and Tiesler 2003; Lovejoy 1985: 47-48; Seidemann and McKillop 2007:303-304).

In the case of studies related to rates of dental wear and determining the age at death of adults, sampling involves the selection of teeth which are in occlusion, or samples where loose teeth can easily be reaffiliated with specific mandibles or maxillae (Lovejoy 1985; Prince et al. 2008; 588-589). The use of teeth which are in occlusion appears to be directly related to the methods which assess rates of wear, in relation to age at death, based off averages calculated using multiple, not singular, teeth in relation to one another; this is particularly true in the case of studies where rates of wear are averaged between similar tooth types (i.e., molars and premolars) (Lovejoy 1985:58; Faillace et al. 2017:777-778).

Dental wear studies that investigate diet typically review broad trends in the rates of wear within an individual's dental arches meaning that samples come from individuals with teeth that are in occlusion (Kieser et al. 2001:207-208). Further, many studies which examine dental wear in relation to human diet consider both microwear and macrowear to determine between the presence of abrasion and mechanical wear resulting for mastication (Kaidonis et al. 2012: 1-2). Microscopic dental wear was not within the scope of this thesis; however, the important point is in both macroscopic and microscopic studies of diet and dental wear researchers select samples of teeth that are still in occlusion (Midt et al. 2019). This is because the analysis of multiple articulate teeth improves the overall integrity of the quantitative data generated and subsequently resulted in analyses which more accurately describe the causative factors influencing rates of dental wear, resulting from diet, than would be possible with singular loose teeth (Fiorenza et al. 2018:153-164).

Abnormalities in the rates and extent of dental wear seen between the anterior or posterior, maxillary or mandibular, or left and right dentition may be a result of multiple factors. Misalignment of the dentition (i.e., malocclusion) can result in an abnormal bite and contact between the occlusal surfaces of teeth which could change the expected level or patterns of observed wear on teeth (Leck et al. 2021:6). The changes in the degree and location of wear, caused by malocclusion, result from abnormal amounts of pressure being placed on varying locations of the occlusal surfaces (Cucina et al. 2019: 251-252). Determining the causative factors and the extent to which malocclusions impacts the degree of observed dental wear is dependent on the observation of the mandibular and maxillary teeth while in occlusion to thoroughly assess the relationship between individual teeth. Additionally, preferential chewing on one side of the mouth resulting from several possible factors such as tooth pain, dental pathologies, or a higher frequency of unilateral antemortem tooth loss could also impact the types and degree of dental wear observed (Haralur et al. 2019: 3-4). However, there is no evidence to suggest that preferential chewing is expressed as asymmetrical dental wear in individuals with a healthy or normal occlusion (Lee et al. 2021: 5-6). The assessment of dental wear in relation to abnormalities in the functional structure of the jaw is dependent on observing the presence and position of the teeth while in occlusion; for this reason, loose, dental assemblages are unable to provide information about potential abnormal anatomical functioning.

Although not directly related to the assemblage used in this thesis, there is a potential that abnormal tooth facets and wear patterns may be used in the study of commingled dental assemblages. Teeth are often used not only for chewing food, but also as a tool; this is clear when one considers how they may use their own teeth from one day to the next (e.g., aiding in opening packages, holding strings to tie knots, chewing on pencils) In some cases, the long-term repetition of using teeth for daily activities can result in abnormal facets and wear patterns in an individual's dentition (Geber and Murphy 2018: 848). One example of these types of facets is the development of "pipe notches" which are commonly seen in some European populations (Geber and Murphy 2018). These notches result in a semi-circular notch being present on the anterior dentition which results from years of biting on the cylindrical stem of a pipe (Geber and Murphy 2018). The implications of these types of wear facets in the analysis of fragmentary remains has been somewhat controversial (Fiorenza and Kullmer 2015: 2-3), however, some research has shown that these types of "life-style" wear patterns can be observed in loose teeth and by extension may elucidate some information on the life of the individual represented by the tooth

(Fiorenza and Kullmer 2015:3-4). The commingled assemblage from Ka'kabish does not have any identifiable "life-style" wear patterns. However, other commingled assemblages may and for this reason future research should consider the observation of "life-style" dental wear on the teeth contained in those assemblages as it may provide specific information about the daily lives and occupations of the populations present in a loose or commingled assemblages (Rivals et al. 2009; Mateovics-Laszlo and Libor 2021; Sanchez-Hernandez et al. 2016).

As mentioned above, much of the information derived from dental wear studies is dependent on the teeth being in occlusion. Loose teeth do present with observable wear but due to current methodological limitations it is difficult, if not impossible, to determine which of the many causative factors resulted in the wear. Further, taphonomy (such as post excavation cleaning of the teeth) may also alter the presence of dental wear on the teeth. Simply, in loose tooth assemblages it is not possible to determine, using macroscopic analysis, which factors had the most significant impacts on the development of wear patterns and as such loose tooth assemblages are not an effective tool for establishing trends in age, diet, or physiological malformations in the population represented by the commingled assemblage.

However, the standardization of processing and recording dental wear should still be considered, in the case of commingled dental assemblages, as the data generated may be useful in larger inter-regional or global comparative dental wear studies. Future research into dental wear analysis such as the continued development of new methodologies may also provide novel approaches which could be implemented in the study of loose tooth assemblages and as such the recording of dental wear data from loose teeth should still be recorded for potential future use. Finally, within certain populations the observation of abnormal, or "life-style", wear facets may prove useful in determining the day-to-day habits or occupations of some of the individuals represented in a commingled assemblage.

5.3 Dental Pathologies

Dental pathologies can arise due to congenital predispositions (a result of complex genetic factors), or they can be acquired. Dental pathologies can provide a deep insight into past populations' health and diet. The pathologies observed and recorded in this thesis include dental caries (cavities) and enamel hypoplasia.

5.3.1 Dental Caries

Within the assemblage, there were thirty-two identifiable caries on twenty-six teeth. The highest concentration of caries were identified on molars; thirteen molars (n=13) in total presented with caries of which five (n=5) had two caries for a total of eighteen (n=18) identifiable caries on the molars. Six (n=7) caries were identified on premolars; four (n=4) premolars had one carie each and one (n=1) premolar had three identifiable caries. Additionally, seven canines (n=7) had one carie each, one (n=1) incisor had a singular carie, and a singular tooth with an unknown FDI number also had a singular carie.

In addition to the caries varying by tooth type, they also were present on different surfaces of the teeth. Eleven caries were identified on the occlusal surfaces (contact points between the maxillary and mandibular teeth) of the teeth. Three cavities were identified on the interproximal surfaces of the teeth. An additional ten caries were also identified, five originated at cementoenamel junction and five from the buccal and lingual surfaces. Further three caries were recorded on the root surface below the cementoenamel junction and the remaining six were too large to discern a point of origin.

The prevalence of dental caries on the occlusal surfaces of the molars and premolars is unsurprising due to their frequent occurrence in ancient human populations (Nath et al. 2022). The cusps and grooves of molars provide spaces where food debris is more likely to be trapped and is subsequently harder to remove (Smith et al. 2019). The higher likelihood of food becoming trapped, especially those comprised of sicky carbohydrates, makes the molars and premolars a more conducive environment to the formation of dental caries (Lanfranco and Eggers 2010:85-86). The presence of caries on the other dental surfaces (i.e., lingual and buccal surfaces, cementoenamel junction, and interproximal surfaces) is commonly seen around the globe and their prevalence increased in response to the development of agriculture (Lanfranco and Eggers 2010:86).

Dental caries are well documented throughout the Maya world and central America and research has been conducted to determine both the prevalence of caries within populations through time and factors that make populations, or specific teeth, more or less susceptible to the development of the pathologies (Cucina and Tiesler 2003; Harmon 2018; Schnell and Scherer 2021). Data related to dental caries has typically been collected from teeth that are in-occlusion, however, the frequency of caries and the teeth on which they form can still be determined in commingled dental assemblages; for this reason, commingled teeth from populations with previously noted caries and known causes, such as a high carbohydrate diet, should still be studied.

The high levels of processed maize in Maya populations was a strong factor contributing to the frequent development of dental caries; although maize itself is not positively correlated to dental caries in the archaeological record (Sreebny 1983). The chemical processing of maize (nixtamalization), commonly used during the production of masa dough, results in a carbohydrate-dense sticky maize based dough that is much more cariogenic than non-processed maize (Watson 2008:208-209). Masa dough was, and still is, commonly used in the production of tortillas and tamales, the latter of which was frequently consumed in Classic and Postclassic period Maya populations in Belize (Cheetham 2010:346-347). Knowing that the Maya who occupied Ka'kabish consumed maize it is not a surprise, and in fact should be expected, that they would have dental caries.

It is not currently known if a significant trend in the location and extent of dental caries can be identified in the commingled assemblage from Ka'kabish. Given the small sample size of teeth with carious lesions, their division between multiple burials, and several identified time periods, statistical analysis was not possible. However, further excavation of the site and its associated burials may yield a larger sample which could incorporate the data from this thesis to analyze the prevalence of caries over-time at the site.

5.3.2 Enamel Hypoplasia

As mentioned in chapter 2 (see section 2.8.2), enamel hypoplasia (EH) form during interruptions in the formation of dental enamel (i.e., enamel matrix secretion) caused by stress (Hakkinen et al 2019:2-3). This is particularly true when stress is a result of dietary deprivation during adolescent development. A frequent factor contributing to dietary stress in ancient populations was the transition from breast feeding to consuming solid foods (i.e., weaning) (King et al. 2018). The link between the formation of EH and weaning has led to methodological approaches that facilitate associating the distance of an EH from the cementoenamel junction with ages at which the EH formed. Because of this, the observation and recording of EH is a vital step in the cataloging of human dental remains and these methods were applied to the commingled dental assemblage from Ka'kabish (see section 4.5).

A total of thirteen incidences of EH were present in the commingled dental assemblage from Ka'kabish. A summary of the EH measurements, associated teeth, and burial location is available in the previous chapter (see section 4.5). It should be noted that no instances of EH were identified in Chultun B-2; it is not clear if this is directly related to the health of the individuals within the chultun or if it is simply the random composition of the teeth in the archaeological record. However, future excavations of both chultun and platform burials at Ka'kabish will provide a larger data set which can be used to increase our understanding of the relationship between EH and the populations contained within certain burials at Ka'kabish.

Each incidence of enamel hypoplasia, and their associated EH measurements, was used to calculate age at formation. Initial age estimates for the formation of EH were calculated using the methods generated by Goodman and Rose (1990:520). However, due to global variations in the rate of tooth formation (Esan and Schepartz 2017), regression equations were used to correlate the EH to a more specific age at formation for a Maya population (Wright 1997) (see Table 4.1).

With the implementation of the regression equation the age of formation of EH was calculated. The overall age at formation of EH ranged from 2.7 years to 5.8 years of age. An additional third maxillary molar also had an identifiable EH. However, due to the late developmental formation of third molars, only a wide age range can be suggested of 5 years through to mid-adolescence. Below is a chronological timeline (Figure 5.1) of the age at formation(*) of the EH identified in the commingled dental assemblage from Ka'kabish.

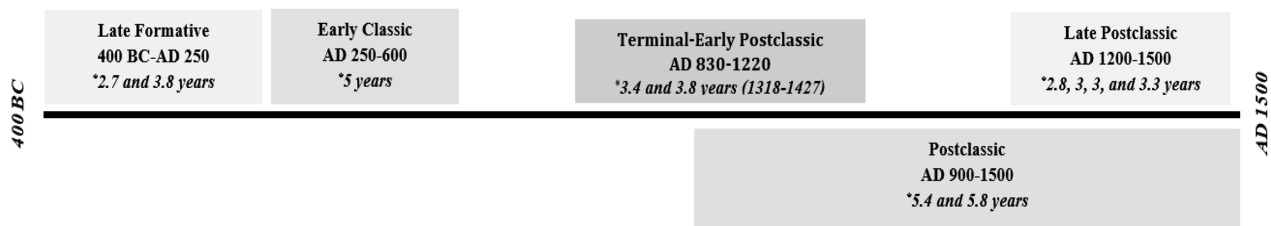


Figure 5.1: Timeline summarizing the age of formation of EH in the commingled dental assemblage from Ka'kabish. **Indicates age at formation*

This data can be utilized in future studies to investigate trends in childhood bioarchaeology and diet- a typically overlooked area of study (Halcrow and Tayles 2008; Halcrow 2017). Particularly, the coupling of stable isotope analysis with this data may aid in the reconstruction in dietary trends over time at Ka'kabish. In doing so, the data generated from this dental assemblage could be compared to those from other sites in the region, such as Lamanai and the Marco Gonzalez and San Pedro sites (Williams et al. 2005) to reconstruct trends in childhood stress in the geopolitical sphere surrounding Ka'kabish. This type of research is beneficial to our understanding of ancient human populations as weaning practices and dietary stress have been strongly linked to biological, cultural, nutritional, and economic aspects of an infant's life and their mother (Dupras et al, 2001; Miller et al. 2016:409). Further, changes over time in the estimated age of weaning can be associated with political and economic upheaval, significant shifts in societal structuring (Pezo-Lanfranco et al. 2020) and shifts in cultural ideologies and social status (Miller et al. 2020:571-572).

The analysis of EH in commingled dental assemblages is useful in the development of bioarchaeological narratives; a singular tooth, from a specific time-period with EH, can identify at what age an individual experienced developmental and/or dietary stress and by extension could elucidate some of the external factors that may have impacted an individual during development (i.e., culturally established ages at weaning and food security). Additionally, as shown in figure 5.1 the analysis of EH in commingled assemblages can be used in the reconstruction of temporal trends in the age at formation of EH in an assemblage. Further, by standardizing the collection of EH data from commingled dental assemblages we can better reconstruct temporal and regional trends in both local and global populations to better understand factors that impacted when and why EH form.

5.4 Dental Calculus

Dental calculus was commonly found throughout the entire commingled dental assemblage from Ka'kabish. The amount of calculus varied between teeth with most having a thin layer covering the lingual and buccal/labial surfaces of the teeth. However, several teeth had large buildups which, in some cases, encased the entirety of the tooth crown. The buildup of calculus on the smooth surfaces of the teeth is unsurprising; the increased presence of saliva on the lingual surfaces of the teeth caused by salivary ducts increases the speed of calculus precipitation (Nasution and Amatanesi 2018:2-3). Additionally, the lack of calculus on the occlusal surfaces of the molars and premolars is likely a result of continual attrition. In the cases of molars with occlusal build up, two scenarios may have resulted in the buildup: the occlusion of the teeth may have been abnormal, preventing continual contact between the maxillary and mandibular molars preventing attrition or the antemortem loss of a complimentary molar on the opposite dental arch may have also prevented attrition. However, it is impossible to determine with any degree of certainty which of these scenarios is the most likely as the teeth are commingled and the dental occlusion could not be observed.

The presence of dental calculus in the archaeological has been extensively documented (Blatt et al. 2011; Dudgeon and Tromp 2014; Evans 1973; Hardy et al. 2009; Hendy et al. 2018; Madella et al. 2014; Ottoni et al. 2021; Warriner et al. 2014;) and over the last decade has become an invaluable resource in the reconstruction of paleodiet (de Oliveira et al. 2021), agricultural practices (Mickleburgh and Pagan-Jimenez 2012), and paleogenetics and proteomics (Hendy et al. 2018; Warriner et al. 2015).

Paleodietary studies have extensively utilized dental calculus in the reconstruction of dietary trends in ancient human populations (Hardy et al. 2009:248-249; Hardy et al. 2018:234;). This is primarily due to dental calculus being highly conducive and stable environment for the long-term preservation of biological materials, such as plant remains, which typically do not preserve well in the archaeological record (Hardy et al. 2018; 234; Mackie et al. 2017:58). Investigations of ancient human diet have observed dental calculus using electron microscopy to identify biological materials such as starches and phytoliths contained within the calculus matrix (see section 5.5). The investigation of ancient human diet using dental calculus samples may also provide information on the agricultural practices of the population from which the samples were sourced (Mickleburgh and Pagan-Jimenez 2012); the observation and identification of starches and phytoliths within calculus samples can be used as evidence in investigations of agriculture cultivates or agricultural intensification (MingQi et al. 2010: 694-695). However, there are limitations in the reconstruction of paleodiet through the microscopic observation of dental calculus. Specifically, the incorporation of plant remains in dental calculus is only evidence of presence not abundance; it is possible to say that a cultivate was present within a population, and likely consumed, however the amount consumed, frequency of consumption, and caloric significance of that plant cannot be determined using microscopy.

There is, however, the potential to overcome this limitation through the complimentary utilization of stable isotope analysis (SIA) of collagen and SEM analysis of botanical remains in dental calculus. The isotopic analysis of collagen from human bone samples can be used to determine the prevalence of C_3 and C_4 plants in an individual's diet (Williams et al. 2017:270) within a 10-year period prior to death (Hedges et al. 2007). Further, SEM analysis of phytoliths and starches can identify specific species of plants (Juhola et al. 2019:2) which SIA cannot be used for. Thus, combining SIA and SEM analysis can aid in determining both the specific species of plants consumed and their potential significance in a populations diet. It should be noted that stable isotope analysis of dentin is only relevant to studies considering diet during periods of tooth formation (Burt 2015: 277-278). In loose tooth assemblages there are no bones which can be used in isotopic studies of dietary trends during an individual's recent life; because of this loose tooth assemblages can only be used to determine the presence of species-specific plants which may have been consumed by an individual and/or the composition of an individual's diet during tooth development.

Significant work also has been conducted to analyze the genetic and proteomic material that can be incorporated into human dental calculus samples. Much of this research has originated within the last decade (Warinner et al. 2014a) and has explored a diverse set of questions pertaining to human health (Warinner et al. 2015; Santiago-Rodriguez et al. 2019; Neukamm et al. 2020) and diet (Hardy et al. 2018; Warinner et al. 2014b; Wright et al. 2021). Genetic and proteomic analysis of human dental calculus deposits does not rely on the frequency of teeth or for the teeth to be in-occlusion and instead is based only on the presence of viable samples within the calculus matrix (Warinner et al. 2015:4-5). For this reason, teeth in loose tooth assemblages should be considered for sampling in proteomic and genetic studies of human dental calculus deposits. The data generated using teeth from loose assemblages could prove to be invaluable to the reconstruction of bioarchaeological narratives of the individuals represented by the teeth. Further, the genetic and proteomic analysis of human dental calculus can also inform us of broader trends such as population health (i.e., the presence of transmissible and contagious viruses and bacteria) and regional or community dietary trends.

There is no doubt that the implementation of dental calculus studies in relation to loose tooth assemblages can greatly aid our understanding of the individuals and general populations from which the teeth originated. Simply recording calculus deposits on commingled teeth may not yield significant information to aid in the construction of a bioarchaeological narrative, but the application of advanced methodologies such as chemical, genetic, proteomic, and SEM analysis can. The recording of dental calculus is a vital first step for preparing loose teeth for future laboratory analysis and as such should not be overlooked.

5.5 Dental SEM

SEM analysis was conducted on calculus samples from the commingled assemblage from Ka'kabish. This pilot project had two primary goals:

First, to assess the viability of SEM analysis on dental calculus deposits from Ka'kabish collected from burial locations that typically contain poorly preserved remains (i.e., chultuns) and second, to determine if SEM analysis on dental calculus specimens from Ka'kabish can be used to aid in sample selection for other forms of analysis such as proteomics or paleogenetics.

The methods used to sample, collect, and prepare calculus specimens as well as imaging methods are available in Chapter 4 (section 4.7). Additionally, the microscopic images of the dental calculus specimens used in the pilot study are available in the appendices (Appendix B). Overall, this pilot project was successful in addressing its two primary goals. First, through this study, it has been determined that dental calculus deposits, recovered from burials that are not conducive to the preservation of human remains, are viable for imaging in all temporal periods from the Late Formative onwards in the geographical area surrounding Ka'kabish. Samples were successfully magnified by up to 100,000x+ while still yielding observable and identifiable particulates and organisms embedded within the calculus matrix.

A brief review of the images generated showed that the samples contained phytoliths, starch granules, and bacterial colonies. Given this information, it is likely that the calculus samples could be processed and used in both proteomic and genetic analysis; this type of testing would greatly increase our understanding of the individuals interred in the chultuns at Ka'kabish. Further, given that this pilot study was conducted on the loose dental assemblage from Ka'kabish, and the data produced will be used in future studies of diet and health it is fair to say that SEM analysis of human dental calculus is a viable tool which can be used in conjunction with commingled or loose dental assemblages to aid in the reconstruction of bioarchaeological narratives.

5.6 Usefulness of Commingled Dental Assemblages

So far, this chapter has provided an in-depth analysis of the data collected for this thesis as well as a discussion of the types of information that can be generated and inferred using commingled dental data. Some of the recurring issues associated with the use of commingled dental data in the reconstruction of bioarchaeological narratives include small sample size, few comparative studies, a lack of affiliated biological information, and a non-specialized excavation approach (i.e., other skeletal data). However, some strong, generalized statements can be made about the individuals represented in the commingled dental assemblage from Ka'kabish.

5.6.1 Limitations of Commingled Assemblages

Several issues arose in this thesis due to the limited sample size. Although several hundred teeth are in the commingled assemblage, much of the valuable data (i.e., dental caries, wear patterns, enamel hypoplasia) was only present on a select few teeth. Not only was there a limited sample of specimens, but the specimens were also spread between four burial deposits each with several levels and multiple individuals. The samples from different burial deposits also had a wide temporal range (Late Formative period to the Late Postclassic period). This means that although general trends could be inferred the sample sizes prevented the implementation of statistical analyses which would have aided in determining the significance of the trends and changes in occurrence rates of wear, pathologies, and calculus build ups over time.

Further, there is no literature on commingled dental assemblage studies that can be used for comparative analysis; this thesis can be used to address this notable gap in the literature. The lack of comparative studies and literature makes it impossible to distinguish if any trends in the commingled dental assemblage form Ka'kabish are either similar or different from those from other sites or regions. Further, a lack of comparative studies meant no pre-existing information was available to suggest potential approaches to processing commingled and loose dental assemblages and how to use that information to generate useful narratives.

Finally, perhaps one of the most limiting factors that restricts the reconstruction of a detailed bioarchaeological narrative of the individuals interred in the chultuns at Ka'kabish is the lack of affiliated skeletal remains. Unfortunately, it was not possible to re-associate the commingled teeth with specific individuals and the teeth had to be clustered by their associated levels and lots (see Chapter 3). As such, the data generated with the commingled assemblage could not be enriched or verified by additional pathological or osteometric information that could have come from associated skeletal remains. Further, many of the methods used in dental anthropology require the teeth to be in-occlusion for the scoring systems to be useful. For example, dental wear can be used in the estimation of age if the teeth are in-occlusion, but this is not possible with commingled or loose teeth.

Many of the limitations mentioned above could have been mitigated by the presence of a bioarcheologist at the time of excavation. Much of the biological material was not collected with the type of analysis used in this thesis in mind. By extension, it was nearly impossible to reconstruct the depositional history of the teeth with a high degree of confidence as much of the biological material affiliated with the teeth lost its contextual relevance due to the commingled nature of the sample. Unfortunately, this is a common limitation in archaeological field work as specialists are not always available during the excavation process. It can, for these reasons, be assumed that this may be a problem recurring problem in studying commingled assemblages that have been excavated in the past or that could be excavated in the future. Despite the many limitations of commingled dental assemblages this research has also yielded some positive results.

5.6.2 Benefits of Commingled Assemblages

Despite the limitations of commingled dental assemblages in the development of bioarchaeological narratives, there are still many benefits to processing these types of assemblages. First, analyzing the commingled assemblage allows a researcher to identify general trends in the data. Second, the curation and processing of the dental assemblage results in a comparative data set that can be used in future studies. Finally, the process of collecting data and cataloging the commingled assemblage can aid in sample selection for future research projects or laboratory analysis.

General trends that can be established in the observation of commingled dental assemblage are varied. However, this study identified several modified teeth that may indicate the status and sex of the individuals contained in the chultuns. This study aided in the reconstruction of the depositional history of the teeth within the chultun and allowed for the assemblage to be associated with specific periods. Moreover, the data collected and analyzed in this thesis provided preliminary insight into potential temporal trends in weaning and adolescent stress at Ka'kabish by reviewing EH measurements; by extension this could aid in the development of further studies implementing methods such as stable isotope analysis.

The process of collecting data for this thesis resulted in a well-curated and cataloged dental assemblage. Clusters of teeth that were only divided by arch are now easily accessible by burial location, level, date, and tooth type. This data was also cataloged into a master file (appendix A), which can be used by researchers who wish to conduct comparative studies or other research in the future.

Given the commingled assemblage has now been curated and processed the identification of samples for future study has been greatly aided. All the information collected from each tooth has been associated with its STN (site tooth number) in the master data set. Any feature of interest for future study (i.e., calculus, caries, EH, dental wear) can now be queried in the master file and the most viable samples can be selected with ease.

5.6.3 Commingled Teeth in Archaeological Narratives

The efficiency of using commingled dental assemblages in the study of ancient human populations is questionable, particularly when one is working with a large commingled and loose dental assemblage. However, as shown in this chapter, commingled dental assemblages are useful in the investigations and reconstruction of ancient human populations despite the somewhat limited array of questions, they can address. General information and trends can be teased from commingled dental assemblages and subsequently used in the construction bioarchaeological narratives of past human populations and, in some cases, individuals. Researchers who wish to reconstruct ancient human populations or to develop bioarchaeological narratives should look to loose and commingled remains to gather general information about the populations they are studying. Further, in cases where loose assemblages resulted due to severe deterioration or destruction of skeletal remains, it may be possible to generate information about the interred individuals that could otherwise go unnoticed if the collection of osteometric data was no longer possible. The amount of work required to process large commingled dental assemblages is quite extensive, but the process yields some information about the population from which they originate. In the case of burials with little to no skeletal material the potential of producing "some valuable/functional information" about the individuals should be more than enough cause to process and analyze the loose dental remains.

5.6.4 Towards a Standardized Approach

It was stated above that researchers should avoid commingled dental assemblages if their desire is to generate data that can be used in the development of bioarchaeological narratives, and this is true. However, that does not mean commingled assemblages should be completely ignored. This thesis has provided an example of how commingled dental assemblages can be processed and the data associated with them collected and recorded. The collection, and curation of large data sets, which can be used in collaborative and comparative research, is the reason researchers should process and study their commingled dental assemblages. Although not useful in the reconstruction of individual-specific narratives, I believe there is a great potential for these types of collections to address complex and important questions.

By collecting and processing loose and commingled dental data and making it available to the research community at large we can facilitate comparative studies on a global scale. The commingled dental assemblage from Ka'kabish may not, by itself, be viable for statistical analysis to identify trends in oral and dental health. However, if multiple data sets on commingled teeth worldwide could be compiled, it would facilitate studies into our understanding of how things like the environment, climate, geography, and genetics can impact global trends in dental health. In short, by processing and making data on commingled dental assemblages readily available, we can address macro-scale research questions that have historically been ignored in favor of studying small site-specific populations.

5.7 Conclusion

The purpose of this chapter was to analyze the data presented in Chapter 4 and discuss the findings of those data in relation to the pressing research questions facing dental anthropologists. Further exploration of common areas of dental anthropological research and methods were presented and discussed in relation to their viability in the study of loose tooth assemblages and the subsequent use of those assemblages in the construction of bioarchaeological narratives.

First, a breakdown of tooth type and frequency was reviewed and was found to helpful in the establish and confirmation of an MNI. The establishment of an accurate MNI can aid in our understanding of why a burial location was used and how frequently. This thesis has shown that there is a strong potential for establishing MNI using loose and commingled dental remains, however, subsequent experimental studies should be conducted to corroborate these findings and explore potential factors which may obscure a burials MNI and the subsequent steps that might be taken to eliminate those factors during burial excavation and initial laboratory analysis.

Rates of dental wear in the commingled assemblage were then discussed. However, due to the nature of the assemblage (e.g., small sample size, loose teeth) it was impossible to determine the significance of the dental wear or the causative factors resulting in the wear (i.e., diet, age, malocclusion). Although dental wear analysis of loose tooth assemblages is currently limited by the requirement that teeth be in-occlusion to determine the causes of wear, it is suggested that this information should still be recorded as the data may be useful in future studies.

Pathologies, specifically dental caries and EH, were also discussed. Dental caries were not significant to the establishment of a bioarchaeological narrative due to the small sample size, which prevented statistical analysis to determine the significance in the rates of dental caries. However, the dental caries data may still prove to be useful in future regional or global studies which seek to look at broad trends in the location and severity of caries on individual teeth.

Enamel hypoplasia's were used to reconstruct a potential age at weaning of some of the individuals in the assemblage. EH data also proved to be useful when combined with ^{14}C dates to construct a preliminary timeline depicting changes and dietary stress during adolescent development between the Terminal, Classic, and Postclassic periods. EH data proved to be one of the most useful forms of analysis, in relation to loose tooth assemblages, and requires little specialized training or equipment to record. For this reason, EH should always been recorded in loose tooth assemblages to aid in the reconstruction of bioarchaeological narratives of both individuals and, potentially, sites.

Additionally, the presence and amount of dental calculus on the teeth was discussed, as was common areas of study in relating to human dental calculus deposits. It was determined that in a commingled assemblage, calculus is of the most beneficial tools to reconstructing bioarchaeological narratives of ancient human diet and health when advanced laboratory analyses such as genetic sequencing, proteomics, or SEM are applied.

Finally, the pilot SEM projected findings were discussed. SEM analysis was determined to be a useful tool in observing dental calculus samples originating from Ka'kabish. Further research is required but the images generated using SEM may prove to be a strong screening tool to assessing sample viability for genetics and proteomics analysis in human dental calculus samples.

Overall, the usefulness of commingled dental assemblages is primarily limited to the development of data sets for use in large-scale inter-regional comparative studies where significant inter-regional comparison of data can be compared using advanced statistical methodologies. However, future applications of advanced laboratory methodologies (i.e., genetics, proteomics, SEM) will greatly increase the amount of data available that can be used to generate individual or site specific bioarchaeological narratives.

6.0 CONCLUSION

The purpose of this chapter is threefold. First, this chapter will summarize the primary findings resulting from the research conducted in this thesis. Second, this section will review the limitations of working with loose and commingled dental assemblages and potential avenues for future research that may mitigate some of the limitations. Finally, this chapter will conclude with a note on ethical considerations in human bioarchaeology and how processing and cataloging commingled dental assemblages is a critical component of ethical research and sample curation.

6.1 Summary of Findings

The first conclusions drawn in the research show that there is a strong potential for establishing MNI using loose and commingled dental remains. As is the case with skeletal remains the identification of the highest frequency of duplicate bones, or in the case of a commingled dental assemblage teeth, can be used to determine the MNI contained within a burial or assemblage. However, future experimental studies should be conducted to corroborate these findings by comparing MNIs established through skeletal remains to those established using commingled dentition to determine a range of accuracy.

In addition to the establishment of an MNI, commingled dental assemblages also prove to be useful in the investigation of dental health and pathologies. Both dental caries and EH were reviewed in this research. Overall, dental caries were not significant in establishing individual bioarchaeological narratives due to the small sample size, which prevented the application of statistical analysis to determine the significance in the rates of dental caries. However, there is potential for further research to be conducted on the significance of dental caries studies in relation to commingled dental assemblages in cases where more teeth are present or where data from multiple similar deposits can be combined. The study of enamel hypoplasia in commingled dental assemblages, however, was found to be extremely useful in the development of bioarchaeological narratives of some of the individuals represented in the assemblage. In this study EH was successfully used to reconstruct a likely age at weaning and/or dietary stress of some of the individuals in the assemblage. This data was subsequently used to develop a preliminary timeline depicting the temporal trends in the age at formation of EH in the Ka'kabish population.

Additionally, this research found that dental calculus is one of the most beneficial tools for reconstructing bioarchaeological narratives of ancient human populations- specifically concerning diet in loose and commingled dental assemblages. Research conducted on calculus samples is typically done by selecting the best samples from individual teeth; the nature of loose and commingled dental assemblages does not limit their potential in dental calculus studies. As such, a well thought out and stratified selection of calculus samples from the commingled teeth can prevent testing of duplicate teeth and subsequently produce good data on the inclusions within the dental calculus deposits

Further, the pilot SEM project findings were found to be a valuable tool in observing dental calculus samples originating from Ka'kabish. In addition to utilizing loose in commingled teeth for the pilot project and showing the value of SEM studies in relation to loose and commingled human dental remains the pilot project also assessed the efficacy of SEM analysis on dental calculus deposits at Ka'kabish and within the surrounding area. Further research is required to process the SEM images and identify the materials contained within the calculus matrix. However, the images generated using SEM may be a strong screening tool for assessing sample viability for genetics and proteomic analysis in human dental calculus samples.

Finally, by collecting and processing loose and commingled dental data and making the associated data available to the research community at large we can potentially facilitate comparative studies on a regional or global scale. By combing multiple data sets we can produce larger samples which will be more valuable for statistical analysis and the data generated may be useful in the reconstruction of trends in ancient human populations and their dental health.

6.2 Limitations

While much of the information and analysis conducted during the course of this thesis was useful and showed great potential for the study of ancient human populations and the development of bioarchaeological narratives the research was not without its limitations. As mentioned in the discussion chapter many of the methodological approaches used in dental anthropological research have been developed for use and analysis on teeth that are still in-occlusion. This is particularly true in the case of dental wear studies. Perhaps the most limiting area of study in commingled dental assemblages is the analysis and interpretation of dental wear on the teeth. Differentiating between intentional wear, abrasion, attrition, and erosion in dental wear studies is dependent on the review of multiple teeth that are in-occlusion; for this reason, it is impossible, in the case of loose or commingled dental assemblages, to determine the cause of wear as such it can only be said that there was either intentional (modification) or unintentional wear (i.e., abrasion or erosion) within a population. Additionally, this research discussed the potential for the study of "life-style" wear facets within the context of a commingled dental assemblage, however, there were no potential examples of this type of wear contained within the assemblage and as a result this area of dental wear analysis could not be studied in-depth.

Another primary limitation in the analysis of commingled and loose dental assemblages is access to monetary resources. Advanced laboratory methods often require specialized personnel and equipment and as a result can cost large amounts of money. Although testing such as DNA sequencing, proteomic analysis, and SEM research could prove to be highly useful in the reconstruction of past populations using samples from commingled dental assemblages the high cost and limited funding opportunities may prevent this type of research. The initial startup costs for an SEM pilot project can range from $2,500-4,000 CAD and expenses can quickly grow depending on the number of samples selected for analysis. A well stratified sample of calculus samples from multiple teeth in an assemblage (e.g., n=20) can easily exceed several thousands of dollars depending on the extent and methods employed.

Finally, the quality of information that can be generated through the study of commingled and loose dental assemblages is closely linked to the level of detail and care given during the excavation process. Many field archaeologists do not have expertise or extensive training in the handling and excavation of human remains; this is a general limitation in the field of archaeology given that it is impossible for every excavation to have trained bioarcheologist on site. As a result, dental remains can be clustered into larger-than-necessary groups during excavation limiting the potential for separating clusters into "individuals". Archaeologists in the field should take additional care during the excavation process of commingled and loose assemblages to provide as much information as possible on the provenience and depositional context of the remains. Simple steps such as removing smaller layers of sediment, drawing tooth placements and number teeth in noted during the excavation process, and frequently photo-documenting the dentition during varying stages of the excavation may greatly aid in the usefulness of commingled and loose assemblages once they have been taken to a lab or handed over to a bioarcheologist for more in-depth analysis.

6.3 Future Research

Future research into the utilization of commingled dental assemblages could focus on multiple areas. To start, research on commingled dental assemblages should focus on the development of large data sets across multiple regions and cultural groups to facilitate experimental statistical studies of commingled dental assemblages. To do this, researchers must do two things: first, record dental data that is present in all aspects of a dental assemblages including loose teeth. Second, make sure that data on archaeological dental samples, loose or otherwise, is accessible to other researchers in order facilitate and foster larger studies in inter-regional or global studies of factors impacting human dental health.

Next, advanced methodologies such as genetic, proteomic, and SEM analysis should be used to facilitate in the development of more specific information about the individuals represented in a commingled dental assemblage. Genetic and proteomic analysis of commingled teeth could provide insight into both the health and diet of specific individuals represented by singular teeth. The benefits of conducting genetic and proteomic analysis is that these types of analysis are individualistic and as such supersede the limitations imposed by working with loose and commingled assemblages.

Additionally, a study specific to the Ka'kabish dental assemblage could utilize dentin samples in SIA investigations of dietary stress and weaning within the population represented in the commingled dental assemblage. Not only would this data be useful in the reconstruction of early childhood dietary trends at the site, but this information could be combined with the EH data identified in this thesis to complete a more in-depth study of adolescent nutrition and dental health at the site. It is my hope that the summer 2022 field season will result in the excavation of more dentition which can be used in the expansion and significance of the temporal trends in dietary stress at Ka'kabish presented in this research.

Finally, future research on the commingled dental assemblage from Ka'kabish should focus on the analysis of hormones contained in dental enamel. The analysis of hormones in tooth enamel can be used to establish the genetic sex of the individuals represented in the commingled assemblage (Stewart et al. 2017). By determining the sex of the individuals contained in the chultuns from Ka'kabish we can better understand the potential function of chultun burials, and the demographics of the individuals contained in them.

6.4 A Final Note on Ethical Considerations

This research has considered the importance of analyzing and curating commingled, and loose dental assemblages recovered from archaeological contexts. The main findings of this research have shown that loose and commingled dental assemblages can and should be used in investigations of ancient human populations and the subsequent development of population specific bioarchaeological narratives. It is possible that the usefulness of these assemblages alone may not provide enough cause for some researchers to process their commingled dental assemblages. The avoidance of conducting research commingled dental assemblages and other complex skeletal materials such as those that are fragmented and highly deteriorated is an ethical oversight on the part of archaeologists.

As archaeologists we are responsible for the stewardship and continued curation of the materials that we are privileged to study. However, there are literal skeletons in the closets of archaeologists around the world that are not actively being studied or utilized in archaeological research. From the perspective of an archaeologist living in North America, I cannot conclude this research project without addressing the need for improved ethical considerations and moral groundings in the anthropological study of ancient human remains which have been exhumed and exported from other nations. In Belize, and other regions of the world, limited funding and resources can lead to a loss of provenience and poor curation (Plumer-Moodie et al. 2019). It is critical that future work, both in the field, and in the lab prioritize the curation and maintained of bioarcheological collection, especially those containing human remains. Within Belize critical work has been conducted to improve the methods of curation and provide guidance on the processes that can be taken to improve the overall preservation of large skeletal assemblages from archaeological sites (Miller Wolf 2019). It is my hope that this thesis can contribute to this goal of improved curation and provide guidance and promote the need to catalog, process, and curate large loose and commingled dental assemblages.

Simply put, to excavate, bag, and export human remains for study and to not process those remains due to the complexity of their preservation or depositional nature is a disservice to the remains we are responsible for and to the decent communities to which they belong. At the very least, if a researcher doubts the usefulness of commingled dental remains in archaeological studies, then the remains should not be removed from their source locations, or the work should be done to treat them with the same level of care and attention as we do with “useful” samples; this research has shown that commingled and loose dental assemblages are useful to archaeological studies and that they can and should be used to their fullest potential. Human remains, both skeletal and dental, should not be left in cupboards, drawers, or cabinets for years on end in the hopes that "one-day" they will be of use. The responsible stewardship of human remains is dependent on the commitment of the archaeologists responsible for them to either utilize them in ethical research projects or to repatriate them to their countries of origin.

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APPENDIX A: Master Data Set

Burial	Individual(s)/Level/Lot			FDI	STN	Presence	Wear/Total		Caries	
Chultun C-1	C1/1	2	557	21	476	1	5	-	-	-
Chultun C-1	C1/1	2	557	31	477	1	5	-	-	-
Chultun C-1	C1/1	2	557	34/35	475	1	7	-	-	-
Chultun C-1	C1/1	2	557	14/15	474	1	5	-	-	-
Chultun C-1	C1/8	7	650	11/21	357	1	2	-	-	
Chultun C-1	C1/8	7	650	13/23	351	1	4	-	7	-
Chultun C-1	C1/8	7	650	23	352	1	2	-	-	-
Chultun C-1	C1/8	7	650	13/23	353	1	4		7	-
Chultun C-1	C1/8	7	650	13	354	1	5	-	-	-
Chultun C-1	C1/8	7	650	28/18	355	1	-		3	-
Chultun C-1	C1/8	7	650	ModCan	356	10	2	-	-	-
Chultun C-1	C1/8	7	650	46	350	1	4.4.2.2	3	-	-
Chultun C-1	C1/8	7	650	36	349	1	4.4.3.4	3.75	-	-
Chultun C-1	C1/8	7	650	MaxPre	348	1	4	-	-	-
Chultun C-1	C1/8	7	650	34/35	341	1	4	-	-	-
Chultun C-1	C1/8	7	650	34/35	340	1	2	-	-	-
Chultun C-1	C1/8	7	650	PreMol	339	1	2	-	-	-
Chultun C-1	C1/8	7	650	34/35	338	1	2	-	-	-
Chultun C-1	C1/8	7	650	34/35	337	1	2	-	-	-
Chultun C-1	C1/8	7	650	33	342	1	3	-	-	-
Chultun C-1	C1/8	7	650	43	343	1	4	-	-	-
Chultun C-1	C1/8	7	650	32	344	1	5	-	-	-
Chultun C-1	C1/8	7	650	Canine	347	-	-	-		-
Chultun C-1	C1/8	7	650	42	346	1	5	-	-	-
Chultun C-1	C1/8	7	650	33	345	1	4	-		-
Chultun C-1	C1/2	4	597	48	253	1	4.4.4.4	4	-	-
Chultun C-1	C1/2	4	597	46	252	1	4.4.3.3	2.75	4	7
Chultun C-1	C1/2	4	597	37	251	1	3.4.4.4	3.75	-	-
Chultun C-1	C1/2	4	597	36	247	1	4.4.4.3	3.75	-	-
Chultun C-1	C1/2	4	597	34	249	1	4.5.5.5	4.75	-	-
Chultun C-1	C1/2	4	597	47	248	1	3.4.3.3	3.25	-	-
Chultun C-1	C1/2	4	597	47	250	1	4.5.5.2	4	-	-
Chultun C-1	C1/2	4	597	ManPre	254	1	2	-	-	-
Chultun C-1	C1/2	4	597	ManPre	255	1	2	-	-	-
Chultun C-1	C1/2	4	597	ManPre	256	1	2	-	-	-
Chultun C-1	C1/2	4	597	ManPre	257	1	2	-	-	-
Chultun C-1	C1/2	4	597	ManPre	258	1	4	-	-	-
Chultun C-1	C1/2	4	597	ManPre	259	1	3	-	6	-

Chultun C-1	C1/2	4	597	ManPre	260	1	2	-	-	-
Chultun C-1	C1/2	4	597	31	261	1	2	-	-	-
Chultun C-1	C1/2	4	597	31	262	1	4	-	-	-
Chultun C-1	C1/2	4	597	27	263	1	4.4.4.4	4	7	-
Chultun C-1	C1/2	4	597	23	267	1	4	-	-	-
Chultun C-1	C1/2	4	597	ModCan	266	10	4	-	-	-
Chultun C-1	C1/2	4	597	ModCan	265	10	5	-	-	-
Chultun C-1	C1/2	4	597	ModCan	264	10	5	-	-	-
Chultun C-1	C1/3	5	605	43	238	1	4	-	-	-
Chultun C-1	C1/3	5	605	33	239	1	3	-	-	-
Chultun C-1	C1/3	5	605	36	245	7	-	-	-	-
Chultun C-1	C1/3	5	605	46	244	7	-	-	-	-
Chultun C-1	C1/3	5	605	35	242	1	2	-	-	-
Chultun C-1	C1/3	5	605	73/83	243	1?	-	-	-	-
Chultun C-1	C1/3	5	605	42	240	1	5	-	-	-
Chultun C-1	C1/3	5	605	42	241	1	4	-	-	-
Chultun C-1	C1/3	5	605	ModInc	229	10	4	-	-	-
Chultun C-1	C1/3	5	605	ModCan	228	10	4	-	-	-
Chultun C-1	C1/3	5	605	?	227	10	4	-	-	-
Chultun C-1	C1/3	5	605	ModCan	230	10	3	-	-	-
Chultun C-1	C1/3	5	605	ModCan	231	10	4	-	-	-
Chultun C-1	C1/3	5	605	ModCan	232	10	4	-	-	-
Chultun C-1	C1/3	5	605	ModCan	233	10	4?	-	-	-
Chultun C-1	C1/3	5	605	ModCan	23	10	3	-	-	-
Chultun C-1	C1/3	5	605	36/46	235	1	1.1.1.1	1	-	-
Chultun C-1	C1/3	5	605	36	236	1	5.4.3.3	3.75	-	-
Chultun C-1	C1/3	5	605	36	237	1	5.5.3.3	4	-	-
Chultun C-1	C1/3	5	605	17/27	196	1	3.3.3.3	3	7	-
Chultun C-1	C1/3	5	605	17	197	1	3.3.4.3	3.25	-	-
Chultun C-1	C1/3	5	605	16/26	198	1	4.4.5.3	4	-	-
Chultun C-1	C1/3	5	605	17	199	1	5.4.3.3	3.75	1	1
Chultun C-1	C1/3	5	605	17/27	200	1	3.3.3.3	3	1	-
Chultun C-1	C1/3	5	605	26/27	201	1	5.5.5.5	5	-	-
Chultun C-1	C1/3	5	605	?	202	1	3.3.3.3	3	1	-
Chultun C-1	C1/3	5	605	?	203	1	-	3.5	-	-
Chultun C-1	C1/3	5	605	16	204	1	3.3.3.3	3	7	-
Chultun C-1	C1/3	5	605	13	226	1	1	-	-	-
Chultun C-1	C1/3	5	605	23	223	1	3	-	-	-
Chultun C-1	C1/3	5	605	23	221	1	5	-	-	-

Chultun C-1	C1/3	5	605	23	222	1	5	-	3	-
Chultun C-1	C1/3	5	605	12	206	1	1	-	-	-
Chultun C-1	C1/3	5	605	11	205	1	2	-	-	-
Chultun C-1	C1/3	5	605	61	224	1	1	-	-	-
Chultun C-1	C1/3	5	605	61/62	225	1	1	-	-	-
Chultun C-1	C1/3	5	605	24/25	205	1	2	-	-	-
Chultun C-1	C1/3	5	605	14	206	1	2	-	-	-
Chultun C-1	C1/3	5	605	15	207	1	3	-	-	-
Chultun C-1	C1/3	5	605	14	208	1	3	-	-	-
Chultun C-1	C1/3	5	605	15	209	1	2	-	-	-
Chultun C-1	C1/3	5	605	?	210	1	3	-	-	-
Chultun C-1	C1/3	5	605	14/15	211	1	4	-	-	-
Chultun C-1	C1/3	5	605	24/25	212	1	1	-	-	-
Chultun C-1	C1/3	5	605	?	213	1	2	-	-	-
Chultun C-1	C1/3	5	605	?	214	1	2	-	-	-
Chultun C-1	C1/3	5	605	?	215	1	-	-	-	-
Chultun C-1	C1/3	5	605	?	216	-	-	-	-	-
Chultun C-1	C1/3	5	605	?	217	-	-	-	-	-
Chultun C-1	C1/3	5	605	?	218	-	-	-	-	-
Chultun C-1	C1/3	5	605	?	219	-	-	-	-	-
Chultun C-1	C1/3	5	605	?	220	-	-	-	-	-
Chultun C-1	C1/11	9	652	26	412	1	3.3.3.3	3	-	-
Chultun C-1	C1/11	9	652	27	411	1	4.3.3.3	3.35	-	-
Chultun C-1	C1/11	9	652	28	410	1	3.3.3.3	3	-	-
Chultun C-1	C1/11	9	652	28	409	1	5.5.5.5	5	-	-
Chultun C-1	C1/11	9	652	16	408	1	5.5.5.5	5	-	-
Chultun C-1	C1/11	9	652	16	407	1	2.2.2.2	2	-	-
Chultun C-1	C1/11	9	652	17	406	1	5.5.2.5	4.25	-	-
Chultun C-1	C1/11	9	652	18	405	1	4.4.3.4	3.75	-	-
Chultun C-1	C1/11	9	652	18	404	1	2.5.2.2	3	-	-
Chultun C-1	C1/11	9	652	25	390	1	2	-	-	-
Chultun C-1	C1/11	9	652	24	289	1	3	-	-	-
Chultun C-1	C1/11	9	652	14	387	1	2	-	-	-
Chultun C-1	C1/11	9	652	15	388	1	2	-	-	-
Chultun C-1	C1/11	9	652	11	387	1	4	-	-	-
Chultun C-1	C1/11	9	652	12	377	1	4	-	-	-
Chultun C-1	C1/11	9	652	21	376	1	3	-	-	-
Chultun C-1	C1/11	9	652	22	375	1	5	-	-	-
Chultun C-1	C1/11	9	652	15	367	1	4	-	-	-

Chultun C-1	C1/11	9	652	14	366	1	2	-	-	-
Chultun C-1	C1/11	9	652	25	365	1	4	-	-	-
Chultun C-1	C1/11	9	652	24	364	1	2	-	-	-
Chultun C-1	C1/11	9	652	23	386	1	4	-	-	-
Chultun C-1	C1/11	9	652	13	385	1	2	-	-	-
Chultun C-1	C1/11	9	652	13	384	1	4	-	-	-
Chultun C-1	C1/11	9	652	13	383	1	4	-	-	-
Chultun C-1	C1/11	9	652	Mod	422	1	4	-	-	-
Chultun C-1	C1/11	9	652	Mod	421	1	4	-	-	-
Chultun C-1	C1/11	9	652	Mod	420	1	2	-	-	-
Chultun C-1	C1/11	9	652	Mod	419	1	2	-	-	-
Chultun C-1	C1/11	9	652	Mod	418	1	2	-	-	-
Chultun C-1	C1/11	9	652	Mod	417	1	3	-	-	-
Chultun C-1	C1/11	9	652	Mod	416	1	2	-	-	-
Chultun C-1	C1/11	9	652	Mod	415	1	2	-	-	-
Chultun C-1	C1/11	9	652	Mod	414	1	2	-	-	-
Chultun C-1	C1/11	9	652	Mod	413	1	4	-	-	-
Chultun C-1	C1/11	9	652	48	402	1	2.2.5.3	3	1	-
Chultun C-1	C1/11	9	652	47	401	1	4.4.3.3	3.5	-	-
Chultun C-1	C1/11	9	652	46	403	1	3.3.3.3	3	-	-
Chultun C-1	C1/11	9	652	46	400	1	5.5.3.3	4	-	-
Chultun C-1	C1/11	9	652	36	399	1	?	-	-	6
Chultun C-1	C1/11	9	652	37	398	1	3.3.4.5	3.75	-	-
Chultun C-1	C1/11	9	652	47	397	1	4.5.3.3	3.75	-	-
Chultun C-1	C1/11	9	652	38	396	1	3.4.3.3	3.25	-	-
Chultun C-1	C1/11	9	652	38	395	1	4.4.3.3	3.5	-	-
Chultun C-1	C1/11	9	652	34	369	1	2	-	-	-
Chultun C-1	C1/11	9	652	44	370	1	2	-	-	-
Chultun C-1	C1/11	9	652	35	371	1	2	-	-	-
Chultun C-1	C1/11	9	652	35	373	1	3	-	-	-
Chultun C-1	C1/11	9	652	34	368	1	3	-	-	-
Chultun C-1	C1/11	9	652	45	372	1	2	-	-	-
Chultun C-1	C1/11	9	652	45	374	1	3	-	-	-
Chultun C-1	C1/11	9	652	31	394	1	5	-	1	-
Chultun C-1	C1/11	9	652	31	391	1	?	-	-	-
Chultun C-1	C1/11	9	652	32	392	1	2	-	-	-
Chultun C-1	C1/11	9	652	42	393	1	2	-	-	-
Chultun C-1	C1/11	9	652	43	382	1	4	-	-	-
Chultun C-1	C1/11	9	652	33	381	1	2	-	-	-

Chultun C-1	C1/11	9	652	33	379	1	4	-	-	-
Chultun C-1	C1/11	9	652	33	380	1	3	-	-	-
Chultun C-1	C1/10	8	651	Canine	428	10	2	-	-	-
Chultun C-1	C1/10	8	651	Canine	427	10	1	-	-	-
Chultun C-1	C1/10	8	651	Canine	426	10	3	-	-	-
Chultun C-1	C1/10	8	651	Canine	425	10	1	-	-	-
Chultun C-1	C1/10	8	651	Canine	424	10	2	-	-	-
Chultun C-1	C1/10	8	651	Canine	423	10	1	-	-	-
Chultun C-1	C1/10	8	651	31	444	1	3	-	-	-
Chultun C-1	C1/10	8	651	41	445	1	5	-	-	-
Chultun C-1	C1/10	8	651	23	429	1	4	-	-	-
Chultun C-1	C1/10	8	651	13	430	1	4	-	-	-
Chultun C-1	C1/10	8	651	41/42	446	1	5	-	-	-
Chultun C-1	C1/10	8	651	42	447	1	4	-	-	-
Chultun C-1	C1/10	8	651	44/45	431	1	2	-	-	-
Chultun C-1	C1/10	8	651	35	432	1	2	-	-	-
Chultun C-1	C1/10	8	651	34	433	1	3	-	-	-
Chultun C-2	C2/3	7	737	38	462	1	3.3.3.3	3	-	-
Chultun C-2	C2/3	7	737	18	460	1	2.3.3.3	2.75	-	-
Chultun C-2	C2/3	7	737	16	459	1	2.3.3.3	2.75	-	-
Chultun C-2	C2/3	7	737	28	458	1	3.5.4.4	4	-	-
Chultun C-2	C2/3	7	737	26	457	1	5.5.4.3	4.25	-	-
Chultun C-2	C2/3	7	737	14	461	1	4	-	-	-
Chultun C-2	C2/3	7	737	22	453	1	4	-	-	-
Chultun C-2	C2/3	7	737	11	450	1	3	-	-	-
Chultun C-2	C2/3	7	737	12	451	1	2	-	-	-
Chultun C-2	C2/3	7	737	21	452	1	3	-	-	-
Chultun C-2	C2/3	7	737	23	448	1	2	-	-	-
Chultun C-2	C2/3	7	737	13	449	1	7	-	-	-
Chultun C-2	C2/3	7	737	24/25	456	1	7	-	-	-
Chultun C-2	C2/3	7	737	24/25	455	1	5	-	-	-
Chultun C-2	C2/3	7	737	14/15	454	1	5	-	-	7
Chultun B-2	B2/1	6	509	46	1	1	2.2.1.1	1.5	-	-
Chultun B-2	B2/1	6	509	47	2	1	2.2.2.3	2.25	-	-
Chultun B-2	B2/1	6	509	36	3	1	5.5.6.4	5	-	-
Chultun B-2	B2/1	6	509	37	4	1	3.2.1.2	2	-	-
Chultun B-2	B2/1	6	509	36	5	1	2.2.1.1	1.5	6	4
Chultun B-2	B2/1	6	509	47	6	1	6.6.4.4	5	-	-
Chultun B-2	B2/1	6	509	37	7	1	5.3.2.2	3	2	-

Chultun B-2	B2/1	6	509	46	9	1	1.1.1.1	1	-	-
Chultun B-2	B2/1	6	509	34	21	1	2	-	-	-
Chultun B-2	B2/1	6	509	34	22	1	1	-	-	-
Chultun B-2	B2/1	6	509	44	20	1	2	-	-	-
Chultun B-2	B2/1	6	509	44	19	1	2	-	-	-
Chultun B-2	B2/1	6	509	35	43	1	2	-	-	-
Chultun B-2	B2/1	6	509	45	43	1	2	-	-	-
Chultun B-2	B2/1	6	509	41	16	1	3	-	-	-
Chultun B-2	B2/1	6	509	31/41	15	1	1	-	-	-
Chultun B-2	B2/1	6	509	31	14	1	2	-	-	-
Chultun B-2	B2/1	6	509	31	10	1	3	-	-	-
Chultun B-2	B2/1	6	509	31	11	1	2	-	-	-
Chultun B-2	B2/1	6	509	42	17	1	1	-	-	-
Chultun B-2	B2/1	6	509	31	13	1	4	-	-	-
Chultun B-2	B2/1	6	509	32	12	1	1	-	-	-
Chultun B-2	B2/1	6	509	43	28	1	2	-	-	-
Chultun B-2	B2/1	6	509	43	27	1	2	-	-	-
Chultun B-2	B2/1	6	509	43	26	1	3	-	5	-
Chultun B-2	B2/1	6	509	33	25	1	1	-	-	-
Chultun B-2	B2/1	6	509	33	24	1	1	-	-	-
Chultun B-2	B2/1	6	509	45	18	1	1	-	-	-
Chultun B-2	B2/1	6	509	13	46	1	4	-	-	-
Chultun B-2	B2/1	6	509	13	47	1	2	-	-	-
Chultun B-2	B2/1	6	509	21	44	1	5	-	-	-
Chultun B-2	B2/1	6	509	13	23	1	1	-	4	-
Chultun B-2	B2/1	6	509	23	45	1	2	-	-	-
Chultun B-2	B2/1	6	509	26	38	1	2.2.2.2	2	4	-
Chultun B-2	B2/1	6	509	15	42	1	-	-	-	-
Chultun B-2	B2/1	6	509	25	39	1	1	-	-	-
Chultun B-2	B2/1	6	509	14	40	1	1	-	-	-
Chultun B-2	B2/1	6	509	18	35	1	2.2.2.2	2	-	-
Chultun B-2	B2/1	6	509	16	37	1	3.3.3.3	3	-	-
Chultun B-2	B2/1	6	509	16	36	1	3.3.3.3	3	-	-
Chultun B-2	B2/1	6	509	26	8	1	3.4.3.3	2.75	-	-
Chultun B-2	B2/2	3	458	36	49	1	1.1.1.1	1	-	-
Chultun B-2	B2/2	3	458	46	48	1	3.3.2.2	2.5	7	-
Chultun B-2	B2/2	3	458	46	51	1	3.3.2.2	2.5	-	-
Chultun B-2	B2/2	3	458	36	52	1	3.3.2.2	2.5	-	-
Chultun B-2	B2/2	3	458	46	50	1	2.2.2.2	2	-	-

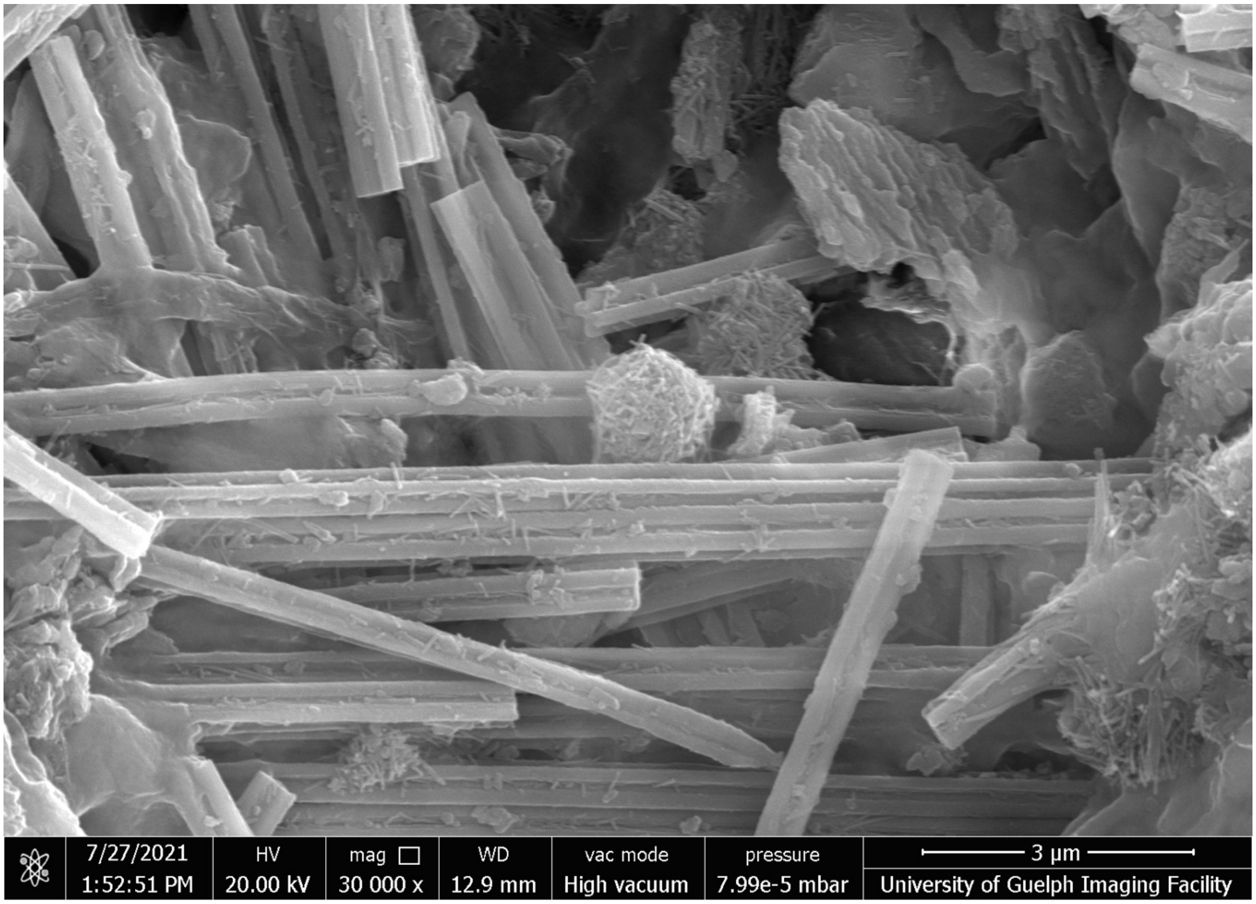
Chultun B-2	B2/2	3	458	44	56	1	1	-	-	-
Chultun B-2	B2/2	3	458	44	55	1	1	-	-	-
Chultun B-2	B2/2	3	458	35	54	1	-	-	-	-
Chultun B-2	B2/2	3	458	33	61	1	-	-	-	-
Chultun B-2	B2/2	3	458	42	57	1	2	-	-	-
Chultun B-2	B2/2	3	458	35	65	1	3	-	-	-
Chultun B-2	B2/2	3	458	45	64	1	1	-	-	-
Chultun B-2	B2/2	3	458	23	61	1	2	-	-	-
Chultun B-2	B2/2	3	458	14/15	53	1	2-3	-	-	-
Chultun B-2	B2/2	3	458	11	63	1	2	-	-	-
Chultun B-2	B2/2	3	458	16	58	1	4.4.2.3	3.25	-	-
Chultun B-2	B2/2	3	458	18	60	1	3.3.3.3	3	-	-
Chultun B-2	B2/2	3	458	17	59	1	3.3.3.3	3	-	-
Chultun B-2	B2/2	3	458	27	57	1	?	-	3	4
Chultun C3	C3/3	3	1003	43	465	1	2	-	-	-
Chultun C3	C3/3	3	1003	43	464	1	5	-	-	-
Chultun C3	C3/3	3	1003	43	463	1	5	-	6	-
Chultun C3	C3/3	3	1003	46	471	1	3.3.3.3	3	-	-
Chultun C3	C3/3	3	1003	14/15	472	1	3	-	-	-
Chultun C3	C3/3	3	1003	36/46	473	1	4.4.4.3	3.75	-	-
Chultun C3	C3/3	3	1003	34	470	1	3	-	-	-
Chultun C3	C3/3	3	1003	15	468	1	3	-	-	-
Chultun C3	C3/3	3	1003	25	469	1	3	-	-	-
Chultun C3	C3/3	3	1003	21	467	1	5	-	-	-
Chultun C3	C3/3	3	1003	14	466	1	2	-	7	-
Chultun C3	C3/1	Surface	797	33	195	1	3	-	-	-
Chultun C3	C3/1	Surface	797	24/25	193	1	2	-	-	-
Chultun C3	C3/1	Surface	797	23	194	1	4	-	-	-
Chultun C3	C3/2	1	796	46	186	1	3.3.2.2	2.5	7	-
Chultun C3	C3/2	1	796	42	187	1	3	-	-	-
Chultun C3	C3/2	1	796	41	188	1	5	-	-	-
Chultun C3	C3/2	1	796	?	189	1	2	-	-	-
Chultun C3	C3/2	1	796	24	191	1	2	-	-	-
Chultun C3	C3/2	1	796	21	192	1	2	-	-	-
Chultun C3	C3/2	1	796	13	190	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	22	178	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	22	179	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	22	177	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	22	176	1	1	-	-	-

Chultun C3	C3/4,5,6	2	798	18	136	1	6.6.4.4	5	-	-
Chultun C3	C3/4,5,6	2	798	17	135	1	3.3.3.3	3	-	-
Chultun C3	C3/4,5,6	2	798	16	134	1	3.3.4.4	3.5	7	-
Chultun C3	C3/4,5,6	2	798	16	133	1	5.5.5.5	5	-	-
Chultun C3	C3/4,5,6	2	798	18	132	1	3.3.3.3	3	-	-
Chultun C3	C3/4,5,6	2	798	?	131	1	?	4	-	-
Chultun C3	C3/4,5,6	2	798	18	130	1	3.3.4.4	3.5	-	-
Chultun C3	C3/4,5,6	2	798	16	129	1	3.3.5.5	4	-	-
Chultun C3	C3/4,5,6	2	798	37	128	1	3.3.3.3	3	-	-
Chultun C3	C3/4,5,6	2	798	14/15	141	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	44/45	140	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	Maxpre	139	1	?	-	-	-
Chultun C3	C3/4,5,6	2	798	24/25	137	1	1	-	1	-
Chultun C3	C3/4,5,6	2	798	23	117	1	4	-	-	-
Chultun C3	C3/4,5,6	2	798	23	126	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	23	125	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	23	127	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	12	160	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	12	159	7	-	-	-	-
Chultun C3	C3/4,5,6	2	798	12	158	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	12	157	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	13	156	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	12	155	1	5	-	-	-
Chultun C3	C3/4,5,6	2	798	13	171	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	13	170	1	5	-	-	-
Chultun C3	C3/4,5,6	2	798	13	173	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	13	172	1	1	-	1	-
Chultun C3	C3/4,5,6	2	798	13	174	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	13	175	1	6	-	-	-
Chultun C3	C3/4,5,6	2	798	ModInc	169	10	-	-	-	-
Chultun C3	C3/4,5,6	2	798	ModInc	168	10	-	-	-	-
Chultun C3	C3/4,5,6	2	798	ModInc	167	10	2	-	-	-
Chultun C3	C3/4,5,6	2	798	ModCan	166	10	2	-	-	-
Chultun C3	C3/4,5,6	2	798	21	180	1	4	-	-	-
Chultun C3	C3/4,5,6	2	798	21	181	1	5	-	-	-
Chultun C3	C3/4,5,6	2	798	11	182	1	5	-	-	-
Chultun C3	C3/4,5,6	2	798	11	165	1	4	-	-	-
Chultun C3	C3/4,5,6	2	798	11	164	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	11	163	1	3	-	-	-

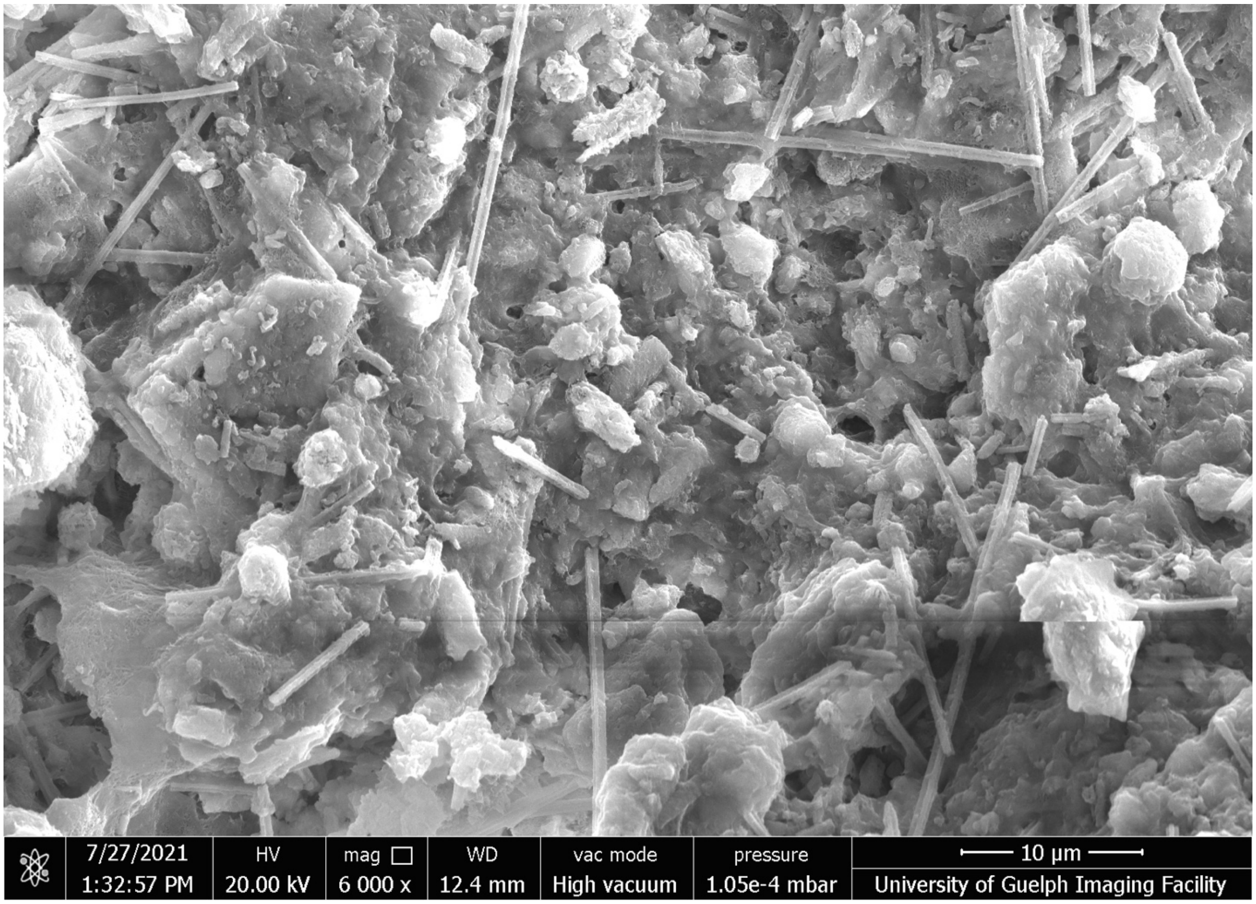
Chultun C3	C3/4,5,6	2	798	11	162	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	11	161	1	1	-	-	-
Chultun C3	C3/4,5,6	2	798	Maxpre	154	1	1	-	-	-
Chultun C3	C3/4,5,6	2	798	Premol	153	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	14/15	152	1	4	-	-	-
Chultun C3	C3/4,5,6	2	798	Maxpre	151	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	14/15	150	1	3	-	7	-
Chultun C3	C3/4,5,6	2	798	14/15	149	1	3	-	4	2
Chultun C3	C3/4,5,6	2	798	14/15	148	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	27	142	1	3.3.3.3	3	-	-
Chultun C3	C3/4,5,6	2	798	26	143	1	4.4.4.4	4	-	-
Chultun C3	C3/4,5,6	2	798	26	144	1	5.5.3.3	4	-	-
Chultun C3	C3/4,5,6	2	798	28	145	1	3.3.3.3	3	-	-
Chultun C3	C3/4,5,6	2	798	26/27	146	1	-	3.5	-	-
Chultun C3	C3/4,5,6	2	798	26	147	1	3.3.3.3	3	-	-
Chultun C3	C3/4,5,6	2	798	decid	185	1	-	-	-	-
Chultun C3	C3/4,5,6	2	798	decid	184	1	-	-	-	-
Chultun C3	C3/4,5,6	2	798	decid	183	-	-	-	-	-
Chultun C3	C3/4,5,6	2	798	46	66	1	4.5.5.3	4.25	-	-
Chultun C3	C3/4,5,6	2	798	46	70	1	4.4.3.3	3.5	-	-
Chultun C3	C3/4,5,6	2	798	46	69	1	5.5.3.3	4	7	7
Chultun C3	C3/4,5,6	2	798	47	68	1	2.2.2.2	2	-	-
Chultun C3	C3/4,5,6	2	798	47	67	1	3.3.5.5	4	-	-
Chultun C3	C3/4,5,6	2	798	36	78	1	5.5.3.3	4	4	1
Chultun C3	C3/4,5,6	2	798	38	77	1	4.4.4.4	4	1	-
Chultun C3	C3/4,5,6	2	798	38	76	1	2.2.2.2	2	-	-
Chultun C3	C3/4,5,6	2	798	36	75	1	4.4.3.3	3.5	-	-
Chultun C3	C3/4,5,6	2	798	38	74	1	4.4.4.4	4	1	-
Chultun C3	C3/4,5,6	2	798	36/38	73	1	-	4	1	7
Chultun C3	C3/4,5,6	2	798	36	72	1	4.4.3.3	3.5	-	-
Chultun C3	C3/4,5,6	2	798	36	71	1	4.4.3.3	3.5	-	-
Chultun C3	C3/4,5,6	2	798	32	105	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	23	104	1	1	-	-	-
Chultun C3	C3/4,5,6	2	798	32	103	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	34/35	93	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	34/35	92	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	34/35	31	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	Maxpre	90	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	Maxpre	89	1	6	-	-	-

Chultun C3	C3/4,5,6	2	798	34/35	88	1	1	-	-	-
Chultun C3	C3/4,5,6	2	798	34/35	87	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	Premol	86	1	2	-	7	-
Chultun C3	C3/4,5,6	2	798	Maxpre	85	1	1	-	-	-
Chultun C3	C3/4,5,6	2	798	14/15	84	1	1	-	-	-
Chultun C3	C3/4,5,6	2	798	34/35	83	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	14/15	82	1	3	-	4	-
Chultun C3	C3/4,5,6	2	798	34/35	80	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	34/35	79	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	42	108	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	42	107	1	5	-	-	-
Chultun C3	C3/4,5,6	2	798	42	106	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	33	115	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	33	114	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	23	122	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	23	124	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	23	120	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	23	121	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	33	116	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	31	119	1	4	-	-	-
Chultun C3	C3/4,5,6	2	798	41	118	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	43	110	1	6	-	6	-
Chultun C3	C3/4,5,6	2	798	43	109	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	43	112	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	43	111	1	5	-	-	-
Chultun C3	C3/4,5,6	2	798	43	113	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	44/45	101	1	1	-	-	-
Chultun C3	C3/4,5,6	2	798	44/45	98	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	44/45	97	1	4	-	-	-
Chultun C3	C3/4,5,6	2	798	44/45	96	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	44/45	95	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	44/45	94	1	4	-	-	-
Chultun C3	C3/4,5,6	2	798	Maxpre	102	1	3	-	-	-
Chultun C3	C3/4,5,6	2	798	14/15	100	1	2	-	-	-
Chultun C3	C3/4,5,6	2	798	24/25	99	1	2	-	-	-

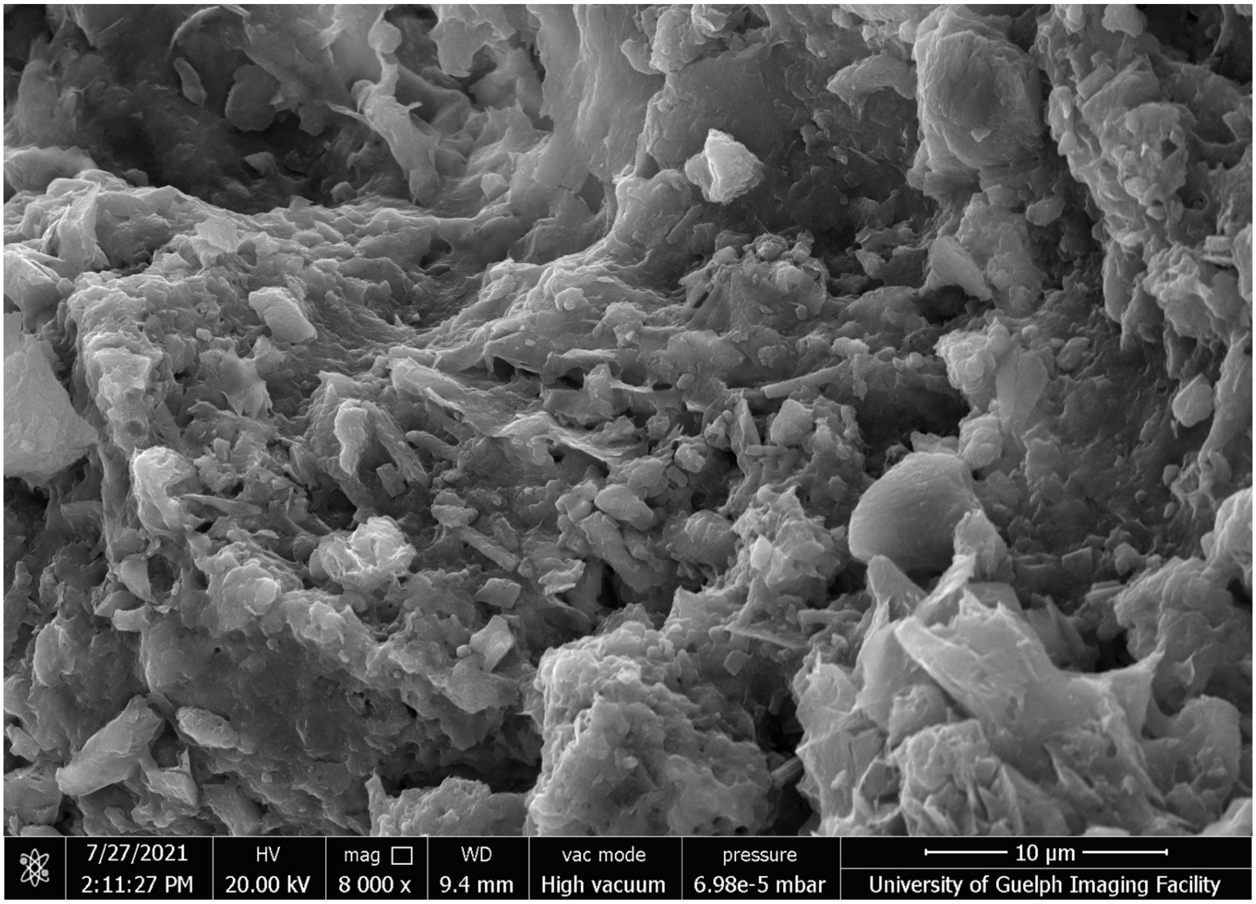
APPENDIX B: SEM Images



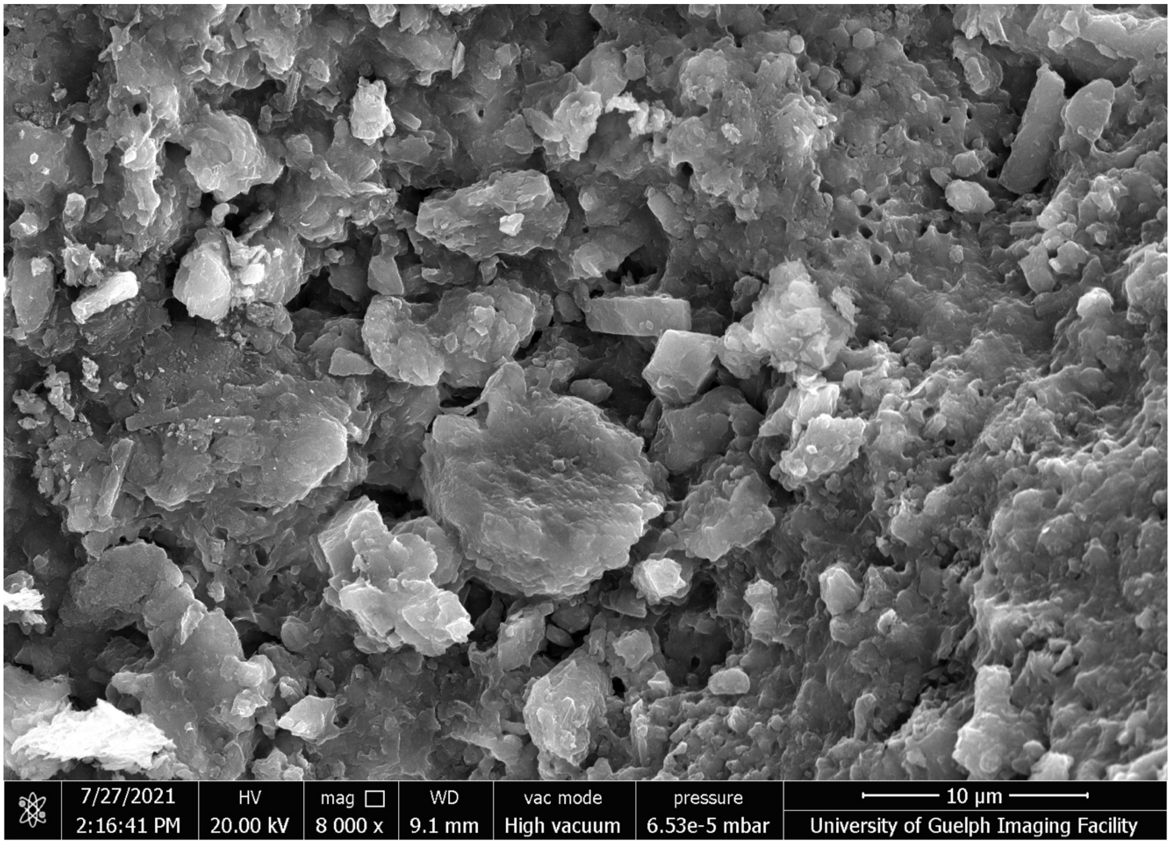
SEM Sample 1, Image 15: 30,000x magnification



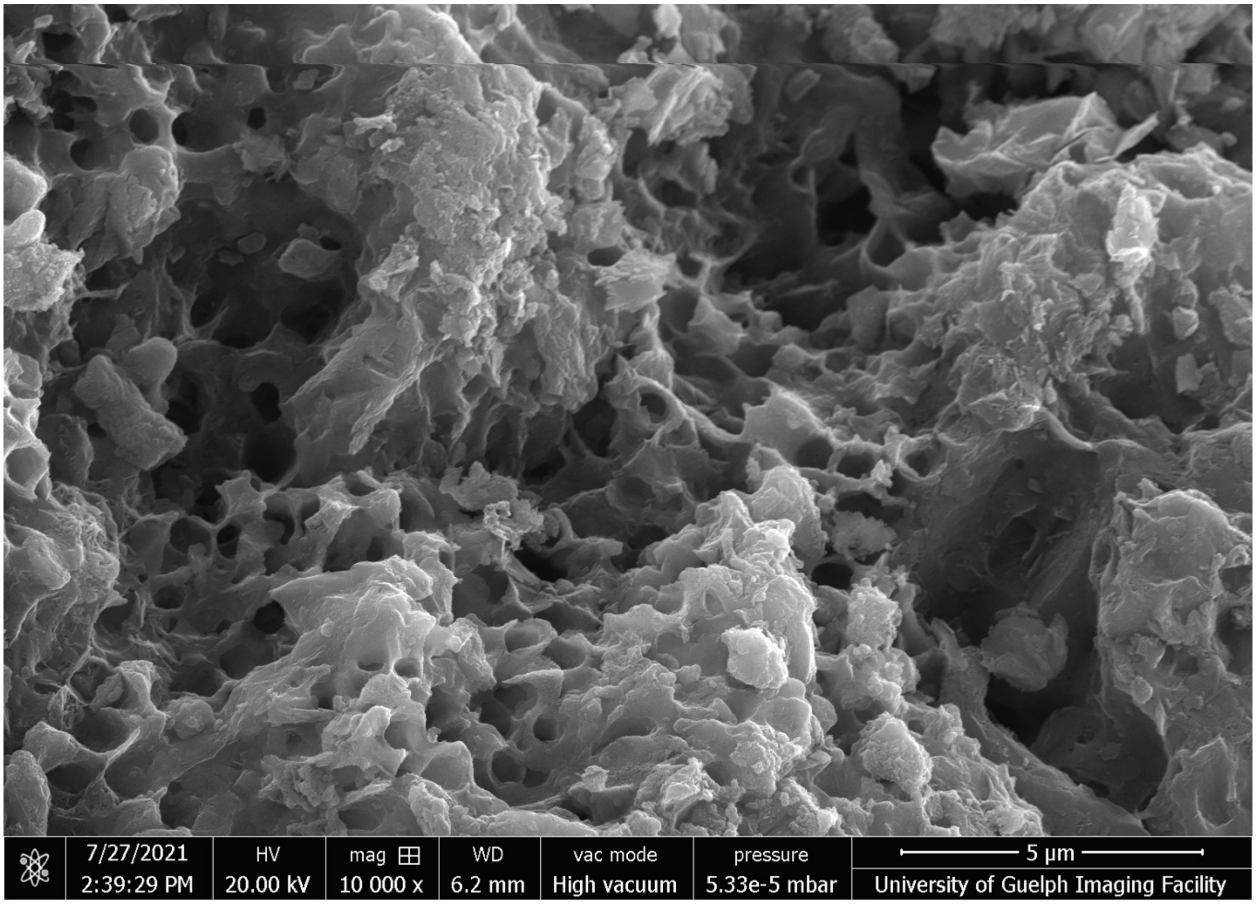
SEM Sample 1, Image 5: 6,000x magnification



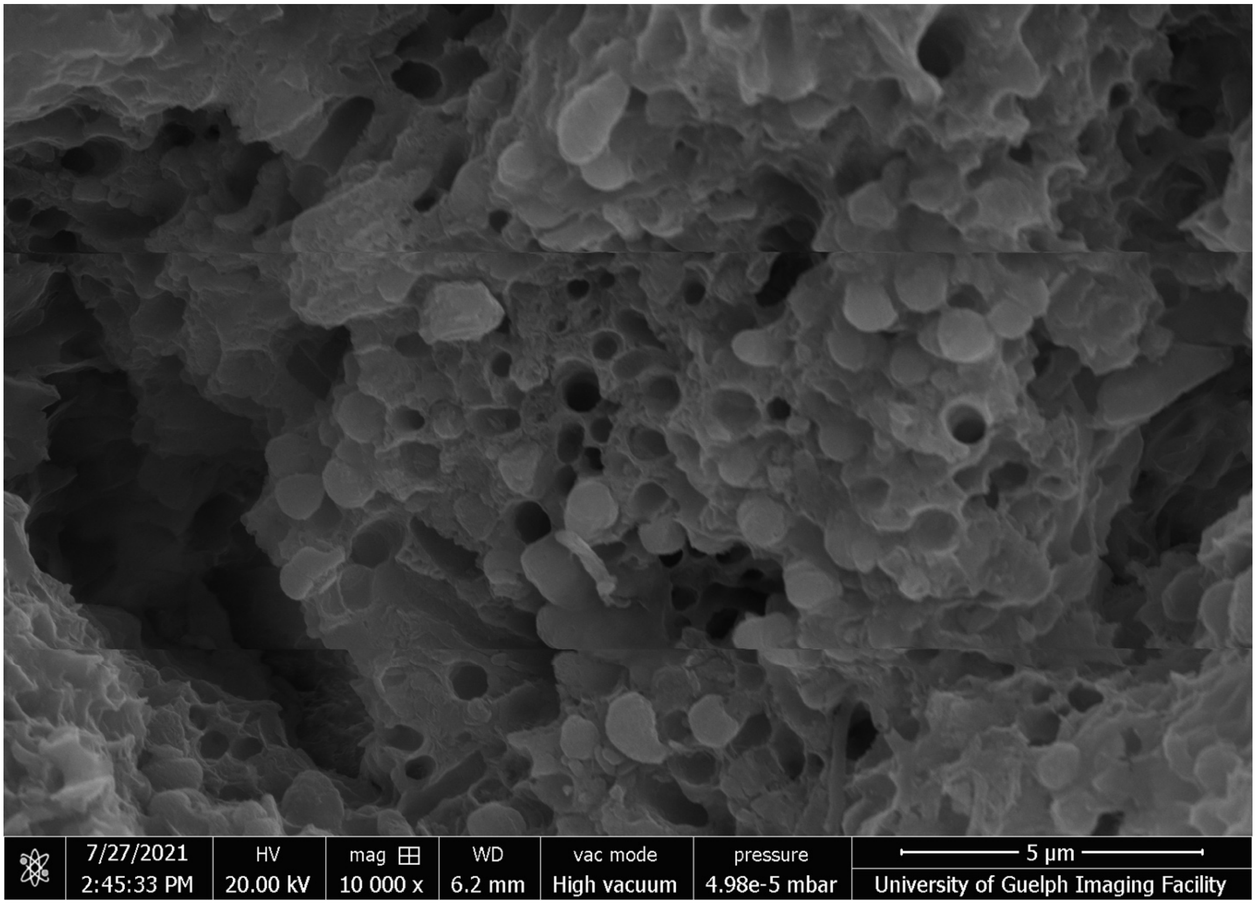
SEM Sample 2, Image 3: 8,000x magnification



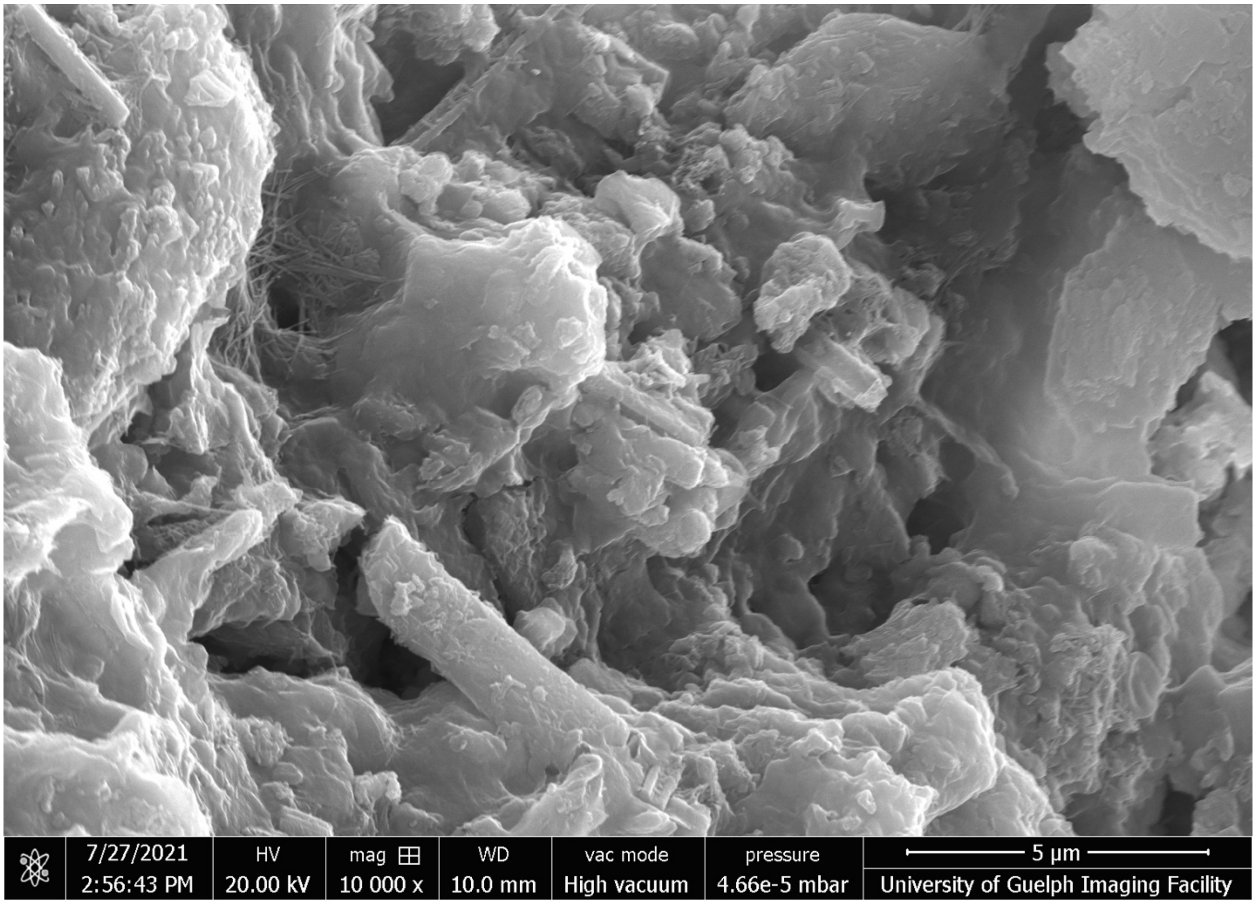
SEM Sample 2, Image 6: 8,000x magnification



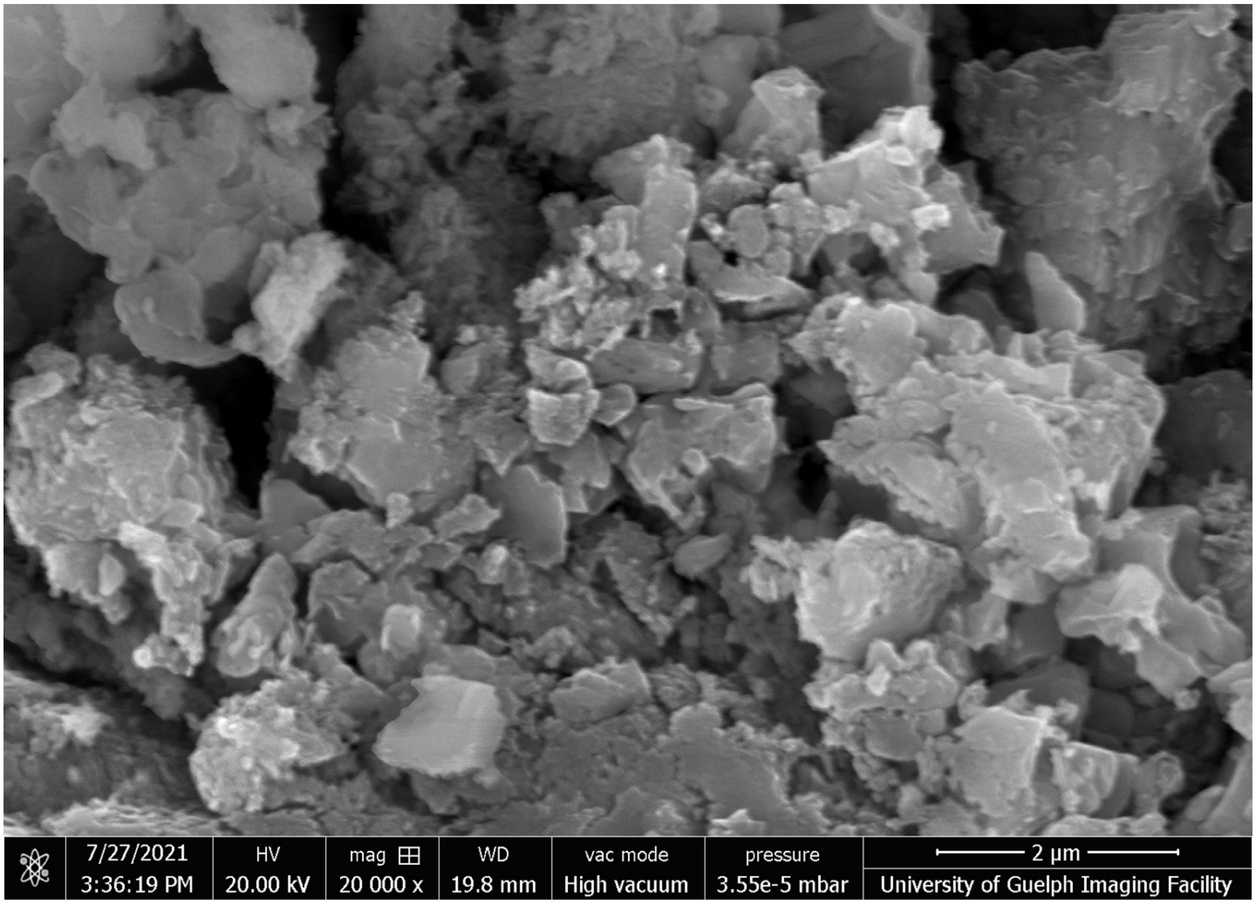
SEM Sample 3, Image 2: 10,000x magnification



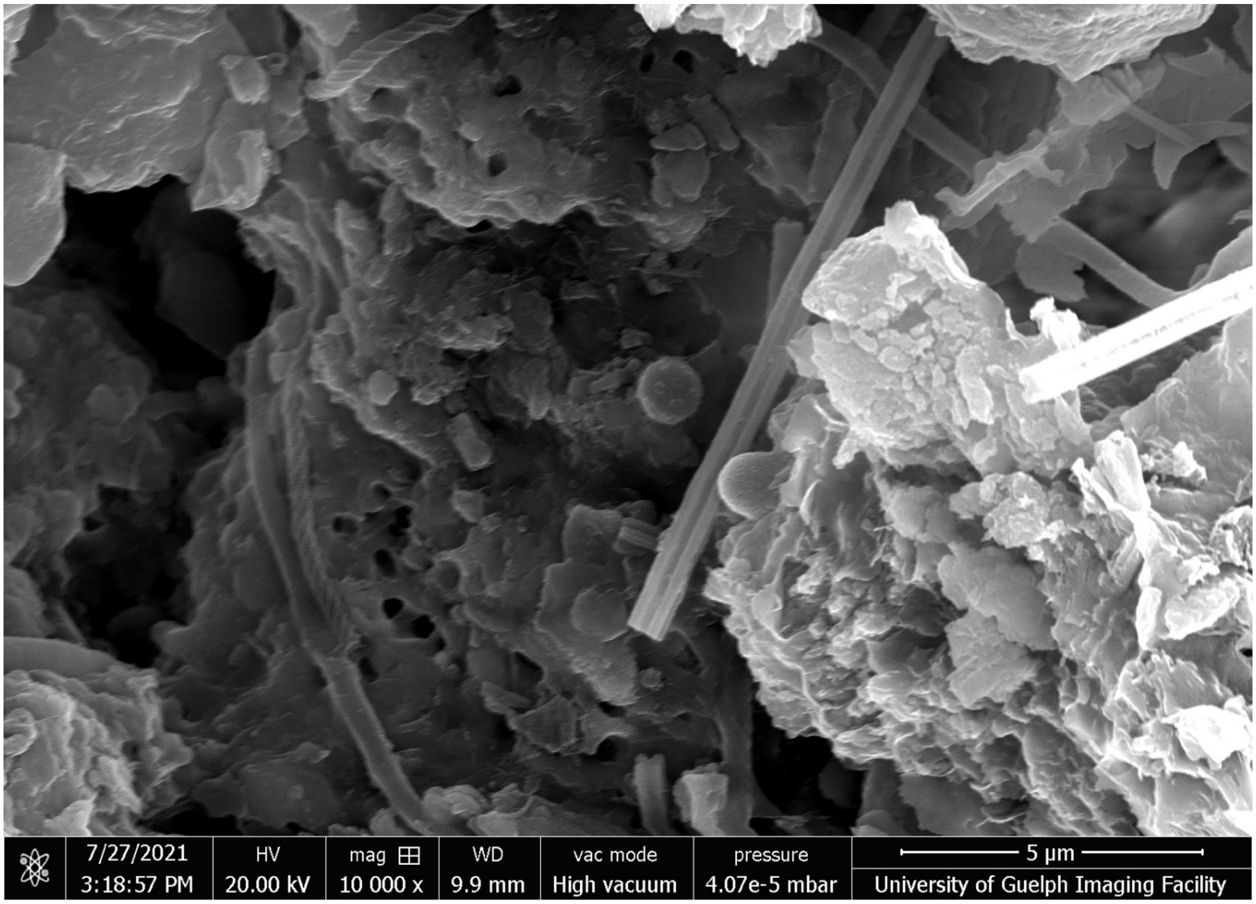
SEM Sample 3, Image 4: 10,000x magnification



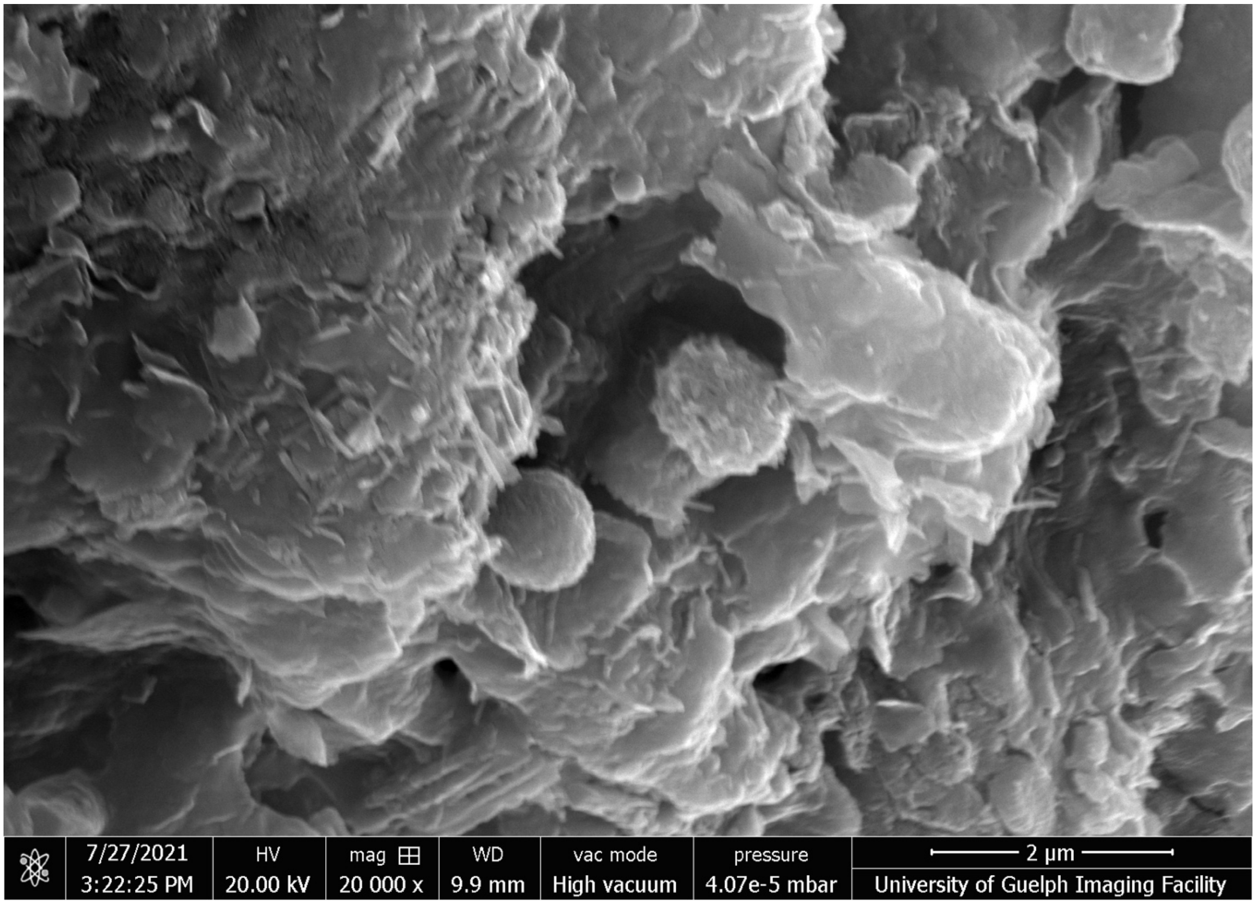
SEM Sample 4, Image 2: 10,000x magnification



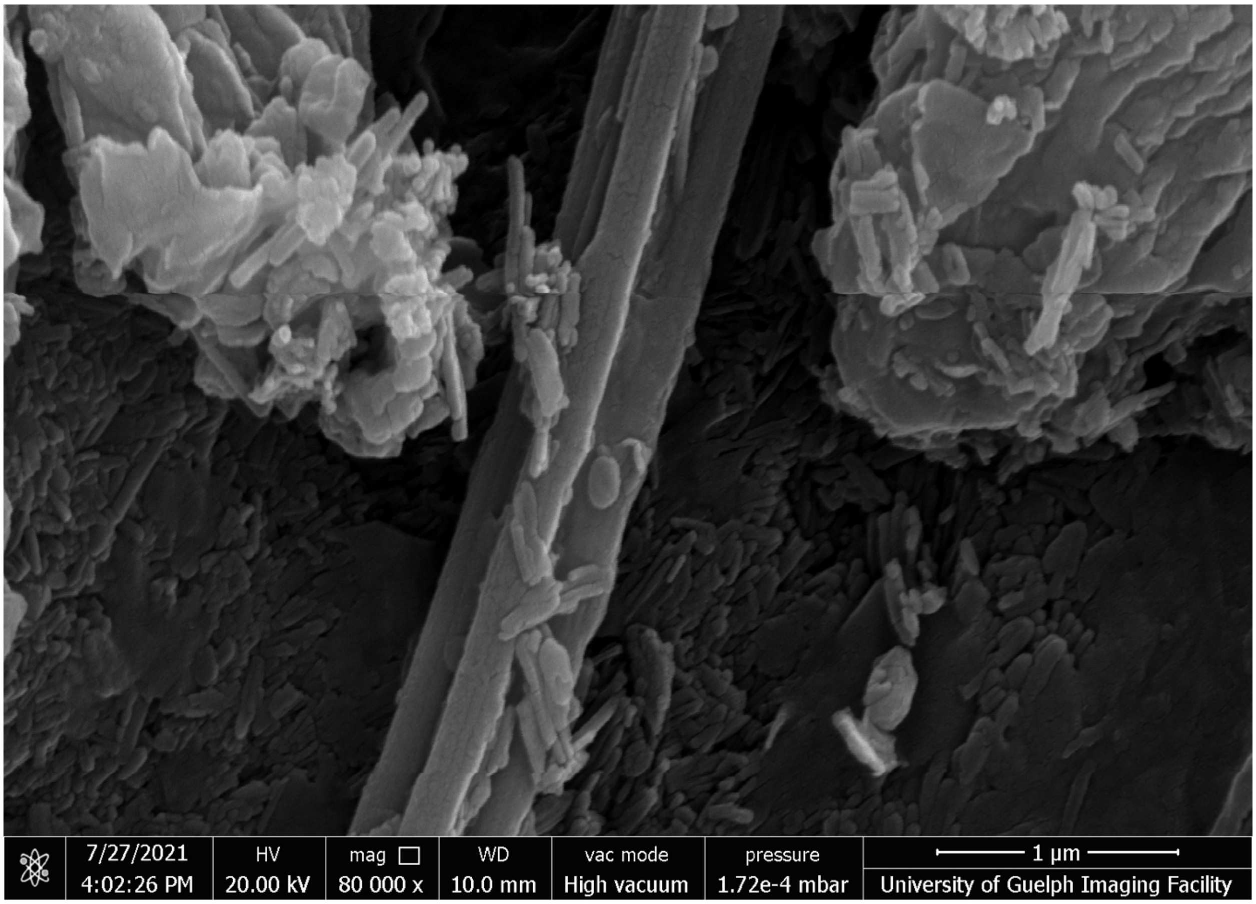
SEM Sample 5, Image 3: 20,000x magnification



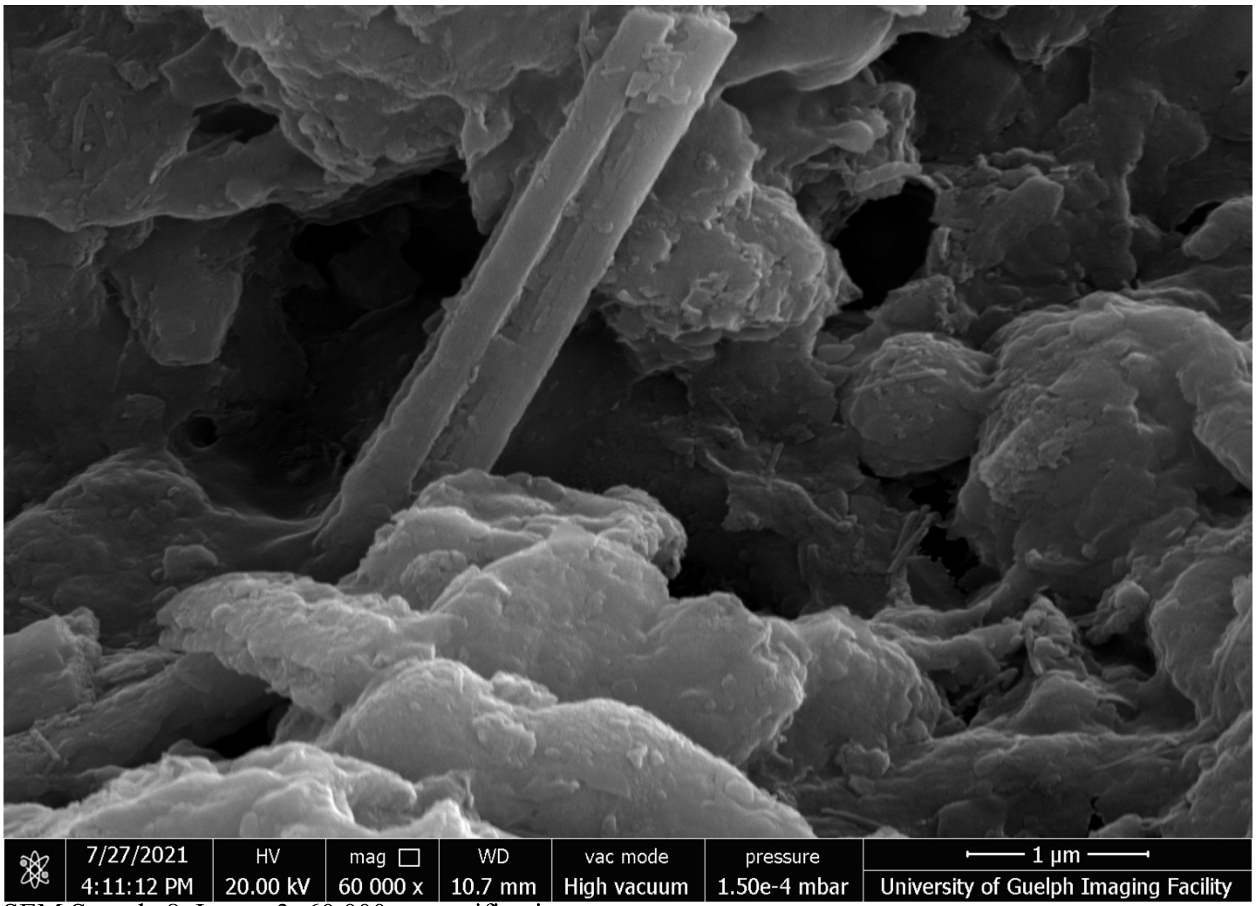
SEM Sample 6, Image 4: 10,000x magnification



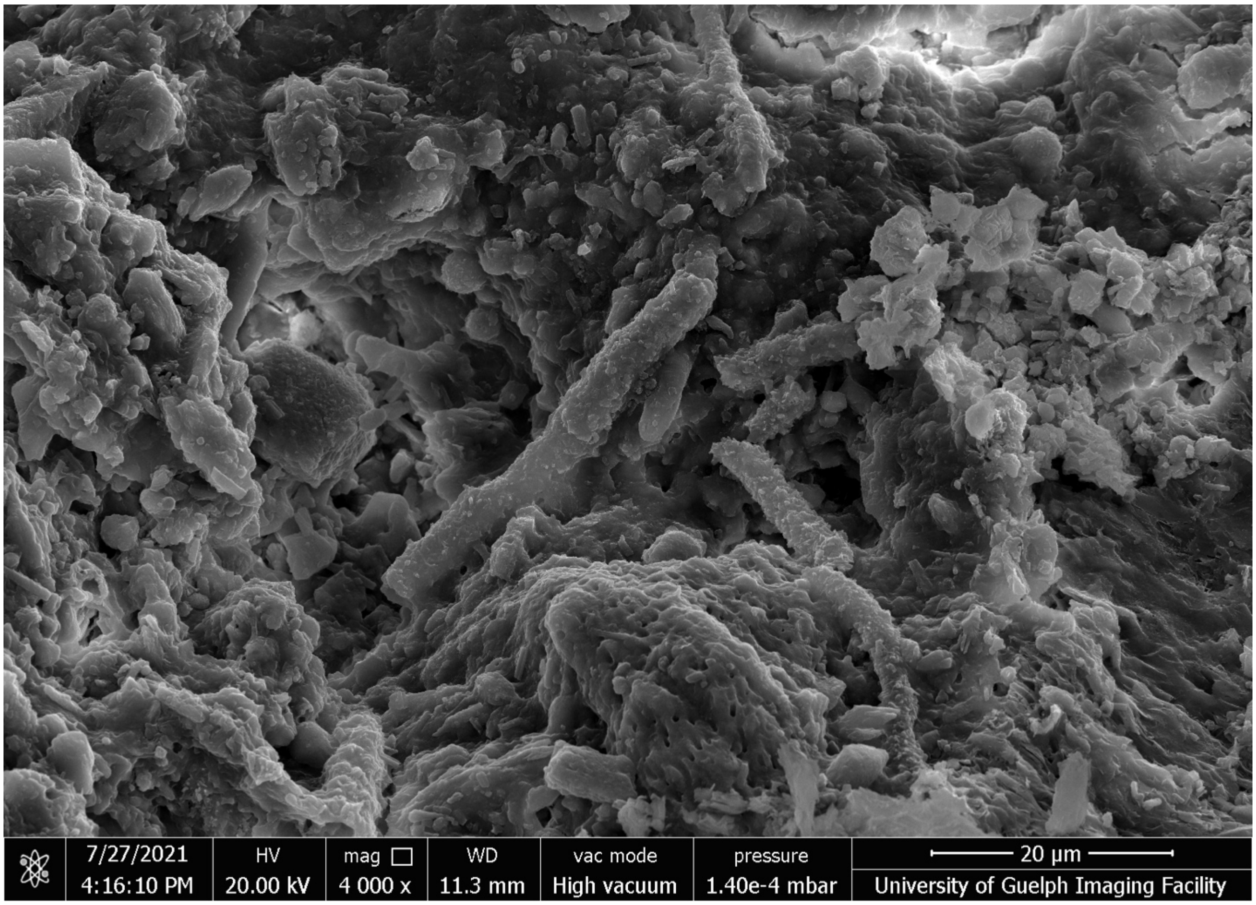
SEM Sample 6, Image 6: 20,000x magnification



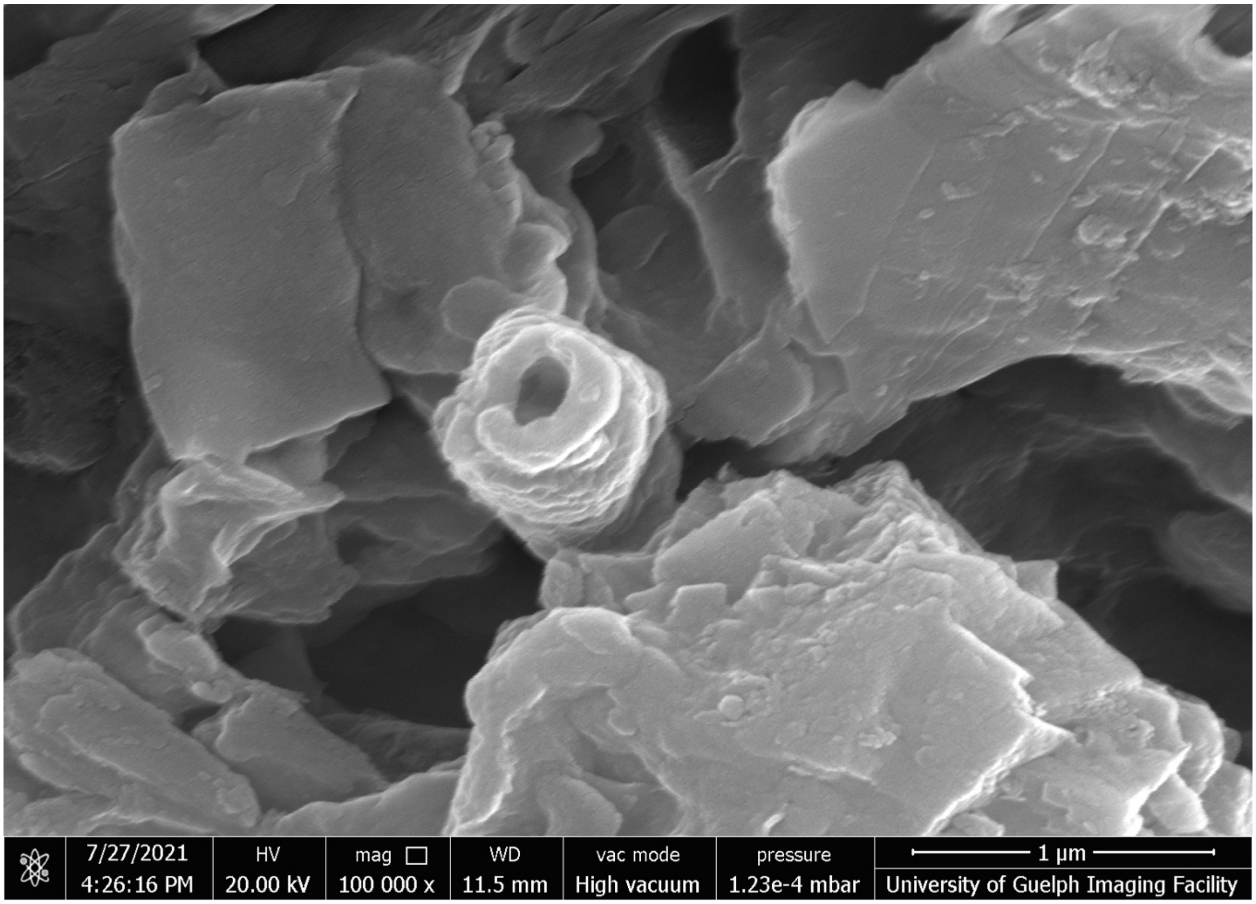
SEM Sample 7, Image 6: 80,000x magnification



SEM Sample 8, Image 3: 60,000x magnification



SEM Sample 9, Image 1: 4,000x magnification



SEM Sample 9, Image 6: 100,000x magnification

APPENDIX C: Dental Calculus Data

Summary of Dental Calculus Scores

Burial	FDI	STN	Calculus Score	Surface Location
Chultun C-1	?	476	1	-
Chultun C-1	?	477	1	-
Chultun C-1	14/15	474	1	-
Chultun C-1	13	354	1	-
Chultun C-1	36	349	1	-
Chultun C-1	MaxPre	348	1	
Chultun C-1	PreMol	339	1	all
Chultun C-1	34/35	338	1	all
Chultun C-1	33	342	2	Lingual
Chultun C-1	43	343	1	Lingual
Chultun C-1	32	344	2	Labial
Chultun C-1	42	346	2	Distal Interproximal
Chultun C-1	48	253	1	Buccal
Chultun C-1	?	251	1	-
Chultun C-1	36?	247	1	Lingual/Buccal
Chultun C-1	34/18?	249	1	Distal labial
Chultun C-1	ManPre	255	1	-
Chultun C-1	ManPre	256	1	-
Chultun C-1	ManPre	257	2	Lingual
Chultun C-1	ManPre	258	2	-
Chultun C-1	ManPre	259	1	-
Chultun C-1	31	261	1	Lingual
Chultun C-1	31	262	1	all
Chultun C-1	23	267	2	all
Chultun C-1	ModCan	265	2	Labial
Chultun C-1	ModCan	264	2	-
Chultun C-1	43	238	1	-
Chultun C-1	35	242	1	-
Chultun C-1	42	240	2	Lingual distal
Chultun C-1	42	241	2	Labial
Chultun C-1	?	227	1	Lingual
Chultun C-1	ModCan	233	1	-
Chultun C-1	23	221	2	all
Chultun C-1	24/25	212	1	Lingual
Chultun C-1	?	213	1	Occlusal

Chultun C-1	27	411	1	-
Chultun C-1	28	409	1	-
Chultun C-1	16	408	1	-
Chultun C-1	25	390	1	-
Chultun C-1	14	387	2	-
Chultun C-1	11	387	1	-
Chultun C-1	12	377	1	-
Chultun C-1	15	367	1	-
Chultun C-1	25	365	1	-
Chultun C-1	23	386	1	-
Chultun C-1	13	383	1	-
Chultun C-1	Mod	422	2	labial
Chultun C-1	Mod	421	1	-
Chultun C-1	Mod	419	1	-
Chultun C-1	Mod	417	2	-
Chultun C-1	Mod	414	2	-
Chultun C-1	48	402	1	-
Chultun C-1	46	403	1	-
Chultun C-1	47	397	1	-
Chultun C-1	38	396	1	-
Chultun C-1	38	395	1	-
Chultun C-1	44	370	1	-
Chultun C-1	35	371	2	-
Chultun C-1	34	368	1	-
Chultun C-1	33	381	1	-
Chultun C-1	33	379	1	-
Chultun C-1	33	380	1	-
Chultun C-1	Canine	427	1	-
Chultun C-1	Canine	424	1	-
Chultun C-1	23	429	1	Labial
Chultun C-1	13	430	1	-
Chultun C-1	41/42	446	3	Lingual and Labual
Chultun C-1	44/45	431	1	-
Chultun C-1	35	432	1	-
Chultun C-2	38	462	1	Lingual
Chultun C-2	18	460	1	-
Chultun C-2	28	458	1	-
Chultun C-2	14?	461	1	-
Chultun C-2	12	451	1	-
Chultun C-2	21	452	1	Labial
Chultun B-2	46	1	1	lingual

Chultun B-2	47	2	1	lingual
Chultun B-2	37	4	1	lingual
Chultun B-2	36	5	2	lingual
Chultun B-2	37	7	1	lingual buccal
Chultun B-2	34	21	1	-
Chultun B-2	34	22	2	lingual
Chultun B-2	44	20	1	lingual
Chultun B-2	35	43	1	Interporximal
Chultun B-2	45	43	1	Interporximal
Chultun B-2	41	16	3	Labial
Chultun B-2	31/41	15	3	Lingual
Chultun B-2	31	14	1	Lingual
Chultun B-2	31	10	2	Occlusal
Chultun B-2	31	11	1	Occlusal
Chultun B-2	42	17	3	Lingual
Chultun B-2	31	13	2	Lingual
Chultun B-2	32	12	2	Lingual and Labial
Chultun B-2	43	28	1	Interporximal
Chultun B-2	43	27	1	Lingual
Chultun B-2	43	26	1	Mesial lingual
Chultun B-2	33	25	1	Lingual
Chultun B-2	33	24	2	Lingual
Chultun B-2	45	18	1	Lingual
Chultun B-2	13	47	1	Mesial labial
Chultun B-2	21	44	1	Labial
Chultun B-2	13	23	1	Labial
Chultun B-2	23	45	1	Labial
Chultun B-2	26	38	1	All
Chultun B-2	46	48	1	all
Chultun B-2	36	52	2	Lingual
Chultun B-2	35	54	3	all
Chultun B-2	33	61	3	all
Chultun B-2	42	57	2	Lingual
Chultun B-2	35	65	2	Labial
Chultun B-2	14/15	53	2	-
Chultun B-2	11	63	2	-
Chultun B-2	27	57	3	all
Chultun C3	43	465	2	Labial
Chultun C3	14/15	472	1	-
Chultun C3	33	195	2	Distal Labial
Chultun C3	42	187	1	-

Chultun C3	41?	188	1	Labial
Chultun C3	22	179	1	Lingual
Chultun C3	23	125	1	-
Chultun C3	ModInc	167	1	-
Chultun C3	21	180	1	Labial
Chultun C3	11	182	1	-
Chultun C3	11	165	1	-
Chultun C3	11	163	1	-
Chultun C3	11	162	1	-
Chultun C3	46	66	1	-
Chultun C3	46	69	1	-
Chultun C3	36/38	73	1	-
Chultun C3	36	72	2	Occlusal
Chultun C3	32	103	1	-
Chultun C3	Premol	86	3	Labial
Chultun C3	34/35	79	2	Lingual
Chultun C3	42	107	1	-
Chultun C3	42	106	2	Labial
Chultun C3	44/45	97	2	-
Chultun C3	44/45	94	2	-
Chultun C3	14/15	100	1	-

APPENDIX D: Export Documents and Ethics Forms

LIST OF ARTIFACTS

PRINCIPAL INVESTIGATOR: **Helen R Haines**

PROJECT: **Ka'Kabish Archaeological Research Project**

PERMIT TO EXCAVATE NUMBER: **IA/H/2/1/18(21)**

ACCESSION NUMBER: **10429**

DATE: **23 July 2018**

Box No.	Material (Pottery, jade, shell, obsidian, soil, bone, granite, stucco etc.)	Quantity (In number of pieces or in grams)	Provenance (Structure, burial, cache, operation, cave, lot etc.)	Description (Fragment, whole, painted, worked, form etc.)	Approved/Denied IA Use Only
Bag 9	Human remains	0.100 kg	Lots 556, 557, 558 Chultun C1 Burial C-1/1	Fragmentary – 1 zip lock bag	Approved
Bag 10	Human remains	0.250 kg	Lots 640 & 650 Chultun C1 Burial C-1/1	Fragmentary – 1 zip lock bag	Approved
Bag 11	Human remains	0.950 kg	Lots 652 Chultun C1 Burial C-1/1	Fragmentary – 1 zip lock bag	Approved
Bag 12	Human remains	0.700 kg	Lots 605 Chultun C1 Burial C-1/1	Fragmentary – 2 zip lock bags	Approved
Bag 13	Human remains	0.800 kg	Lots 651 Chultun C1 Burial C-1/1	Fragmentary – 1 zip lock bag	Approved
The following are all in One Large Zip Lock Bag – to be sealed as per Canadian Customs Requirements					
Bag 14	Human remains	0.450 kg	Lot 523 +464 Chultun B2 Burial B-2/3?	Fragmentary – 1 zip lock bag	Approved
Bag 15	Human remains	0.800 kg	Lots 441, 457, 458 –8 Chultun B2 Burial B-2/2	Fragmentary – 2 zip lock bags	Approved
Bag 16	Human remains	1.550 kg	Lots 509, 521 Chultun B2 Burial B-2/1	Fragmentary – 4 zip lock bags	Approved
The following are all in One Large Zip Lock Bag – to be sealed as per Canadian Customs Requirements					
Bag 17	Human remains	1.750 kg	Lot 798 Chultun C-3	Fragmentary – 1 zip lock bag	Approved
Bag 18	Human remains	1.600 kg	Lot 798 Chultun C-3	Fragmentary – 3 zip lock bags	Approved
Bag 19	Human remains	2.000 kg	Lot 798 Chultun C-3	Fragmentary – 2 zip lock bags	

EXAMINER: Antonio Beardall	APPROVED BY: Dr. John Morris
POST: Archaeologist	POST: Director
SIGNATURE:	SIGNATURE:
DATE: August 28, 2018	DATE: August 28, 2018

LIST OF ARTIFACTS

PRINCIPAL INVESTIGATOR: **Helen R Haines**
PROJECT: **Ka'Kabish Archaeological Research Project**
PERMIT TO EXCAVATE NUMBER: **IA/H/2/1/18(21)**
ACCESSION NUMBER: **10429**
DATE: **23 July 2018**

INSTITUTE OF ARCHAEOLOGY BELMOPAN BELIZE C.A.

Box No.	Material (Pottery, jade, shell, obsidian, soil, bone,)	Quantity (In number of pieces or in grams)	Provenance (Structure, burial, cache, operation, cave, lot etc.)	Description (Fragment, whole, painted, worked, form etc.)	Approved/Denied (IA Use Only)
The following are all in One Large Zip Lock Bag – to be sealed as per Canadian Customs Requirements					
Bag 2a ✓	Human remains	1.0 kg	Lot 727 – Chultun C2 Burial -C2/1 ✓	Fragmentary ✓ 4 bags ✓	Approved
Bag 2b ✓	Human remains	1.150 kg	Lot 727 – Chultun C2 Burial -C2/1 ✓	Fragmentary ✓ 6 bags	Approved
Bag 3 ✓	Human remains	0.2 kg	Chultun C2 Lots 671, 672, 694, 703, 721, 781 ✓	Fragmentary 6 bags – in one larger zip lock bag	Approved (781 1 bag, 721 1 bag, 671 2 bags, 703 2 bags, 672 2 bags, 694 3 bags)
Bag 4 ✓	Human remains	0.35 kg	Chultun C2 (?) C3 Lots 797, 796, 1003 ✓	Fragmentary – 3 bags – in one larger zip lock bag ✓	Approved
Bag 5 ✓	Human remains	0.450 kg	Lot 750 – 5 bags ✓ Chultun C2 Burial C-2/4?	+ 749 1 bag Fragmentary 6 bags	Approved
Bag 6a ✓	Human remains	1.120 kg	Lots 737 &738 – 1 bag, 2 bag Chultun C2 Burial C-2/2&3?	Fragmentary – 3 zip lock bags ✓	Approved
The following are all in One Large Zip Lock Bag – to be sealed as per Canadian Customs Requirements					
Bag 6b ✓	Human remains	1.40 kg	Lots 737 &738 – 5 bags, 2 bags Chultun C2 Burial C-2/2&3?	Fragmentary – 4 zip lock bags ✓	Approved
Bag 7 ✓	Human remains	0.400 kg	Lot 639 ✓ Chultun C1 Burial C-1/1	Fragmentary – 2 zip lock bags ✓	Approved
Bag 8 ✓	Human remains	0.250 kg	Lot 597 ✓ Chultun C1 Burial C-1/1	Fragmentary – 1 zip lock bag ✓	Approved

EXAMINER: Antonio Beardall	APPROVED BY: Dr. John Morris
POST: Archaeologist	POST: Director
SIGNATURE: [signature]	SIGNATURE: [signature]
DATE: August 28, 2018	DATE: August 28, 2018

LIST OF ARTIFACTS

PRINCIPAL INVESTIGATOR: Helen R Haines
PROJECT: Ka'kabish Archaeological Research Project
PERMIT TO EXCAVATE NUMBER: IA/H/2/1/18(21)
ACCESSION NUMBER: 10429
DATE: 23 July 2018

INSTITUTE OF ARCHAEOLOGY BELMOPAN BELIZE C.A.

Box No.	Material (Pottery, jade, shell, obsidian, soil, bone, granite, stucco etc.)	Quantity (In number of pieces or in grams)	Provenance (Structure, burial, cache, operation, cave, lot etc.)	Description (Fragment, whole, painted, worked, form etc.)	Approved/Denied IA Use Only
The following FAUNAL material are all in individual bags in separate Zip Lock Bags in larger Zip Lock bags -- to be sealed as per Canadian Customs Requirements					
Bag 1	Faunal	20	Lot 652	Shell beads	Approved
Bag 1	Faunal	16	Lot 650	Shell beads	Approved
Bag 1	Faunal	1	Lot 558	Shell beads	Approved
Bag 1	Faunal	6	Lot 598	Shell beads	Approved
Bag 1	Faunal	45	Lot 605	Shell beads	Approved
Bag 1	Faunal	1	Lot 457/458 – B2/2	Bone ear spools	Approved
Bag 1	Faunal	11	Lot 798	Incl. Bone ear spools	Approved
Bag 20	Faunal	9	Lot 555	Fragments	Approved
Bag 20	Faunal	257	Lot 556	Incl – 1Shell bead	Approved
Bag 20	Faunal	197	Lot 558	Incl – 1 shell bead	Approved
Bag 20	Faunal	96	Lot 590	Fragments	Approved
Bag 20	Faunal	75	Lot 598	Incl. 6 beads & 1 partial bone ear spool	Approved
Bag 20	Faunal	125	Lot 605	Bone fragments	Approved
Bag 20	Faunal	45	Lot 639	Fragments	Approved
Bag 20	Faunal	25	Lot 650	Bone fragments	Approved
Bag 21	Faunal	262	Lot 652	Fragments	Approved
Bag 21	Faunal	47	Lot 652	Bone – Incl. 1 disk and 1 shell bead	Approved
Bag 21	Faunal	2	Lot 670	Fragments	Approved
Bag 21	Faunal	45	Lot 671	Fragments	Approved
Bag 21	Faunal	67	Lot 672	Fragments	Approved
Bag 21	Faunal	552	Lot 694	Fragments	Approved
Bag 22	Faunal	196	Lot 703	Fragments	Approved
Bag 22	Faunal	129	Lot 721	Fragments	Approved
Bag 22	Faunal	17	Lot 727	Fragments	Approved
Bag 22	Faunal	1	Lot 796	Strombidae shell	Approved
Bag 22	Faunal	5	Lot 798	Fragments - Incl. 2 shell beads	Approved
Bag 22	Faunal	2	Lot 1003	2 shell beads	Approved
Bag 22	Faunal	3	Lot 1004	Fragments	Approved
Bag 22	Faunal	43	Lot 1006	Fragments – Incl. 1 shell bead	Approved
Bag 22	Faunal	22	Lot 1007	Fragments	Approved
Bag 22	Faunal	8	Lot 1008	Fragments	Approved
Bag 22	Faunal	21	Lot 1009	Fragments	Approved
Bag 23	Faunal	20	Lot 1083	Fragments	Approved
Bag 23	Faunal	85	Lot 1084	Fragments	Approved
Bag 23	Faunal	148	Lot 1087	Fragments	Approved

EXAMINER: Antonio Beardall	APPROVED BY: Dr. John Morris
POST: Archaeologist	POST: Director
SIGNATURE:	SIGNATURE:
DATE: August 28, 2018	DATE: August 28, 2018

PROCEDURES FOR THE HANDLING OF HUMAN REMAINS

Contact officer: Vice President, Research & International

For the purposes of this document, human remains includes the following: bodies, and parts of bodies, of once living people from the species Homo sapiens (defined as individuals who fall within the range of anatomical forms known today and in the recent past). This includes osteological material (whole or part skeletons, individual bones and teeth or fragments of bone and tooth), soft tissues (including organs, skin, muscle, tendon, nail) and embryos. It does not include slide preparations of human tissues that have been purchased from an established scientific supply company.

ACCEPTING HUMAN REMAINS

Any human remains that enter facilities owned or managed by Trent University must be acquired following the laws of the jurisdiction of their origin.

Human Remains from Canada

All human remains from Canada knowingly received by employees of Trent University must be accompanied by written documentation from the Provincial/Territorial Registrar of Cemeteries (or equivalent).

In the case of Aboriginal remains, the Registrar of Cemeteries is responsible for designating the First Nations group that has legal or moral authority to represent the individual. The Ontario Cemeteries Act gives legal authority to the Registrar to determine the relevant parties that will enter into negotiations with the Registrar for a site disposition agreement. The site disposition agreement specifies how the human remains will be managed.

Written documentation from the relevant parties as designated by the Registrar is also required before Trent University employees accept human remains.

Human Remains from Outside Canada

Any human remains that enter facilities owned or managed by Trent University must be acquired following the laws of the jurisdiction of their origin. If the remains originate from outside of Canada, they must be legally imported to Canada following rules specified in:

- Canadian Border Services Memoranda D19-9-3 (Importation and Exportation of Human Remains) and
- D19-4-1 (Export of Controlled Cultural Property / Cultural Property Export and Import Act).

The remains must be accompanied by written documentation from the relevant authorities that give permission for the remains to be transported from the jurisdiction of origin, and the

conditions under which the remains are to be stored and/or analysed and/or returned to the jurisdiction of origin.

Human Remains Donated from Medical Schools

Written documentation in the form of a donor record form must accompany human remains that are donated from medical schools, anatomy departments, or other institutions of permanent curation.

ON RECEIPT OF HUMAN REMAINS

Only permanent faculty will accept and store human remains at Trent University. When received, the following documentation must be collected:

- date of delivery to the University
- name of party relinquishing the remains
- name and signature of Trent employee receiving the remains
- the site disposition by the provincial/territorial Registrar of Cemeteries,
- written permissions by relevant groups noted in the site disposition and
- agreements on duration – either temporary loan or permanent curation (determined by the researcher and relevant authority).
- in the case of human remains from outside Canada, written documentation from the relevant authorities that give permission for the remains to be transported from the jurisdiction of origin and the conditions under which the remains are to be stored and/or analysed and/or returned to jurisdiction of origin.

All human remains delivered to the University, either on temporary loan or for permanent curation will be given temporary (former) or permanent (latter) accession numbers to facilitate tracking and inventory. These numbers will be marked on the boxes and bags containing the remains, and will be recorded in the log.

For all human remains temporarily curated in the University, the duration of the loan must be predetermined (by the researcher and relevant authority) and documented in writing. In the event that additional time is required to complete the scientific study of the remains, written permission must be secured from the relevant authority.

STORAGE AND AUTHORISED ACCESS

Trent University employees will store all human remains that are permanently in its custody, in inert, archival quality boxes, (eg, coroplast boxes developed for human remains).The only exception to this would be a special request, by an associated First Nation group, for an alternative material (e.g., wood).

All human remains will be kept in secured storage facilities that differ depending on the nature of the material.

- Osteological teaching collections are currently stored in the osteology teaching lab (DNA C231).
- Research collections are currently stored in secured storage (DNA C145.1).
- Curated First Nations material is currently stored in a secured cabinet in DNA C145.1.
- Samples in labs or under control of individual researchers are currently stored in their respective secured laboratories.

Access is limited to course instructors/teaching assistants (e.g., DNA C231), department technician (DNA C145.1) or individual researchers and their lab members; unauthorized persons will not be able to access human remains.

TRAINING

All individuals working with human remains will be required to undergo training in human remains protocol, safety, and security procedures. This training will be provided by their supervisor/course instructor/the department technician. The training will include a one day session/workshop that all teaching assistants, graduate students and research technicians will be required to attend. Additionally, all undergraduate students working with the osteological teaching collection will be given an orientation session prior to the commencement of laboratory exercises. Written guidelines (draft provided by departmental technician) will be provided to all individuals working with human remains, and they will be required to sign a statement of understanding.

Note: guidelines/training to be written by Anthropology with input from Indigenous Studies

APPROVED USES OF HUMAN REMAINS

All human remains curated by the University will be used for scientific study only with the written permission of the designated authority (as outlined in paragraph 2). The permission will also articulate how the research is to be shared, communicated and/or archived. Copies of this agreement and relevant documents will be retained by the department technician.

With the exception of human remains donated/purchased from medical schools, anatomy departments, or medical supply companies, no osteological human remains will be used for teaching unless explicit permission is provided by affiliated groups. Any exhibition of human tissues will consider the cultural sensitivities of the affiliated groups.

In the event that permission is granted by affiliated groups (as determined by the Registrar) to take samples of bone, tooth and/or soft tissue for later study (e.g. radiocarbon dating, histological examination, chemical analysis, DNA analysis), the established protocol (see Buikstra and Ubelaker 1994)1 for removing and storing such samples will be followed.

Trent University will honour reasonable requests for handling, storage or ceremony that are made by affiliated groups while the remains are in our care.

Field Protocol

The recovery of buried human remains is a task that requires understanding of archaeological excavation procedures, human skeletal anatomy and cultural protocol. Experienced and appropriately-trained personnel must be present to supervise the excavation. Excavations must take place in a controlled setting to allow for the identification and recovery of information concerning the context of burial.

1 Buikstra, J. and Ubelaker, D. (1994) Standards for Data Collection from Human Skeletal Remains. Arkansas Archeological Survey Research Series No. 44.

The archaeological excavation of human remains in Ontario requires approval from the Registrar of Cemeteries, the landowner and, for aboriginal burials, also the local First Nation as decided by the Registrar of Cemeteries. Outside of Ontario, relevant local laws must be followed.

In Ontario, archaeological excavations of burial features must be directed by an archaeologist holding a professional or research license issued by the Ministry of Culture. This is a legal requirement of the Ontario Heritage Act and is not negotiable.

When Trent University personnel are recovering recent (forensic) human remains for legal authorities, the Police and/or the Coroner, or a legal representative of the Coroner must be present at all times.

Human remains and/or burial offerings from archaeological contexts in Ontario will be transported and/or stored by Trent University with all required approvals as detailed on page 1 "Human Remains from Canada". In forensic cases a written agreement between the Coroner and Trent University that specifies the conditions of storage and the final disposition of the remains is necessary.

RELATED DOCUMENTS

All protocols regarding handling, storage and research of human remains follows the Vermillion accord on Human remains, established at the 1989 World Archaeological Congress.

The Vermillion Accord on Human Remains

1. Respect for the mortal remains of the dead shall be accorded to all, irrespective of origin, race, religion, nationality, custom and tradition.

2. Respect for the wishes of the dead concerning disposition shall be accorded whenever possible, reasonable and lawful, when they are known or can be reasonably inferred.

3. Respect for the wishes of the local community and of relatives or guardians of the dead shall be accorded whenever possible, reasonable and lawful.

4. Respect for the scientific research value of skeletal, mummified and other human remains (including fossil hominids) shall be accorded when such value is demonstrated to exist.

5. Agreement on the disposition of fossil, skeletal, mummified and other remains shall be reached by negotiation on the basis of mutual respect for the legitimate concerns of communities for the proper disposition of their ancestors, as well as the legitimate concerns of science and education.

6. The express recognition that the concerns of various ethnic groups, as well as those of science are legitimate and to be respected, will permit acceptable agreements to be reached and honoured.

The Cemeteries Act -

http://www.search.e-laws.gov.on.ca/en/isysquery/6e87f781-619d-478e-8b0e-83a6af50cba7/2/doc/?search=browseStatutes&context=#hit1

Reference Cited

Buikstra, J. and Ubelaker, D. (1994) Standards for Data Collection from Human Skeletal Remains. Arkansas Archeological Survey Research Series No. 44.