Who were the people of the Fourth Cataract? Using dental non-metric traits to explore population history in the middle Nile valley from the Neolithic to Medieval period.

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Abstract

The 4th Cataract human skeletal collection, curated at the British Museum, is unique containing remains dating from the Kerma to Medieval periods, but from within a 30km region along the Nile. The geographically focused nature of this collection provides opportunities to explore biological continuity, in situ evolution, and migration. Nubia has a long and rich history with distinct shifts in cultural practices. Situated between sub-Saharan Africa to the south and Egypt/Mediterranean to the north, Nubia is often considered a corridor through the Sahara. Many archaeological excavations have taken place there in the recent years, steadily increasing the number of skeletal collections available for study. These distinctive qualities make Nubia ideal for investigating population movement and origins of the cultures that developed there.

Dental nonmetric traits, following the Arizona State University Dental Anthropology System, were used to study inter-group differences based on biodistances. Both model-free and model-bound statistical analyses were used. Data from the 4th Cataract were compared to samples from Upper and Lower Nubia to investigate both geographical and temporal patterning. Results were then contextualised further through comparisons with samples from East Africa and proximate regions in Eurasia.

Results revealed biological continuity in the 4th Cataract region from the Kerma through Medieval periods (MMD range 0.001 - 0.082). Continuity was also observed in Upper and Lower Nubia from the Neolithic onwards. Evidence for the movement of people was identified in the data, but changes were not wholesale and varied depending on region/time-period. Comparisons with East African and Eurasian published data showed that both regions were important influences in Nubian populations. Similarities between Nubian and sub-Saharan groups appear to be clinal, with influence from this region diminishing temporally from the Neolithic onwards. Biological affinities with Egyptian/Eurasian groups revealed geographical patterning, but also appear to be related to the Egyptian invasion of Nubia. This study also found that the relationship between cultural change and population movement was complex. This research highlights the importance of using both archaeological and biological methods when investigating past population dynamics.

Declaration

I, Emma L.W. Phillips confirm that no portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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Tooth Abbreviations

Individual teeth are referred to using the below abbreviations in order of jaw, side, tooth type, then position.

Lower (mandibular)	L
Upper (maxillary)	U
Left	L
Right	R
Incisor	I
Canine	C
Premolar	P
Molar	M
Position	1,2,3

The number is used to donate the position in the dental arch from the midline to the back. For example, a Lower left lateral (2nd) incisor would be LLI2. Canines do not have a number as there is only one on each side of both dental arches.

Chapter 1 - Introduction

Understanding of ancient Nubian populations and their cultures in the middle Nile valley has been the focus of increased research in the last few decades. Through the study of occupation sites, burials, and related material culture, new insights into the complex dynamics of these people are progressively being revealed. This project investigates not only the origins of the Nubian people, but whether shifts in culture were accompanied by changes in the biological relationships between groups through time. Building and expanding upon previous studies using dental nonmetric traits in the region, this project offers new data on the origins of the people of the 4th Cataract region and how they relate to other Nubian, African, and Eurasian groups. Additionally, these data are used as a tool to explore human migration in Africa.

Nubia is situated in present-day southern Egypt and northern Sudan (also known as the Middle Nile valley), stretching from the 1st to the 6th cataract of the Nile River. Nubia is divided into two regions. Lower Nubia, the northern area, is located between the 1st and 2nd Cataracts. Upper Nubia is further south, between the 2nd and 6th Cataracts (Adams, 1977). The southern boundary of Upper Nubia has been debated, with some researchers using the 4th Cataract (Nielsen,1970; Carlson and Van Gerven, 1979). The 6th Cataract is used in this study as sites associated with Upper Nubian cultures have been found within this area (Edwards, 2004). With the re-desertification of the region at around 5000BCE (Kuper and Kröpelin, 2006), the Nile became the principal method of travel through the ever increasing harsh conditions of Northeast Africa (Fox, 1997). As this ‘long and narrow oasis’ (Säve-Söderbergh, 1979) traverses the length of Nubia, it has often been thought of as the corridor between sub-Saharan Africa and Mediterranean and Egyptian cultures (Carlson and Van Gerven, 1979). This puts Nubia in a unique position, facilitating the movement of people through the Sahara (Edwards, 2007).

Excavations in Nubia, often fuelled by rescue archaeology projects, have unearthed a wealth of material that has greatly added to the study of the regions past cultural practices, as well as new human osteological and bioarchaeological research (Binder et al., 2014; Buzon, 2006; Galland et al., 2016; Godde, 2009, 2012; Irish, 2005; Irish and Usai, 2021; Johnson and Lovell, 1995; Stynder et al., 2009). The result is that Nubia is one of the best documented regions in Africa (Edwards, 2007). Due to this increase in information, there has been much discussion as to the origins of different ancient Nubian populations, and the cultural shifts visible in the archaeological record. In the past, theories had been purely based on material culture but more recent research has looked at how biological methods can help better understand the variation observed in past Nubian populations.

Developments in cultural behaviour are often complex and can be multi-factorial. Early researchers believed that migration or invasion from outside populations was solely responsible for the development of Nubian cultures (Smith and Jones, 1910; Reisner, 1910). Although this view is outdated, more recent scholars have suggested that migration may have instigated cultural change at some points in Nubian history (Bietak,1987; Buzon and Simonetti, 2013; Edwards, 2019; Emery, 1965; Kendall, 1999). As well as cultural change, migration can affect the biological make-up of the indigenous population. Admixture (when two groups interbreed) can occur when a new group moves into an already populated area. Additionally, a new group may replace an existing population.

Shifts in socio-cultural behaviour can occur without the movement of people. Adams (1968; 1970) was the first to suggest Nubian cultures developed from the indigenous population evolving *in situ*. Since then, several studies have explored if there was biological continuity in Nubia over time. Continuity denotes a stable population, one to which no substantial changes have occurred. Nubia has a rich history, with distinct shifts in cultural behaviour in the archaeological record (Edwards, 2004). In situations where migration is not the driving force, then cultural diffusion may be responsible for these shifts. Diffusion is where information /behaviour /material /beliefs are exchanged without the movement of people (Fort et al, 2015).

The 4th Cataract region had been an important area in Nubia's history, having been the location of the temples of Gebel Barkal, city of Napata, and Napatan royal cemeteries (Emberling, 2012). Due to the difficultly of access by river and land, little archaeological investigation was done until the Merowe Dam Archaeological Salvage Project (MDASP) (Ahmed, 2014). The MDASP started in 1991 and finished in 2008 (Emberling, 2012). The associated surveys and excavations produced a great amount of new data, both from settlement and burial sites. These data greatly enhanced what is known of the region, as well as Upper Nubia, and how regional peoples interacted with neighbouring cultures (Edwards, 2007). During the excavations skeletal assemblages were recovered ranging in age from the Kerma to the Medieval/Christian era (Emberling, 2012). A large proportion of them (circa 500 individuals) are curated in the British Museum. The collection was donated to the Museum by the National Corporation for Antiquities and Museums (NCAM), Sudan. This unique collection includes individuals from sites spanning 4000 years, but are from the same 30km-wide locale. Researchers believe that the 4th Cataract region was not heavily populated until the Medieval period (Wesley, 2012). A lack of suitable agricultural land, navigational issues on the Nile, and desert roads which bypassed the area may explain the sparsity in occupation (Emberling, 2012). Forming the core of this study, the 4th Cataract collection offers an opportunity to investigate biological continuity, *in situ* evolution, migration, and cultural diffusion without geographical distance being an influence.

Dental nonmetric traits, secondary morphological features of the crown and root which are not critical to the structure of the tooth, have been found to be good proxies for neutral genetic traits (i.e., those not affected by selection) (Irish et al., 2020). These traits have been used identify variation between groups on both global and regional levels (see Scott and Irish, 2017). Previous research has shown that sub-Saharan African and North African dentitions are distinct (Irish, 1998). Nubia is located between the two regions and as such is ideally placed for studying migration patterns from both north and south. Dental nonmetric studies on Nubian material have investigated relationships between groups from different areas (i.e., Upper or Lower Nubia) and from different periods, but often not together (see Irish, 2005).

This project aims to further develop these previous studies and use dental nonmetric data to investigate relationship between samples across Nubia over time. Samples from the previously unexplored 4th Cataract region will be analysed to understand how the indigenous population changed over time. Additional dental data from newly recorded (n= 16) and previously published Nubian collections (n= 10), dating from the Neolithic to Medieval period, will also be used to contextualise the data gathered from the 4th Cataract peoples. These collections originate from sites across Upper and Lower Nubia. Using a broad spectrum of comparative samples offers the chance to explore temporal and geographical patterning in biological relationships between Nubian groups. Published data from East Africa and Eurasia will also be used to understand if biological affinities among Nubians were influenced by the movement of people from the north or south. The comprehensive range of samples will help to also understand the Nubian origins and how populations and cultures developed in the region. Model-free and model-bound quantitative analyses will be used to investigate the following broad research questions:

4th Cataract and Nubia (Neolithic – Medieval)

- Was there population continuity in the 4th Cataract region between the Kerma and Medieval periods?
- Are biological changes in the population correlated with diachronic changes in social and cultural practices, via architecture, funerary rights, and other archaeological evidence?
- What is the relationship with other ancient Nubian populations? Is temporal or geographical patterning evident?

Human Migration

- Are Nubians indigenous to the region? Do these data indicate immigration and replacement from the north and/or south? Alternatively, do the assemblages infer a mixture of genetic information?

- Can model-bound quantitative analyses be used to further explain any evidence of migration in Nubia and Africa from the Neolithic period onwards?
- How can the theoretical and methodological approaches of this study be used by other researchers to illuminate population history in other world regions and periods?

To contextualise the cultural patterning in Nubia, Chapter 2 provides an archaeological background, from the Neolithic (c. 5000-2500 BC) to Medieval (c. AD 540-1500). This chapter focuses on cultural changes, continuities, and regional variations. Previous theories regarding the peopling of Nubia are also discussed. Chapter 3, provides information on dental nonmetric traits, bio-distance studies, and previous research in the middle Nile valley. The chapter focuses on dental nonmetric studies, but also covers other physical and molecular studies. To quantify whether the above research questions have been addressed, several testable hypotheses will be proposed in Chapter 4. These hypotheses are based on the cultural changes/continuities highlighted in Chapter 2, which build on the research outlined in Chapter 3. Chapter 5 presents the materials and methods used. Each skeletal collection is described and details about the burials listed. Methods concerning the recording of dental nonmetric traits are discussed, as are intra- and inter-observer error tests; statistical methodologies will also be outlined. Chapter 6 describes the results from 4th Cataract, Nubia, and the wider results from East Africa and Eurasia. Chapter 7 discusses and evaluates the previous results. Chapter 8 provides concluding remarks on the study, revisiting the broader research questions listed above. This final chapter also includes ideas for future research.

Chapter 2 - Archaeological background

This chapter identifies the shifts in cultural behaviour that are used to contextualise the findings from the biodistance study and help develop the hypotheses outlined in Chapter 4. The study of Nubian archaeological has revealed a rich material culture and history. This history has been divided into distinct time periods, based on changes to cultural practices viewed through the archaeological record. Although the term Nubia is used to describe a large part of the middle Nile Valley, there are regional differences in the customs observed, environment, and people that inhabited these regions. Below is an overview of the periods in Nubian history covered by this thesis, from the Neolithic to the Medieval period. Each section below will provide an archaeological review of the relevant time period in Nubian history. The origins of the cultures discussed in each section will be outlined, leading on to an overview of each period. In each, regional differences will be noted, where relevant. Only archaeological research/theories will be presented in this chapter; a review of the biological research from each region studied is provided in Chapter 3.

2.1 Neolithic (c.6000-4000 BCE) – the beginning of complex societies

2.1.1 Origins

Many theories concerning population continuity/discontinuity between the Palaeolithic and Neolithic populations in Nubia have been proffered (further details in Chapter 3). Although the picture is far from clear, there is evidence of cultural continuity throughout Nubia (Sadig, 2013), and, to some extent, biological continuity at least in Upper Nubia (Irish, 2021). This continuity is partnered with innovations in food production from the Near East. The introduction of domesticated cattle and ovicaprids (Linseele, 2013), and later cereals (Welmoed et al., 2016) triggering a shift from a hunter-fisher-gatherer society to one of food production (Salvatori and Usai, 2019). Although these interactions with the Near East would have been facilitated by the movement of people between these regions (Bar-Yosef, 1998), biodistance studies have not identified a significant migration of agriculturalists into the Nile Valley (Irish, 2021). How the Neolithic culture was transmitted throughout Nubia is unclear. Salvatori and Usai (2016) suggest that waves of people started to move down the Nile (c. 5500 BCE) from the Dongola Reach, potentially due to climate change, bringing with them the new Neolithic package. Although, there are no signs that existing populations in the southern regions of Nubia resisted (i.e. inter-personal violence) the immigration of new groups from the north (Salvatori and Usai, 2016).

2.1.2 Overview

The Neolithic culture horizon can be found in sites in the northern part of Nubia circa 6000 BCE, extending to the area around Khartoum by 5000 BCE (Salvatori and Usai, 2019; Honegger, 2004; Sadig, 2010). The Neolithic period saw the re-aridification of the Egyptian Sahara. The increased dry conditions to the north meant that human settlements migrated to the banks of the Nile and down into the Sudanese plains (Kuper and Kröpelin, 2006; Honegger, 2019). This move to the more southernly areas of Nubia can be seen in the archaeological record, where many more Neolithic sites can be found in Upper Nubia when compared to Lower Nubia (Edwards, 2004). Unlike other regions, the Neolithic in Nubia and sub-Saharan Africa saw a move from a more sedentary existence to that of nomadic pastoralism (Haaland, 2012) or semi-nomadic agropastoralism (Salvatori and Usai, 2019). This more mobile way of life is mirrored in the settlement patterns.

Archaeological data suggests settlement sites were not permanent, being used only for part of the year (Honegger, 2019). The transition to food producer from that of hunter-fisher-gather was initiated by the introduction and domestication of livestock (bovines and ovicaprids) from the Near East in the early part of the 6th Millennium BCE (Honegger, 2019; Linseele, 2013). Cereal production came later to the Nubians, with the earliest example dating to c. 5311–5066 BCE (Welmoed et al., 2016). It is also clear that Neolithic groups still relied on readily available wild grains, especially in the early Neolithic (Krzyżaniak, 1991).

Burial traditions in Nubia changed during the Neolithic period. In the Palaeolithic cemeteries, individuals are rarely found with grave goods. In contrast, during the Neolithic period individuals are often buried with ceramics, tools, personal adornments, bucrania, and vegetal pillows (Honegger, 2019; Usai, 2016). Numerous Neolithic cemeteries have been excavated in Nubia to date, including but not limited to: El Kadada (Geus, 1984), El Ghaba (Lecointe, 1987), Kadruka (Reinold, 1994), Kadero (Krzyzaniak, 1996), R12 (Salvatori and Usai, 2004), and Al Khiday (Salvatori et al., 2018). All the aforementioned cemeteries are similar in character, with large burial mounds containing richly furnished inhumations. Burials from the Early Neolithic period do not have a standard alignment, with graves from the later part of the Neolithic usually aligned East-West (Honegger, 2019). Social status is also visible in burials for the first time, with some more richly furnished than others (Sadig, 2010)

Although there was a general homogeneity in burial customs throughout Nubia, some regional differences have also been observed most notably in associated grave goods (Usai, 2016). Additionally, in El Multaga, between the 3rd and 4th Cataract, an alternative Neolithic burial custom was observed (Peressinotto et al., 2004). Individuals were buried in a contracted position, in small pits covered by low mounds. Burials were not part of a large complex, but found in isolation (Osypiński, 2014). Moreover, burials at El Multaga had fewer grave goods than at other contemporary cemeteries. Ceramics associated with other Nile valley Neolithic cultures were found in the graves. This alternative burial style is thought to represent a nomadic group local to that region (Peressinotto et al., 2004). The variation in burial practice observed in El Multaga has been proffered as reason why so few Neolithic burial sites were discovered in the 4th Cataract region. If the Neolithic inhabitants of this region were part of the same culture as El Mutaga, then the small superstructures could easily have been lost by wind erosion, leaving burials undetectable (Osypiński, 2014).

A cultural revolution was also taking place (Sadig, 2010). The introduction of more refined lithic tools, pottery techniques develop, and items used for personal adornment can be seen in the archaeological record. Cattle became a vital part of the Nubian culture, featuring in cave drawings and also in burial practices (Wengrow et al, 2014). Human figurines also suggest that tattoos and pigments (ochre and malachite) may have been used for personal adornment (Nordstrøm and Haland, 1972). In Neolithic Nubia, there is a level of cultural homogeny, especially in the early stages of this period (Sadig, 2010). This cultural ‘package’ is thought to have been dispersed by a network of trade and inter-regional marriage (Salvatori and Usai, 2016). Increasing aridity, during the later phases of the Neolithic, meant that barriers in the landscape appeared, with some inhabitable areas becoming less accessible. This changing environment is thought to have led to a greater sense of regionality in the later stages of the Neolithic period (Edwards, 2004).

As the Neolithic ended c. 4000 BCE, Egypt began to diverge from the rest of the region, and we can see the emergence of predynastic cultures (Bard, 1994). This period of prosperity in Egypt is seemingly in contrast to that of Nubia, where a hiatus in settlement is observed (Sadig, 2010). Although the reason for the hiatus is not known, it may be linked to an increase in aridity. The change in the environment may have caused the inhabitants to move south to more habitable regions (Honegger, 2019), or return to a more nomadic lifestyle (Edwards, 2004). It is not until c. 3800 BCE that human settlement in Nubia is once more apparent in the archaeological record (Salvatori and Usai, 2007; Gatto, 2019; Honegger, 2019). In Lower Nubia, an agropastoral culture known as the 'A-Group' has been identified as occupying the area from c. 3800 BCE. In the Dongola Reach, Upper Nubia, another agropastoral group is present, the pre-Kerma culture (first observed in archaeological record c. 3500 BCE). Similarities between the two groups have been noted (Honegger, 2020). In the southern reaches of Nubia, burial complexes dated to the late Neolithic have been recorded (e.g., Kadada (Reinold 2007) and El Geili (Caneva 1988)). Apart from these later Neolithic sites, no others are found in this area until the Meroitic period (Usai, 2016).

2.2. Bronze Age – the rise of Kerma

2.2.1 Origins

The pre-Kerma culture preceded the establishment of the Kerma civilisation in Upper Nubia. Pre-Kerma was an agropastoral society dated to c. 3400 – 2500 BCE.

Although a distinct culture, pre-Kerma is believed to be the progenitor of Kerma people. Material culture relating to this group has been observed from Elephantine to the 4th Cataract area of the Nile (Honegger, 2019). It is not clear whether this activity involved movement of people from the Kerma area or if it was just the result of cultural exchange. The Kerma culture developed in the same area of the Nile valley c. 2500BCE, with a city at Kerma at its centre. Various other groups also inhabited the Nile Valley and its hinterlands during this period, including the: C-Group culture, Pan-Grave culture and Kingdom of Egypt. Archaeological data suggests that these groups interacted with the Kerma culture (Raue, 2019). Whether these political/cultural interactions also included genetic mixing of populations is still unclear.

The origins of the C-Group are more widely debated. For many years scholars believed that there was a hiatus in Lower Nubia between the decline of the A-group and the emergence of the C-Group. It is now more widely thought that the A-Group returned to a more nomadic way of life due to adverse climatic conditions (Gatto, 2020). This has led to people suggesting that the C-Group is a continuation of the A-group (Raeue, 2019). Bietak (1987) suggested that the C-group's origins can be found in the south/southwest of Sudan (Kordofur, Dafur and Wadi Howar). Another theory is that the early C-group developed from parts of the A-Group, desert-based groups (moving to the Nile Valley), and Kerma culture (Hafsaas, 2020).

2.2.2 - Overview

The Bronze Age in Nubia is most linked to the rise of the Kerma culture (c. 2500 BCE – 1500 BCE). This was a period of change and innovation, and saw the rise of the first sub-Saharan kingdom, known as Kush. This culture was based around the political and religious hub of Kerma, in the Dongola Reach of Upper Nubia near the 3rd Cataract (Adams, 1970). At its zenith, the Kerma culture controlled around 700km of the Nile Valley (Honegger, 2019). The kingdom and culture spread standardised pottery, structures, and burial practices throughout the Nile Valley (Bonnet, 2019). Pottery was produced in large quantities and was of a high quality (David and Salvatori, 2018). The classic Kerma style was tulipform, highly polished and red in colour (Privati, 1999). This pottery technique has thought to have been used to mimic metal and has some similarities to ceramics from sub-Saharan Africa (Edwards, 2004). Typical burial practices for the period involved a contracted body, head to east, facing north, that was often placed on cow hide. (Honegger, 2019). Although there was a high level of cultural homogeneity throughout the Kerma controlled area, there were still regional variants (Paner, 2003).

The Kerma period is split into three main phases: Kerma Ancien (c. 2500-2050BCE), Kerma Moyen (c. 2050-1750BCE), and Kerma Classique (c.1750-1500BCE) (Edwards, 2004). During the early stage of the Kerma Ancien period there is more variety in grave goods than in later periods (Paner, 2003). This also coincides with the introduction of Tumuli in Nubia. At the beginning of the Kerma Ancien period, some homogeneity can be observed in burials and grave goods. As the period progresses, the first signs of social stratification become evident in the burial record (Honegger, 2019). Similarities in the material culture between Kerma Ancien material and that of the early C-Group from Lower Nubia have been noted (Edwards, 2004). Additionally, iconography observed in predynastic Egypt, where some women are associated with sticks and men with archery, is also apparent in Kerma

Ancien (Honegger, 2019). Kerma Moyen burials are also bigger than those from the preceding period. Graves are often focused around one main grave, with surface offerings becoming part of the burial rite. This may be part of the emergence of ancestor cults (Bonnet, 1992). During this period, Egypt invaded and occupied Lower Nubia (Török, 2008). The Kerma Classique period saw the Kerma culture move into Lower Nubia after the Egyptians retreated, with some possible skirmishes into Egypt proper (Edwards, 2004). Burials during this period became even more elaborate (Bonnet, 1992). This was also the period when the urban settlement at Kerma itself was at its largest, and most complex, and fortified (Bonnet, 2021). The Kerma period comes to an end with the Egyptian invasion of Nubia and the fall of the city of Kerma.

Concurrent to the Kerma culture in Upper Nubia, the C-Group occupied Lower Nubia during the Bronze Age. Although the C-Group is a distinct culture to that of Kerma, it is thought that their origins could be similar, with suggestions that the C-Group migrated to the area from the south (Williams, 2014). During the early Kerma period there are many similarities between the two cultures, especially in ceramics and burial style. By the Kerma Moyen period, the two groups had diverged particularly in their material culture (Edwards, 2007). Egypt invaded Lower Nubia during the Middle Kingdom period (Knoblauch and Raue, 2019), occuping the region for around 200 years. During this time Egypt built fortifications throughout Lower Nubia, to facilitate the trade of exotic goods from Upper Nubia and exploit local natural resources (Hafsaas, 2021). C-Group groups were also known to have immigrated to Egypt during the Middle Kingdom. Cemeteries containing C-Group, Pan-Grave and Egyptian burials have been found at Egyptians sites such as Hierakonpolis

(Friedman, 2007; Irish and Friedman, 2010) and Wadi Kubbaniya (Hafsaas, 2021). It is thought that C- and Pan-Grave groups moved to Egypt as mercenaries (Darnell, 2004). Lower Nubia was later invaded by Kerma, with the incursions from both groups (Egyptian and Kerma) have influencing C-Group culture as observed in sites and artefacts (Johnson and Lovell, 1995). C-Group ceramics are often found in Kerma burials and settlements, revealing the link between the two cultures.

The Pan-Grave culture was also present in Lower Nubia (and Upper Egypt) during this period (Edwards, 2004). It is thought to have its origins in the Eastern Desert, potentially related to nomadic groups from that region (Bietak, 1986). Some scholars believe that a group called the Medjay, listed in Egyptian texts, are the same as the Pan-Grave people (Liszka, 2011). It is thought that the latter moved to occupy parts of the riverine areas from c. 1725 BCE (Hafsaas, 2021). Pan-Grave burials are normally found within or close to C-Group cemeteries, forming a distinct group (Emberling et al., 2014). Although Pan-Grave material is not often found in the Kerma region, ceramics from this culture have been found in graves from the 4th Cataract area. The Pan-Grave ceramics have been observed in multiple graves not in distinct groups of graves. The ceramics are often part of an assemblage also containing pottery associated with Kerma, C-group and Egyptian cultures. The inclusion of Pan-Grave material in the 4th Cataract graves in this manner has indicated a cultural affinity to these nomadic groups (Emberling et al., 2014).

2.3 New Kingdom / post-New Kingdom – Egyptian occupation

2.3.1 Origins

During the New Kingdom period the Egyptians invaded Nubia (c. 1500 BCE) and created settlements along the Nile up to the 3rd Cataract (Spencer, 2019). Cultural and biological evidence suggests that people from Egypt immigrated to Nubia throughout the period of occupation (Buzon and Simonetti, 2013). There is also strong evidence that indigenous people were still living in Nubia, both in Egyptian towns as well as the hinterlands surrounding these settlements (Schrader et al., 2019). To what extent the two cultures interacted is still widely debated.

What happened during the post-New Kingdom period after the official withdrawal of Egypt from Nubia is unclear. Some believe that the power vacuum was filled by Nubian rulers (those still active south of the 3rd Cataract) (Morkot, 2000, 1994). It is also unclear to what extent the population changed in the post-New Kingdom period. Whether or not all Egyptians, Egyptianised Nubians or individuals of mixed heritage left Nubia has been questioned (Buzon et al., 2016). Some revivals of indigenous Nubian customs during this time have suggested a return of people with Nubian heritage from the unoccupied regions (Smith, 1995).

2.3.2 Overview

At the start of the New Kingdom (c. 1550 BCE) the Egyptians once more looked to extend their southern border into Nubia, having previously invaded Lower Nubia during the Middle Kingdom (Spencer, 2019). The Egyptians pushed on into Upper Nubia, with the aim of breaking the stronghold of Kerma, which was achieved in the reign of Thutmoses III (c. 1479–26 BCE) (Morkot, 2013). The indigenous Nubian population did not submit willingly to Egyptian rule and rebellions continued to take place 200 years after occupation began (Edwards, 2004). Nubia was split into two regions, Wawat (Lower Nubia, capital Aniba) and Kush (2nd-3rd Cataract, capital Soleb then followed by Amara West (c.1300BCE)) (Spencer, 2014).

In Lower Nubia, Egyptians re-established forts built during the Middle Kingdom occupation. In Upper Nubia, fortified temple towns were constructed along the Nile between the 2nd and 3rd Cataracts (Spencer, 2019). These towns include Sai, founded in the early-mid New Kingdom (Budka, 2017), Tombos, founded in the reign of Thutmoses III (Smith and Buzon, 2018), Soleb and Sedeinga, founded in the reign of Amenhotep III, Sesebi, in reign of Akhenaten (Morkot, 2001), and Amara West during the reign of Seti I, several centuries later (Spencer, 2014). Large cemeteries containing burials ranging from elite pyramid tombs to simple chamber tombs are associated with the temple towns (Lemos and Budka, 2021). These towns were centres for administration and controlled the movement of goods along the Nile. It is thought that one of the driving forces for the invasion of Nubia was to gain control of certain industries, most importantly gold production (Spencer, 2014). It is thought that these temple towns were inhabited by Egyptian immigrants (soldiers and administrators), Nubians, and others, as well as people relocated from existing Nubian New Kingdom settlements (Spencer, 2014). Others have suggested that prisoners of war from the Near East were sent to Nubia during this period (Davies, 2014). Although the Egyptians left boundary marker stelae at Kurgus (Welsby, 2004) by the 5th Cataract of the Nile, it is unclear if there was an Egyptian presence beyond the 3rd Cataract. Morkot (2001) suggests that the area below the 3rd Cataract was controlled by Nubian rulers, who paid tribute to Egypt and where Nubian practices prevailed with no Egyptian infrastructure. No New Kingdom settlements have been found between Kawa, in the Dongola Reach and Jebel Barkal, at the 4th Cataract (Spencer, 2019).

Questions have also been raised regarding to what extent the indigenous population assimilated into the Egyptian culture. Previously it was thought that a process of Egyptianisation took place, with the indigenous Nubian culture fading during colonial rule and Nubians fully adopting the Egyptian culture thereafter (e.g., Reisner, 1918; Emery, 1965; Trigger, 1976; Kemp, 1978; Leclant, 1978; Smith, 1998; Redford, 2004; Morris, 2005). Although there is evidence that Egyptians tried to incorporate the Nubian elite into their culture it is unclear to what extent, non-elite indigenes took on Egyptian culture (Morkot, 2001; Van Pelt, 2013). Egyptian temples were built throughout Nubia and the cult of Amun was refocused around Gebel Barkal in Upper Nubia, to convert the locals to Egyptian belief structure (Morkot, 2013). Egyptian objects has been found in many non-elite graves throughout Nubia. Recent research has suggested that inclusions of this kind should be viewed with caution and may simply be indicative of availability of goods rather than a shift in ideology (Van Pelt, 2013). There is also evidence of indigenous Nubian culture enduring in the New Kingdom. Nubian pottery was still used throughout the period (Binder, 2017; D’Ercole et al., 2017). Depictions of Nubians show that indigenous fashions were upheld in both elite and non-elite groups (Van Pelt, 2013). The funerary record shows there are some examples where the indigenous burial form persisted into the New Kingdom (Adams, 1977; Williams, 1983).

The post-New Kingdom period in Nubia (9th and 8th century BCE) has previously been considered an archaeological 'dark age,' with a perceived hiatus between the collapse of Egyptian control and the rise of the Napatan state (Morkot, 1994). Signs of depopulation were observed in Lower Nubia but this movement of people appears to have been linked to climatic and economic causes (Morkot, 1994). In Upper Nubia, the archaeological evidence tells a different story. Continued use of cemeteries across Upper Nubia indicate that groups were still living in the area. Examples of these burials include: Aniba (Naser, 2017) Amara West (Binder, 2017), Sai (Thill, 2007), Tombos (Smith, 2007), Sanam (Lohwasser, 2010), and Hillat el Arab (Vincentelli, 2006). Isotopic evidence from Tombos suggests that immigration ceased during this period (Buzon et al., 2016). Additionally, no signs of reconstruction to New Kingdom towns can be observed in the archaeological record in the post-New Kingdom era, indicating that these towns were abandoned or continued to be used without modification (Buzon et al., 2016). Post-New Kingdom burials retain Egyptian features but reintroduced more traditionally Nubian customs. Flexed body position, tumuli and funerary beds became more popular (Binder, 2011). This reintroduction of Nubian elements has been compared to patterning in the later phases of Egyptian controlled sites in Lower Nubia during the Middle Kingdom (Smith, 1995).

2.4 Napatan – Nubian revival, Pharaohs of Egypt

2.4.1 Origins

The origins of the Napatan culture are unknown. Historically an external catalyst has been suggested, with both Egypt (particularly Thebes) (Emery, 1965; Kendall, 1999) and Libya (Reisner, 1921) being proffered as the source of this influence. More recently scholars have looked within Nubia for Napatan origins. Some have suggested that the Napatan kingdom arose from of the remnants of the Kerma culture, with Nubian elites taking control after the Egyptians retreated. These elites are thought to have been living south of the 3rd Cataract during the New Kingdom (Edwards, 1998; Buzon et al., 2016). Morkot (1994, 2000) proposes the Napatan culture is a successor of the New Kingdom era, heavily influenced by the cultural mixt of Kerma and Egyptian beliefs and ways of life.

2.4.2 Overview

The 8th century BCE saw the resurgence of a powerful kingdom in the Dongola Reach. At its peak it covered a vast area, extending from Aswan in Egypt to below Khartoum in central Sudan (Edwards, 2004). This period is often split into two main phases, Napatan (c. 800 - 300 BCE) and Meroitic (300 BCE – 350 CE), which are defined by the relocation of the royal cemeteries. Initially the main political and religious activity was centred on the Napata region. The three main royal cemeteries were located at el-Kurru, Nuri and Jebel Barkal, with major settlements associated with them (Schrader et al, 2014). Jebel Barkal had been an important religious centre in the New Kingdom and was associated with the cult of Amun (Adams, 1984). This cult was continued under the Napatan rulers, with palaces and temples constructed in the area (Morkot, 2000). There is evidence of significant trade relationships with various groups including Egyptians, Assyrians, and Greeks (Edwards, 2004)

By the mid-8th century, the Napatan state gained sufficient power to invade and conquer parts of Egypt. The Nubian rulers of Egypt styled themselves as Pharaohs, establishing the XXVth Dynasty. The first Napatan Pharaoh (Piankhi) referred to himself (and to the Napatan) as saviours of Egyptian civilisation (Morkot, 2000). Whilst in power, the Napatan Pharaohs embraced both Nubian and Egyptian art and cultural practices. New cultural forms were also created that were based on elements from both cultures (Smith 1998, 2013; Torok 1995, 2009; Buzon et al., 2016).

The merging of the two cultures helped develop settlements in Nubia, with Egyptian officials and artisans moved to Napata to help develop the city (Adams, 1964). Some New Kingdom settlements remained in use throughout the Napatan period including: Sai, Soleb, Kawa, and Qasr Ibrim (Welsby, 2019). New settlements were also created at Tare (Török, 1997), Krtn, Soniyat (Żurawski, 2005), with the farthest south being at Meroe (Welsby, 2019). In Lower Nubia, only a few settlements have been located at Qasr Ibrim (Rose, 2011) and Buhen (Haycock, 1972). Some have suggested that Lower Nubia was depopulated during this period, becoming a buffer zone between the Napatan empire and Egypt (Adams, 1977). It is thought that desert roads, lined with outposts, helped connect the vast empire (Auenmüller, 2019).

Only a few non-Royal Napatan cemeteries have been excavated, with most of the information on mortuary practices comes from highly elite settings. Mortuary practices at the royal cemeteries (listed above) changed throughout the Napatan period (Lacovara, 2018). In the early phases indigenous Nubian practices prevailed including flexed body position, tumuli superstructures, a north-west to south-east body orientation, and the use of funerary beds. As time went on, more Egyptian elements were added, with individuals buried in coffins in an extended position, and orientated east-west. Mummification was adopted for the Kings of the 25th Dynasty (Lohwasser and Kendall, 2019). Large pyramids were also used as superstructures for royal tombs (Lacovara, 2018). These pyramids were similar to ones constructed during the Nubian New Kingdom, rather than the royal pyramids in Egypt (Lohwasser and Kendall, 2019). Elaborate horse burials also occurred at el-Kurru (Chaix, 2006).

Non-royal tombs reveal regional differences, often dependent on the geology of the area. Some were cut out of rock, others were dug into the ground and brick lined (Lohwasser and Kendall, 2019). Social stratification was apparent within cemeteries, evidenced by the grave goods present. In several cemeteries groups of individuals had been buried in a traditionally Nubian manner (flexed position, on beds), whereas others were in an Egyptian style (extended, in coffins) (Lohwasser and Kendall, 2019). Dome burials, a practice unique to the 4th Cataract region, have been dated to the Napatan period. These graves are circular and covered with tightly fitting stones creating a dome (Paner and Borcowski, 2007). Individuals were either lain in natural niches or more often directly on the ground and covered by a large flat stone rather than sand/gravel/earth. The earliest dated Dome Grave is from the late Kerma/New Kingdom, but by the Napatan period it was the dominant burial form in the area. Dome Graves from the 4th Cataract share similarities with burials on the Arabian Peninsula in 3rd-2nd millennia BCE (Paner and Borcowski, 2007)

2.5 Meroitic – Southern expansion into a Sudanic State

2.5.1 Origins

Around 300 BCE, the royal burials and state capital were moved from Napata to Meroe (Adams 1977; Grzymski 2004; Török 1997) situated between the 5th and 6th Cataracts of the Nile. Why the royal presence moved south is unknown, although a change in focus of trade from Egypt and the eastern Mediterranean to the Red Sea and Indian Ocean has been proposed (Haaland, 2014). The former kingdom expanded into an empire during this period, covering vast swaths of the Middle Nile Valley (from the 1st Cataract to the confluence of the White and Blue Niles) (Welsby, 2005), as well large parts of the hinterland to the east and west of Meroe (Wolf, 2019). This extensive territory encompassed many different cultural and ecological regions. It is thought that existing populations in these areas may have been culturally and, potentially, biologically distinct (Edwards, 1998). As such, Meroitic populations may have varied considerably from region to region, also from elite to non-elite.

2.5.2 Overview

The Meroitic period saw major cultural advancements. The first official written language was established, which was unique to sub-Saharan Africa at this point (Rilly and De Voogt, 2012). There also seemed to have been an introduction of indigenous cults into the official religion, like the addition of the god Apedemak (thought to be of Kushite origin) (Zabkar, 1975; Haaland, 2014). Technological advances were made in ceramics, textiles, iron work and building techniques (Leclant, 1981; Ting and Humphris, 2017). There is evidence for centralised production of pottery, iron, religious materials, and potentially buildings (Edwards, 1998, 2014). Evidence from imported goods and historical sources indicate the Meroitic empire was a part of a vast trade network, which connected it to not only the Mediterranean world as well as the Red Sea ports and as far afield as India (Abdu and Gordon, 2004; Adams, 1977; Edwards, 2004; Welsby, 1996). Trade was also extensive within Nubia, spreading along the Nile (and its tributaries) and deep into the desert (Haaland, 2014). Although there was a level of cultural homogeny throughout the Meroitic kingdom, evidence of regional variability exists in both the material culture and burial record (Edwards, 1998)

Three cemeteries are associated with Meroe (Begrawiya North, Begrawiya West, and Begrawiya South), which surround the Royal pyramids. The earliest royal Meroitic burials were similar to those from the Napatan era, but later burials diverged in character. Meroitic kings were no longer mummified, and were instead interred in a coffin placed on a bed. Ba statues are commonly found in Meroitic elite burials throughout Nubia. Additionally, milk was used as a libation instead of water (Helmbold-Doyé, 2019). Elite graves are also marked by pyramids in the Meroitic period, whereas this was restricted to royals only in the Napatan era. However, non-royal pyramids were mainly made out of mud-brick rather than stone (Francigny, 2012). Bodies were predominately extended and oriented East-West (Dunham, 1957; Dunham, 1963).

Between the 1st and 3rd cataracts of the Nile, non-elite individuals were interred in simple chamber tombs, often with no visible superstructure (Francigny, 2012). Further south, up-steam along the Nile, tumuli are associated with non-elite Meroitic burials (Edwards, 1998; Wolf and Nowotnick, 2005; Welsby, 2008). Some variability has been recorded in the substructures of non-elite cemeteries, even within the same burial complex (Wolf and Nowotnick, 2005; Francigny, 2012). This period also sees multiple individuals buried in the tomb (Welsby, 2008) or chamber, and the reuse of Napatan graves, potentially indicating a cult of ancestors (Török, 2002; Francigny, 2012). Individuals were placed in extended and flexed positions, with both body position also present in the same burial complexes. Orientation of the body also varied in this period (Edwards, 1998; Wolf and Nowotnick, 2005; Welsby, 2008).

The regionality described above is often thought to arose from the organisation of the Meroitic empire. It is now believed the empire was organised as a Sudanic state, based on a prestige-goods economy rather than subsistence-based, like that of Egypt (Haaland, 2014). Regional groups and territories were controlled using local elites. The latter would pay homage and taxes to Meroe in return for titles and privileges (Brass, 2014). Meroe controlled the trade in luxury/prestige goods. These goods were used to convey social status and to control political relations (Edwards, 1996). As such, many regional groups were not influenced by Meroitic culture and exhibited very different traditions and beliefs. While the elites who controlled different areas may have adopted standard Meroitic practices, these new beliefs/ standards may not have been imposed on non-elites, especially in rural areas (Edwards, 1998). As such, the Meroitic empire was very diverse culturally, linguistically, and biologically (Lohwasser, 2014).

2.6 Post Meroitic – Regional complexity and a shift in power

2.6.1 Origins

The reasons why the Meroitic empire fell has been a source of much debate. The rise of groups from the west or south, known as the Noba (Kirwan 1957; 1959; Williams, 1991; Török, 1988), into Nubia have been identified as catalysts for Meroe's demise (Phillipson, 2012). It is not clear if the Noba lived under Meroitic rule or just on the fringes of the empire (Welsby, 2002). There are also theories that the Axumite state, based in Ethiopia, had some part to play (Edwards, 2019) by having control over some of the beforementioned group (Leclant, 1981). It is thought that the 'Kasu' were also inhabiting the southern areas, near Meroe, and these groups were the remnants of the Meroitic empire (El-Tayeb, 2012). These theories have not been substantiated and what really caused the demise of the Meroitic culture remains to be clarified. Whoever the new rulers of political powers that developed in Nubia were, no claims of connections to the old Meroitic elite/royals were made in the post-Meroitic or Medieval period (Edwards, 2019).

In Lower Nubia, cultural continuity between the Meroitic and subsequent X-Group (also known as Ballâna) culture has been observed (Trigger, 1969), but it is not known whether that continuity was also biological (Dann, 2013). Egyptian sources also talk about cultures called the Noubades (Noba) and Blemmyes, which inhabited Lower Nubia in this period. The Blemmyes are said to have lived in the Eastern Desert, whereas the Noubades occupied the riverine areas. It is not believed that the Blemmyes were a new culture to the region (Power, 2012). The Noubades are believed to the be the progenitor culture of the Kingdom of Nobadia that emerged during the Medieval period (Welsby, 2002).

2.6.2 Overview

The Post-Meroitic period (c. 350-550 CE) is considered a transitional phase where the Meroitic culture dissipates, and new local power centres emerged creating a distinct political landscape. Meroitic ceased to be a state language, with Greek and Nile Nubian becoming the main languages at this time (Edwards, 2007). The main urban centres, including Meroe show signs of destruction and abandonment. Centralised production of wheel-made pottery and glass beads also ceased. The iron working industry, centred in Meroe, seems to have continued into the post-Meroitic period (Humphris, 2014; Humphris and Scheibner, 2017). Although trade, with at least Egypt, was still evident (especially in Lower Nubia), imported material is less abundant in more southernly sites and is non-existent near Meroe (Edwards, 2019). Fortifications were built along the Nile and in other regions of Nubia (Edwards, 2019; Obłuski, 2006).

The saqia, a waterwheel, used to aid irrigation and agriculture was introduced (Edwards, 1998). Its use meant that crops could be grown in more variable areas, with potentially two yields per year, and started an agricultural revolution (Fuller, 2014). With a new relationship with agriculture and the land, society evolved with a new importance placed on human labour. The increased need for labour may have caused higher levels of immigration, whether by choice or force, raising the heterogeneity of populations in this period (Fuller, 2014).

The burial customs also change. Tumuli replaced all other superstructures seen in the Meroitic period. The bodies were aligned north to south, with their head to the south. Multiple burials were no longer practiced (Vila, 1982; Shinnie, 1996). Bed-burials were introduced during the post-Meroitic period. Weaponry is more often found in graves (Edwards, 2019). Although a level of homogeneity can be observed in the post-Meroitic burial customs there was also variants observed on a regional and cemetery basis (Lenoble and Sharif, 1992; Edwards 1998; El-Tayeb and Kolosowska 2007; El-Tayeb, 2012). Continuity between the Meroitic and post-Meroitic has also been observed in the burial record, with some cemeteries containing burials from both periods and transitional graves (i.e., elements representative of both eras) (El-Tayeb and Kolosowska, 2007).

Extensive, often richly furnished, tumuli graves were found throughout Nubia in the post-Meroitic period, which are thought to represent the new ruling class. The most famous of these graves are in Lower Nubia at Ballana and Qustul (Emery and Kirwan, 1938). They contained high-status imported goods and personal adornments (including crowns). Animal sacrifice was common from Lower Nubia and northern regions of Upper Nubia (Edwards, 1994; Dann, 2008). In the south near Meroe, the cemetery of al-Hobaji also contained elite post-Meroitic graves. Some of these tumuli graves were over 40 metres in diameter (Lenoble 1997). Imported goods were not often present in al-Hobaji graves, but iron weaponry was predominant (Edwards, 2019).

Between the 4th and 5th Cataracts, ‘Eastern Desert Ware’ vessels are found. These ceramics are not common in neighbouring regions (e.g., the Dongola Reach) (Kolosowska, 2010). Their presence indicates cultural interaction with groups from the east (e.g., the Blemmyes). Settlement patterns in the 4th Cataract area suggest that the inhabitants were pastoralists during this period, spending part of the year herding livestock away from the river (Wolf and Nowotnick, 2005). The importance of animals to the post-Meroitic is reflected in the regional burials, which often contain animal remains (camels, cattle, sheep, and goats) (Osypinska, 2010).

2.7 Medieval - Kingdoms of Nubia and the introduction of Christianity

2.7.1 Origins

The origins of the Medieval period in Nubia (c. 550 – 1500 CE) can be found in post-Meroitic times, with many of the customs established during the earlier period continuing. The beginnings of the three main Nubian medieval kingdoms, Nobadia, Makuria and Alodia, were evident in the post-Meroitic period. The earliest and most studied is the emergence of Nobadia in Lower Nubia. High status burials at Ballana and Qustul are thought to be predecessors of the Nobadian Kings. Less is known about the beginnings of the kingdoms of Makuria and Alodia. It has been suggested that by the 6th century CE the Nubian population was quite homogenous, descending from the people of the Meroitic empire and Noba (who moved to the region in the post-Meroitic era) (Welsby, 2002).

The Medieval period is closely associated with the introduction of Christianity, which spread from the Mediterranean through Egypt and into Sudan, in the 5th century CE (Crowfoot, 1927). Although this new religion would have been spread through human contact, no mass immigration is thought to have occurred in relation to this change in ideology (Adams, 1993).

2.7.2 Overview

From the middle of the 6th century three distinct kingdoms were present in Nubia: Nobadia, Makuria, and Alodia. However, they were just a few of many smaller states in and around Sudan (Adams, 1993). Since the 6th century all three kingdoms shared a language (Old Nubian) and, after the introduction of Christianity, a religion. All three also shared the same rules for royal succession. A matrilineal system was in place throughout Nubia, where the son of the sister of the ruling monarch was the heir (Munro-Hay, 1982). There is a great disparity between the level of information on each Nubian kingdom. Most knowledge is of Nobadia, with relatively little known about Alodia (Welsby, 2002).

Nobadia was based in Lower Nubia up to the 3rd Cataract (Edwards, 2019). The material culture is distinct from that of Makuria and Alodia (also known as Alwa) (Welsby, 2002). The capital of the empire lay at Faras (Welsby, 2006). Makuria was further south, covering the area between the 3rd and 5th Cataracts, with its capital at Old Dongola (Edwards, 2019). The material culture of Makuria was very similar to that of Alodia, with ceramics associated with Alwa Ware. This has meant that the border between Alodia and Makuria is not clear from the archaeological record (Welsby, 2002). The most southerly kingdom, Alodia, with its capital at Soba, included the area upstream of the 5th Cataract (Edwards, 2019). The archaeological record has shown that urban centres in Nobadia and Makuria were complex fortified settlements comprised of high-status houses, monasteries, churches, and sites for industries such as pottery production (Drzewiecki and Ryndziewicz, 2019). The only major centre identified so far in Alodia is Soba. Although only 1% of Soba has been excavated, the buildings, finds and cemeteries point to a metropolis comparable to those in Makuria and Nobadia (Welsby, 1998).

In the early medieval phase all three kingdoms showed continuity in material culture from the post-Meroitic period. This continuity is most keenly observed in Nobadia, where settlement use and religious beliefs reveal links to the X-Group and Meroitic empire (Weeks, 1967). Additionally, Faras is located close to the high-status burials at Ballana and Qustul (Adams, 1993). Both Old Dongola and Soba were new settlements, away from previous centres of power in their respective regions (Welsby, 2002). Historical sources describe that Nobadia had a hostile relationship with its neighbour to the south, Makuria, but relatively cordial association with Alodia (Adams, 1996). At some point in the later part of the 7th century CE, Nobadia and Makuria merged, with the capital based at Old Dongola (Obłuski, 2016). During the Medieval period, the kingdoms of Makuria and Alodia may also have been joined due to marriages between the ruling families of each state (Godlewski, 2006).

Nobadia was the first kingdom to convert to Christianity, with the first church built between 569 – 575 CE (Welsby, 2002). Existing temples and religious buildings there were repurposed as churches (Godlewski, 2019). Early churches in Makuria were created from scratch, and were heavily influenced by Byzantine architecture. These early churches have been found to have varying forms and structures (Godlewski, 2019). Little is known about the religious structures at Soba (Welsby, 2002).

The transition to Christianity was not instantaneous and often restricted to the riverine areas. The state conversion of all three kingdoms was probably more linked to politics and creating alliances than beliefs of the rulers in the beginning (Welsby, 2002). As more people in both the ruling classes and the general population began to adopt Christian beliefs, Christian burials became the norm. Early non-Christian graves were very similar to those of the post-Meroitic era. A level of continuity between the early medieval and later Christian burials has been observed (Welsby, 2002). Often the same cemetery was used for both pagan and Christian graves. Additionally, transitional graves have been discovered that share similarities with both burial practices. Christian burials were very uniform and modest, with no burial goods. Individuals were placed in long narrow pits, aligned east-west. Bodies were usually in an extended, supine position, with head positioned at the western end. Bricks or stones were placed around the head for protection. Often the individuals were wrapped in blankets/shrouds. Lamp boxes were associated with graves, especially in the early Christian period (Welsby, 2002). The homogeneity of burial practice makes identifying social status almost impossible. Zurawski (1999) suggested that an individual covered in an expensive material during burial may have been a Makurian king. Christian symbolism became widespread throughout Nubia, with crosses and references to archangel Michael on pottery, tattoos, and other items (Welsby, 2002; Vandenbeusch and Antoine, 2015). Monasticism played a large part in Christian Nubian society, with monks playing a vital role in royal court and higher levels of society. To date, 13 monastic sites have been identified in Nubia (Obłuski 2019).

During this period is seems that Nubia was densely populated, and that the larger urban sites (e.g., Faras, Old Dongola, Soba, Qasr Ibrim) were used to mass produce certain items. Smaller towns and villages located nearby and along the river would have traded at these centres (Adams, 1993). Fortified settlements were also built throughout Nubia in the Medieval period, indicating that the inhabitants deemed defensive measures necessary (Żurawski, 2019). Additionally, areas like the 4th Cataract and Batn-El-Hajar, which were historically thought to be as inhospitable, saw large increases in settlements and inhabitants (Welsby, 2002). The need for defence may have been linked to climatic uncertainty in Africa and also worldwide (Graham et al, 2010). Extreme variations in the Nile water levels were recorded and severe droughts were cited in Ethiopian sources (Bell, 1970; Hassan, 2007).

Hostilities between Makuria and Arab-controlled Egypt began c. 645 CE (Welsby, 2002). After a failed invasion of Makuria, a peace treaty (known as a Baqt) was signed (c. 652 CE) between the Makurians and Arab empire. The Baqt led to peaceful co-existence between the two groups for several centuries (Spaulding, 1995). It was not until the Ayyubids took control of Egypt in the 12th century CE (Hafsaas, 2019) that peace with the Nubian kingdom of Makuria was broken, by incursions from both sides (Welsby, 2002). Tensions increased further whilst Egypt was under Mamluk rule, which was coupled with dynastic conflicts in Makuria (Edwards, 2019). By the 15th century CE, Old Dongola had fallen to Egypt. The inhabitants of Makuria were forced into ever decreasing pockets under the remnants of Christian rule (e.g., Qasr Ibrim and Gebel Adda) (Welsby, 2002). Little is known about the demise of Alodia. Evidence from Soba suggests that by the 13th century CE some of the Churches and tombs had been destroyed (Edwards, 2004). The

Christian era in Nubia was followed by establishment of new states through the region. Most famous of these the Sultanates are Funj and Darfur in the southeast of region (Edwards, 2019).

2.8 Summary

The distinct periods in Nubia history described above were identified by cultural shifts seen in the archaeological record. In addition, patterns of continuity have also been observed between different time periods. In many cases it is not clear whether these patterns of cultural continuity or shifts are associated with the movement of people to different areas or just the transmission of ideas between groups. In order to further explore the origins and movement of the inhabitants of Nubia, the next chapter will discuss biological research that has been conducted in the region.

Chapter 3 – Biodistance and previous research in Nubia

Previous biodistance research from Nubia will be discussed in this chapter, It complements the archaeological information in Chapter 2. Firstly, the concept of biodistance studies will be outlined. The review will then focus on dental nonmetric traits, examining their use, genetic background, and the heritability of traits. Previous biodistance research from Nubia will then be discussed. Finally, genetic and molecular findings from Nubia will be considered.

3.1 Biodistance studies

Biological distance, often shortened to biodistance, is a measure of the similarities or differences between groups based on morphological variation (Buikstra et al., 1990). The distance between groups is quantified using statistical methods (Hefner et al., 2016). Variations can be classified as metric or nonmetric, and are usually derived from bones or teeth. Teeth are often considered more reliable than bones (Baby et al., 2017), with the dentition regarded as less affected by environmental factors (Conceiçã oand Cardoso, 2011). Additionally, once fully developed, teeth and their morphology are little remodelled, unlike bones (Demirjian et al., 1973; Trinkaus, 1978).

The observed variations are known as phenotypes (Relethford, 2016). Phenotypes are the expression of genotypes, but the relationship between the two is not one-to-one. Phenotypes are affected by environmental and epigenetic factors (Peaston and Whitelaw, 2006), whereas genotypes are generally stable throughout life (Wojczynski and Tiwari, 2008). A great amount of research has been undertaken to understand the genetic component of the phenotypic variation studied in biodistance. It is generally thought that most metric and nonmetric traits are the result of polygenic inheritance (i.e., cumulative effects of many genes). The genes responsible for the individual traits are still unknown, but heritability values for cranial and dental metric and nonmetric traits have shown a high genetic component in their expression (e.g., Scott et al., 2018; Paul et al., 2020; Stojanowski et al., 2017; Relethford, 2002).

Genetic influence can be additive or nonadditive. Additive genetic influence is where several genes have an effect on a phenotype in an cumulative manner. Comparatively, nonadditive genetic influence refers to instances where not all genes are involved in the expression of a phenotype, e.g. genetic dominance or epistasis (Falconer and Mackay, 1981). Dental metric traits are generally associated with higher heritability estimates than nonmetric traits, potentially having a higher additive genetic component. Although it has been suggested that the disparate heritability estimates between the two categories of traits may be due to differences in measurement types (continuous vs. ordinal) and, potentially, the analytical methods utilised. This makes direct comparison complicated (see: Paul et al., 2020; Stojanowski et al., 2018). Additionally, Herrera et al., (2014) found that cranial metric traits were strongly correlated with mitochondrial DNA, whereas cranial nonmetric traits were more highly correlate to Y-chromosome DNA, adding the potential for each dataset to provide insights into a different part of the genome.

3.2 Dental Non-Metric Traits

Dental nonmetric traits concern variation observed in the secondary features of tooth crowns and roots. They often have a range of expression from absent to marked (Scott and Irish, 2017). These dental variations have been used to successfully study biological affinities in both living populations and archaeological assemblages across the world, including but not limited to Africa (Irish, 1998a; Irish, 1997; 1998b; Irish and Guatelli-Steinberg, 2003; Irish and Turner, 1990), the Americas (Aguirre et al, 2006; LeBlanc et al, 2008; Willermet et al, 2013), Asia (Kaburagi et al, 2010; Matsumura, 2006; Peiris et al, 2011; Ullinger et al, 2005), Europe (Coppa et al, 2007; Horwath et al, 2014; Khudaverdyan, 2014), and Oceania (Ichikawa and Matsuno, 2008; Itou and Matsuno, 2011). Dental nonmetric traits have been used to not only investigate the origins of populations, but in studies exploring biological affinities among groups and microevolution within groups (Irish and Turner, 1990). Their widespread use in population studies means that the results can be easily compared where analogous methodologies have been used. Dental nonmetric traits are useful tools for the below reasons:

- Teeth are often well preserved in archaeological contexts (Hillson, 1996)
- There are multiple traits across all four classes of teeth (i.e., incisors, canines, premolars and molars) (Alvesalo and Tigerstedt, 1974)
- Selection is thought to have a minimal effect on the traits (Hanihara, 2008).
- They have demonstrated inter-group variation (Hanihara, 2008)
- Negligible variation linked with age or sex have been observed (Hanihara, 1992; Turner et al, 1991)
- A high genetic component in trait expression and occurrence have been noted (Irish, 2015; Rightmire, 1999)
- Traits are evolutionarily conservative (Scott and Turner, 1997)

Although the above characteristics are widely accepted, much research has gone into furthering our understanding of the biological reasons why dental nonmetric traits are so useful in biodistance studies. Heritability has often been investigated, with the mode of inheritance a key focus (Bailit, 1975; Harris and Bailit, 1980; Sofaer, 1970). Researchers have tried to fit nonmetric dental traits into a simple mode of genetic inheritance (i.e., dominant or recessive) with varying levels of success (Kraus, 1959; Portin and Alvesalo, 1974; Turner, 1967). Sofaer (1970) was the first to suggest they were quasi-continuous in nature. Quasi-continuous traits are those that, due to interactions genetic loci or environmental influences, have a range of phenotypic expression (Mendell and Elston, 1974). Scott (1973) found that dental nonmetric traits were subject to polygenic modes of inheritance by looking at correlations between parents and offspring in 253 white American families. Additionally, the results support the theory that dental nonmetric traits were threshold dichotomies (Scott, 1973). Harris's (1977) work on 315 families from the Solomon Islands also found that dental traits were polygenic. Additionally, the results suggested that expression of dental nonmetric traits are effected by factors including environment, dominance, epistasis and, potentially, sex. Harris (1977) also proposed that not all traits were inherited by the same means.

Recent advances in molecular research have increased our understanding of which genes are associated with the expression of certain dental traits (Bianchi et al., 2007; Kimura et al., 2015; Kimura et al., 2009; Lee et al., 2012; Tan et al., 2014; Vukelic et al., 2017). Kimura et al. (2009) found that a variant of ectodysplasin A receptor gene (EDAR 1540C) was highly correlated with the presence of incisor shovelling individuals from a Japanese populations (mean shoveling ASUDAS grades ranged between 2.59-3.06). The authors found that EDAR 1540C had an additive effect, explaining 18.9% of the total variance in the expression of shovelling within the populations. Associations between another EDAR variant (EDARV370A) and dental trait expression were also found in a study of an Uyghur population (Tan et al., 2014). In this study, the presence of incisor shovelling and double shovelling, and mesial marginal ridge in the upper canines were significantly associated to EDARV370A. All three traits were found to fit the additive effects model of inheritance. Nonetheless, the involvement of specific genes in the expression of dental traits is complex. Bianchi et al. (2007) found that a polymorphism of PAX9 was present more often in individuals with 3rd molar agenesis from a European sample. Conversely, when the same gene was investigated in Japanese and Korean populations it was found not to be associated with 3rd molar agenesis (Lee et al., 2012). Researchers investigating the WNT10A gene found that the associated intronic polymorphism rs10177996 was corelated with the expression of several nonmetric traits (UI1 shovelling, UM1 cusp 5, LP2 cusp number, and LM2 cusp 5) as well as larger crown dimensions. The derived allele of this polymorphism is found at higher frequencies in Eurasian than African populations. The latter generally have larger dentitions compared to European and Asian populations. The results indicate that although the derived allele may be responsible for larger teeth in Eurasians, other genes are responsible in African groups (Kimura et al., 2015). These mixed findings add support for dental nonmetric traits being polygenic.

The heritability of dental nonmetric traits has been studied in detail, but is population specific and usually calculated for one generation. Heritability can be measured two ways. Broad-sense heritability measures the amount of variance in the phenotype caused by non-additive genetic factors (e.g., dominance or epistasis). Narrow-sense heritability, the preferred method, only measures the quantity of phenotypic variance caused by additive genetic factors (Wang et al., 2013). Research by Hlusko and colleagues revealed the involvement of additive genetic effects on phenotypic expression in the primate dentition (Hlusko et al., 2007; Hlusko et al., 2004; Hlusko and Mahaney, 2003; Hlusko and Mahaney, 2009; Koh et al., 2010). This research has been key to understanding heritability of dental traits in humans (Paul et al., 2020). Twin studies have been utilised to further investigate dental trait heritability rates in humans (Biggerstaff, 1973; Laatikainen and Ranta, 1996; Scott and Potter, 1984). Paul and colleagues (2020) performed a review of the heritability of 26 permanent crown traits. Their study was based on data from participants of a longitudinal twin study that has been running for over 30 years in Adelaide, Australia. The dentitions of the individuals in this study have been extensively researched and has greatly expanded our understanding of the genetic background in dental trait expression (Higgins et al., 2009; Hughes et al., 2001; 2007; 2014; 2015; Hughes and Townsend, 2011; 2013a; 2013b; Paul et al., 2020: 2021; Townsend et al., 1988; 2003; 2005; 2006; 2009a; 20009b; 2012; 2015; Townsend and Martin, 1992) The study revealed that narrow-based heritability rates in permanent teeth for undichotimised traits were wide ranging but moderate. Heritability (h^2) ranged from 0-1 (mean= 0.611), with approximately 80% of the crown traits differing significantly from zero. Data also revealed that 62% of traits generated heritability rates within the range (0.4–0.8) commonly reported for dental nonmetric traits (Scott and Turner, 1997). Paul and colleagues also noted that when traits were dichotomised, they produced heritability estimates that exceed those reported above. Results suggest that non-metric traits have a significant additive genetic component, albeit slightly less than the odontometric traits from the same group (Paul et al., 2020).

Twin studies have been criticised as it remains unclear whether results from such groups are representative of the general population, where most individuals are not twins (Townsend et al., 2009b). Studies using the African American Gullah sample produced more conservative heritability estimates (Stojanowski et al., 2018; Stojanowski et al., 2019). When heritability in anterior tooth traits were assessed, estimates ranged from 0-0.82 for those traits significantly different from zero. Mean heritability values of 0.342 for the left side and 0.334 for the right have been reported (Stojanowski et al., 2018). These heritability estimates are lower than those noted in previous studies (Scott et al., 2018). Post-canine dental traits produced higher heritability estimates, which were generally comparable to other studies and were of a moderate value (the mean value of significant heritability estimates across all teeth was 0.748) (Stojanowski et al., 2019). The relatively low heritability estimates in the Gullah results have been questioned and could be related to high levels of environmental stress associated with this particular population (Scott et al., 2018). Environmental stresses have been linked with lower heritability levels in some populations (Alvesalo and Tigerstedt, 1974; Riga et al., 2014). Alternatively, Stojanowski and colleagues believe that the make-up of the Gullah community may be more reflective of archaeological collections, with potentially high levels of endogamy and distant kin-relationships (Stojanowski et al., 2017; Stojanowski et al., 2018).

To understand if nonmetric data are an insightful and strong proxy for genetic data, studies using both dental and genetic data have been conducted to determine if they produce comparable results (Herrera et al., 2014; Hubbard et al., 2015; Irish et al., 2020; Ricaut et al., 2010). Ricaut et al (2010) used genetic data and nonmetric skeletal and dental traits from the Egyin Gol necropolis to investigate intra-cemetery affinities. The genetic and nonmetric data were, however, not paired from the same individuals. The nonmetric traits were able to distinguish two distinct groups, although they only found 57% of the familial groupings detected by DNA. Irish et al. (2020) matched dental nonmetric and genomic data from population groups from Africa and globally to see if they were related. The two data sets were highly correlated, suggesting that dental nonmetric traits are a good proxy for neutral (not associated with natural selection) genetic data. Hubbard et al (2015) collected DNA samples and scored the teeth of living individuals from four ethnically diverse groups in Kenya. Results revealed that the genetic and dental data were strongly correlated, but the genetic data had a higher level of accuracy when used to distinguish between groups.

The above findings show a strong link between genetic and phenetic (nonmetric) data, but also some discrepancies. Although some inconsistencies are most likely due to differences in methods and the data sets, the genetic and phenotypic data ultimately should not completely correlate, as ‘phenotype = genotype + environment’ (Scott et al, 2018, p.140). Whilst such studies are important to demonstrate a link between genetics and phenotypic expression, ancient DNA is not an infallible tool when researching relatedness. Ancient DNA has a higher risk of degradation and as such can lead to a distorted view of intergroup affinities (Relethford, 2007). As such dental non-metric data provides a cheap and reliable avenue to explore population affinities when molecular data is unavailable.

3.3 Previous biodistance research in Nubia

Biodistance studies have been performed on Nubian collections using metrics, both dental (Calcagno, 1986; Calcagno, 1989) and cranial (Carlson, 1976; Mukherjee and Rao, 1955; Van Gerven, 1982; Van Gerven et al, 1977), as well as nonmetric traits, both cranial (Godde, 2009; Godde, 2010; 2012; 2013; Godde and Jantz, 2017; Prowse and Lovell, 1995) and dental (Greene, 1972; Greene, 1982; Greene et al, 1967; Irish, 2008; Irish and Friedman, 2010; Irish and Turner, 1990; Johnson and Lovell, 1995; Schrader et al, 2014; Turner and Markowitz, 1990). Mukherjee, Rao and Trevor (1955) were the first to use biodistance to look at biological continuity in Nubia. They found that Meroitic, X-Group and Christian samples from Lower Nubia shared a close affinity based on craniometrics. Since this early work, biodistance studies have been undertaken to further investigate population continuity, with most focused on skeletal material from Lower Nubia. Whether there was biological continuity in Nubia from the late Pleistocene into the Holocene has been widely debated. Greene (1967; 1972) compared a Palaeolithic group (erroneously referred to as Mesolithic in the text) to later Meroitic through Christian groups from Wadi Halfa in Lower Nubia using dental metric and nonmetric data. The study reported cultural and biological continuity for over 12,000 years, with no evidence of major population replacement. Although differences between the Palaeolithic and later samples were noted, they were ascribed to in situ evolution. As such, any visible variation was appointed to changes in subsistence and consequently a softer diet. Other researchers using the same Lower Nubian samples, in addition to other samples, found similar results using craniometric (Carlson and Van Gerven, 1977; Carlson and Van Gerven, 1979; Small, 1981), cranial nonmetric (Godde and Jantz, 2017) and dental data (Smith and Shegev, 1988).

Others have argued that these Palaeolithic groups are distinct from later Holocene samples, inferring there was a population replacement event in Nubia. Studies using dental nonmetric traits found that the groups from Upper and Lower Nubia (Neolithic – Christian era) differed significantly from the Palaeolithic group from Jebel Sahaba (Irish, 2005; Irish and Turner, 1990; Turner and Markowitz, 1990). These differences were also observed in studies using cranial (Groves and Thorne, 1999) and post-cranial traits (Holliday, 1995).

Recent research has also revealed a more complex picture. Godde (2012), using discrete cranial traits, found evidence of extra regional gene flow in Nubian populations from the Palaeolithic to C-Group. Although the author could not rule out population replacement the data did not support continuity. As such, a theory of fluctuating periods of in situ evolution was suggested. Galland and colleagues (2016) used 3D geometric morphometrics of the cranium to investigate the relationship between groups from Lower Nubia between the Palaeolithic and Meroitic periods. The results suggest that changes in the shape of the mandible correspond to change in subsistence from hunter-gatherer to farming (i.e. due to change in associated diet). Data from the cranial vault and biodistance statistics (using all cranial measurements) show that the Palaeolithic group differs from later samples, which may support an influx of people into the area after this period. Irish and Usai (2021) re-evaluated dental nonmetric data from Nubia, adding a new

Palaeolithic sample from Al Khiday in Upper Nubia. The dental data revealed that Jebel Sahaba was still distinct from the later Holocene samples, but Al Khiday shared a close affinity to several samples from both Upper and Lower Nubia. The results suggest continuity in Nubia from the Pleistocene to Holocene, but that the likely progenitor is best typified by the late Palaeolithic sample from Upper rather than Lower Nubia. Additionally, the Jebel Sahaba individuals share close affinities with sub-Saharan West Africans.

Unlike the differing views regarding the Palaeolithic groups, most authors agree that there has been a level of biological continuity from the Neolithic to Medieval periods in both Upper and Lower Nubia (Armelagos et al., 1972; Calcagno, 1986; Carlson, 1976; Carlson and Van Gerven, 1977; Carlson and Van Gerven, 1979; Galland et al., 2016; Greene, 1967; Greene, 1972; Greene, 1982; Irish and Usai, 2021; Schrader et al., 2014; Stynder et al., 2009; Van Gerven, 1982; Van Gerven et al., 1977). Few differences have been observed in Nubian populations from the Neolithic onwards. Irish (2005) found, in a study using dental nonmetic traits, that an A-Group sample differed significantly from a C-Group sample but shared a close affinity to a Kerma sample (and other Upper Nubian Groups). The results indicate overall biological continuity in Nubia but that the C-Group may have immigrated into Lower Nubia from outside the area. Conversely, a craniometric study found that the A-Group and C-Group shared a close affinity (Galland et al., 2016). The same study observed that the C-Group was distinct from the New Kingdom sample, and the results did not support the idea that inhabitants of Lower Nubia in the New Kingdom were 'Egyptianized' C-Group (Galland et al., 2016). Dental nonmetric research on samples from the Neolithic-Christian periods revealed that samples fell into two distinct groups, one contained Neolithic-New Kingdom samples, the other Meroitic-Christian (Irish, 2005). These results suggest a potential change in biological affinities between the New Kingdom and Meroitic.

The relationship between the Kerma culture of Upper Nubia and the C-Group of Lower Nubia has also been investigated. Irish (2005) found that two Kerma samples differed significantly from a C-Group collection. Additionally, differences between two C-Group samples were noted in cranial non-metric research (Godde and Jantz, 2017). The results of these two studies indicate that there was biological variability within Nubia during this period, as well as potentially within the C-Group cultural group.

During the New Kingdom period, Egypt invaded and controlled Nubia for around 600 years (Spencer, 2019). Biodistance research has been used to uncover not only whether Egyptians migrated to Nubia during the New Kingdom, but whether there is evidence of admixture between populations. Biodistance studies, using both craniometric and dental non-metric data from sites in Upper and Lower Nubia, have shown signs of admixture (Buzon, 2007; Irish and Freidman, 2010). Dental data from the New Kingdom collections from both Lower and Upper Nubia share close affinities with both Nubian and Egyptian assemblages (Schrader et al., 2014). The two New Kingdom samples also had a high level of relatedness to one another (Schrader et al., 2014). A craniometric study from Tombos revealed that Egyptians, Nubians, and people of mixed heritage were buried at the site (Buzon, 2006). Additionally, there was evidence of potentially ethnic Nubian individuals buried in Egyptian styled tombs (Buzon, 2006). Further research from Tombos indicated that there was population continuity between the New Kingdom and post-New Kingdom periods, with an increase in Nubian individuals after the New Kingdom period (Buzon, 2014; Buzon et al., 2016).

Previous biodistance studies suggest skeletal assemblages from the Meroitic period share greater affinities with samples that are geographically close compared to those from similar time-periods (Irish, 2005; Irish, 2008). Phillips and colleagues (2022) investigated the theory in more detail, comparing data from Lower Nubia, the 4th Cataract region, and Gabati (Phillips, Irish and Antoine, 2022). Results suggest that samples group by region, confirming the patterning observed in previous research. This regional patterning indicates that while there may have been some movement of people throughout Nubia during the Meroitic period, there is no evidence of mass migration or the repopulating of regions.

It has been proposed that there was an influx of people into Nubia after the fall of the Meroitic empire (Phillipson, 2012). Several studies have reported differences between Meroitic and post-Meroitic groups. Stynder et al. (2009) reported a general level of biological continuity from Meroitic to Medieval samples from Missiminia in Lower Nubia, although the craniometric data did reveal some variation between the Meroitic and X-Group samples. It was proposed that these differences could be indicative of new groups moving into to the region. Vollner’s (2016) study, also based on craniometric data, found significant differences between the Meroitic and post-Meroitic periods in the Gabati collection from Upper Nubia. Furthermore, the Gabati assemblage shows higher than average phenetic variation, attributed to either external gene flow or genetic drift. Dental nonmetric trait analysis of the collections at Gabati also found differences between the Meroitic and post-Meroitic, but these were not statistically significant (Phillips et al., 2022). Irish (2005) found that the X-Group shared a close affinity to other Lower Nubia samples, suggesting biological continuity. Data from other studies have also pointed towards continuity between the Meroitic and X-Group periods in Lower Nubia (Greene, 1967; Greene, 1982; Turner and Markowitz, 1990; Van Gerven et al., 1977). A dental nonmetric study compared samples from Upper and Lower Nubia to East African collections (Phillips et al., 2021). The data suggested that gene flow from East Africa increased during the post-Meroitic period but only in Upper Nubia, not Lower Nubia (Phillips et al., 2021).

Two studies have investigated the relationship between samples from different medieval kingdoms, one using craniometrics (Vollner, 2016) and the other cranial nonmetric traits (Streetman, 2018). Samples from Kulubnarti (two cemeteries) and Mis Island (three cemeteries) (located in Makuria) and Gabati (located in Alodia) were compared. Gabati was found to be biologically distinct from the Makurian samples in both studies. This could indicate that there was no admixture between the inhabitants from the different medieval kingdoms (Streetman, 2018; Vollner, 2016). Conversely, dental nonmetric trait analysis revealed that the medieval cemetery 3-J-23 from Makuria shared similarities with Gabati, suggesting that people from the south moved to Makuria during this period (Phillips et al., 2022). When comparing the samples from Makuria using cranial nonmetrics, Streetman (2018) found that one of the Kulubnarti cemetery samples shared a close affinity to those of Mis Island, while the other Kulubnarti sample was distinct. As the Kulubnarti cemeteries have been shown to be contemporaneous, the differences indicate that two genetically different groups inhabited the area during this period (Streetman, 2018). Conversely, the craniometric data revealed no significant differences between the Kulubnarti samples (Vollner, 2016). When the samples from Mis Island were investigated further, one cemetery (3-J-18)differed significantly from the other two cemetery samples (3-J-10 and 3-J-11) (Streetman, 2018). Streetman (2018) suggested that 3-J-18 was a sanctuary for refugees (either political or health) and this is why the sample is distinct from the others on Mis Island. Vollner (2016) also found 3-J-10 and 3-J-11 share a close affinity. These intra-regional (see Chapter 5) results show that there was also variation within localities, as well as throughout Nubia during the Medieval period.

Godde (2011) looked at the relationship between biological, temporal, and geographical distance in Nubian samples, following the isolation model laid out by Konigsberg (1990). Konigsberg (1990) showed that biological and geographical distance should be positively correlated (following the isolation-by-distance model), and biological and temporal distance should be negatively correlated (following the island model) (further details in Chapter 5). Samples ranging from the Kerma – Medieval period were included from Lower and Upper Nubia. Cranial nonmetric traits were used as the basis for the biological distance values. Godde (2011) found no significant correlations between temporal and biological distance, or geographical and biological distance, although some results followed the predictions made in the model. The suggested reasons for why the models did not work with these data were three-fold. Firstly, the river and straight-line distances used do not fully represent the routes used by populations at the time and therefore do not truly represent spatial distances between samples. Secondly, previous research had suggested high levels of biological variation in Nubians (Godde, 2010) which may have obscured the temporal patterning. Lastly, differing rates of migration in Nubia during this period may have complicated the temporal model, which assumes a steady rate of migration (Godde, 2011).

Although the biodistance research summarised above has produced varying results, some general patterning was noted. Overall biological continuity in Nubia from the Neolithic onwards was consistently observed. Additionally, results revealed that both geography and time had effects on inter-group affinities. While differences in methods and statistical analysis may be responsible for the highlighted variations, the different data sets could also be the source of the discrepancies.

3.4 Molecular and biochemical research in Nubia

Research using DNA has broadened our understanding of the relationship between Nubian populations over time. Genetic data reveal more detail about gene flow than morphological data (Sirak et al., 2021). However, due the intensely dry and hot conditions in Nubia, extraction of DNA is generally not successful. Yet, some DNA studies have been completed using Nubian material. These studies are based on both archaeological material (Fox, 1997; Breidenstein, 2019; Cherifi and Amrani, 2020; Sirak et al., 2021) and living populations (Krings et al., 1999).

Sirak and colleagues (2021) recovered nuclear DNA from 66 individuals from the two medieval cemeteries at Kulubnarti in Lower Nubia. The results revealed evidence of Eurasian admixture. The admixture identified was recent or ongoing, probably beginning in the Meroitic period. The Eurasian ancestry detected is most similar to groups from Bronze Age Levant, probably introduced via Egypt. Additionally, Eurasian genetic material was found in more females than males suggesting female mobility. Cherifi and Amrani (2020) successfully extracted mitochondrial DNA (mtDNA) from 11 X-Group individuals from Missiminia in Lower Nubia. The mtDNA revealed both sub-Saharan African and Eurasian haplotypes. The haplotypes identified are most commonly found in western and eastern sub-Saharan Africa, as well as the Near East. Another study recovered mtDNA from six individuals from four different Nubian skeletal collections (Breidenstein, 2019) dated to the Napatan to Medieval periods. Haplotypes associated with sub-Saharan Africa and modern-day Sudan were found in two individuals (one Napatan, one Medieval). The other four individuals (Meroitic-Medieval) had haplotypes associated with the Near East. This research indicates that people from the Near East had an important influence on the genetic make-up of Nubian populations. Fox (1997) investigated gene flow along the Nile using mtDNA recovered from Upper Nubian individuals. The hypervariable region 1 (HV1) in the mtDNA control region and polymorphic HpaI site at position 3592, commonly found in sub-Saharan African and mostly absent from North African and European groups, was used as the basis for the study. The marker was found at a frequency of approximately 39% in the Meroitic population studied, which compares with 69% in sub-Saharan Africans. The results suggest admixture in the Meroitic group with people from the south.

Krings et al. (1999) took samples from 224 living people from Egypt, Nubia and southern Sudan. The study analysed the variation in mitochondrial DNA from the individuals, using the same HpaI (np3,592) marker as Fox (1997) to designate each mtDNA as either ‘southern’ or ‘northern’. Significantly different levels of the northern and southern mtDNA were found in the individuals from the three regions. A gradient of the amount of northern mtDNA was observed, with the highest diversity found in Egypt and the lowest in southern Sudan. The opposite was true for the southern-mtDNA. The presence of the northern-mtDNA in southern regions and southern-mtDNA in the northern areas of the Nile valley indicate that gene flow, and therefore migrations, had occurred in both directions. Additionally, diversity associated with southern-mtDNA types decreased from south to north, the reverse was true for the northern-mtDNA adding support for the migrations. Egypt and Nubia produced similar results, inferring historical interactions between the two. The authors proposed that the Nile was not a barrier for migration and probably assisted in the movement of people. The changes in gene flow revealed in the DNA data probably happened within the last few thousand years. Additionally, the migration from south to north was the latest change, and more substantial in relation to gene flow. The migration from north to south appears to have occurred earlier and was smaller in scale.

Buzon and colleagues used strontium isotopes to identify the presence of non-local individuals in Nubian samples (Buzon and Simonetti, 2013; Buzon et al., 2007; Buzon et al., 2016; Schrader et al., 2019). Several studies using isotopes have focused on Tombos, positioned at the 3rd Cataract of the Nile, over the New Kingdom and post-New Kingdom. These studies identified several individuals as immigrants to Tombos during the New Kingdom period, with origins from either Lower Nubia, Egypt or the 4th Cataract region (Buzon and Simonetti, 2013; Buzon et al., 2007; Schrader et al., 2019). Isotope data suggest some of the non-local individuals may have been from Thebes (Buzon et al., 2007), which was the base of the Egyptian administration,where the viceroy of Nubia resided (Morkot, 1994). Strontium isotopic data from individuals at Amara West, a New Kingdom town in Upper Nubia, also indicated the possible presence of immigrants. The ranges indicate that they may have come from the north (Buzon and Simonetti, 2013). Data from post-New Kingdom Tombos suggest that the inhabitants were local to the area and immigration from Egypt had ceased (Buzon and Simonetti, 2013; Buzon et al., 2016).

Schrader et al. (2019) obtained strontium isotopic data from two additional sites from the 3rd Cataract region, Abu Fatima (a Kerma period town) and Hannek (a rural community in use during the New Kingdom and Napatan). Seven non-local individuals were found out of the 29 individuals tested from Abu Fatima. Data indicates that all seven individuals originated from further north, with data matching isotopic ranges from other sites in Nubia. Only one of the four individuals tested from Hannek was non-local, potentially originating from the 2nd Cataract region or Egypt. Geological research has revealed that aeolian sands may have impacted the composition of Nile sediments over time, potentially confusing the complex isotopic results from the region (Woodward et al., 2015). Based on their findings, it remains unclear if the non-local individuals identified in the previous isotopic research can be relied upon.

3.5 Summary

Dental nonmetric traits have been shown to be a good proxy for genetic material, albeit with some shortcomings. In areas where conditions are not conducive to obtaining genetic data, studies using nonmetric and metric data provide unique insights into inter-group relationships. The previous bioarchaeological research on Nubian groups revealed that shifts in biological affinities were potentially related to geography and/or time. Genetic data has also identified haplotypes associated with sub-Saharan African and Eurasian groups in Nubian individuals. Additionally, evidence of potential migration events from the north and south has also been observed in the data. The previous research presented above highlights how biological data can be used to further understand past populations and the basis of shifts in culture. The information provided in this chapter and the previous chapter (Chapter 2) will be used to formulate the research questions and hypotheses developed in Chapter 4.

Chapter 4 – Research questions and hypotheses

Cultural and biological evidence for the origins and movement of people in Nubia was reviewed in Chapters 2 and 3. This review helped develop five research questions which will be used to investigate temporal shifts, geographical patterning, migration, and biological continuity in middle Nile valley populations. Hypotheses were formulated to test the research questions. Hypothesis testing uses both a null and an alternative hypothesis. The null hypothesis (Ho) is the theory being tested, which is often states that there is 'no difference.' The alternative hypothesis (Ha) states a different theory to the null hypothesis, one with a positive/negative outcome. If the null hypothesis can be rejected, then there is evidence to support the alternative hypothesis. The first question is focused on the 4th Cataract region. In the following two questions, the scope is broadened to include other collections from Nubia (Upper and Lower) and contextualise the findings from the 4th Cataract. The final two questions look at evidence for genetic influence from outside Nubia.

4.1 Was there population continuity in the Fourth Cataract region between the Kerma – Medieval periods?

The skeletal collection from the 4th Cataract is unique, spanning 4000 years (Kerma – Medieval period) but originates from a 30km wide geographically focused locale (Emberling, 2012). As such, it offers the opportunity to explore biological continuity, in situ evolution, and immigration, whilst limiting the impact of geographical proximity. Several studies have reported results that support biological continuity from Neolithic – Medieval period in both Lower and Upper Nubia (Armelagos et al., 1972; Calcagno, 1986; Carlson, 1976; Carlson and Van Gerven, 1977; Carlson and

Van Gerven, 1979; Galland et al., 2016; Greene, 1967; Greene, 1972; Greene, 1982; Irish and Usai, 2021; Schrader et al., 2014; Stynder et al., 2009; Van Gerven, 1982; Van Gerven et al., 1977). Where differences have been found between samples, in situ evolution or immigration of non-locals to the area have been proposed as causes (Galland et al., 2016; Irish, 2005).

Although the 4th Cataract region is the location of Gebel Barkal and Napata, it was not heavily populated until the Medieval period (Emberling, 2012). The region is hard to access by river and land, in the past being circumvented by routes through the desert (Auenmüller, 2019). Therefore, potentially the region was not on the main trade/migration route along the Nile. As such, it may not have been subject to the associated flow of people present in other regions of Nubia. Even with the accessibility issues, distinct periods have been identified in the region's burial practices, architecture, and material culture (Emberling, 2012). These changes often correspond to those seen in other parts of Upper Nubia, inferring some cultural interactions with other regions (Welsby, 2010; Welsby, 2006; Wolf and Nowotnick, 2005). It is not clear whether these diachronic changes were also associated with populations shifts in biological affinities. Additionally, the 4th Cataract region has links with Eastern Desert cultures (from Neolithic – post-Meroitic), which is unique in Upper Nubia (Paner and Borcowski, 2007). These cultural links may reflect gene flow between the two regions.

To understand whether there was biological continuity in the 4th Cataract region from the Kerma to the Medieval periods, biodistance values between the collections will be assessed. If there are no significant differences between samples from different time periods, this supports biological continuity. If differences are found, then it could be suggestive of migration or in situ microevolution. The hypothesis below will be used to test whether biological continuity is evident in the 4th Cataract material. Therefore Ho: there is no difference, as opposed to Ha: there are significant differences between samples from consecutive time periods in the 4th Cataract group.

This project also examines data from samples outside the region. The following two research questions use data from Upper and Lower Nubia to contextualise the 4th Cataract findings. These data will be assessed to test whether patterns observed in the 4th Cataract are evident in the other regions of Nubia.

4.2 Is there evidence of geographical patterning in the biological affinities between Nubian groups (Neolithic – Medieval)? Are intra-regional affinities higher than inter-regional affinities?

Biological affinities between Nubian samples from within the same region (intra-regional) have been found to be higher than biological affinities between samples from the same period but different regions (inter-regional) (Irish, 2005; Phillips et al., 2022). Although this regional patterning has been noted, it has not always been the main focus of the research. Additionally, close intra-regional affinities have been observed in several studies which have focused on one specific area of Nubia (Armelagos et al., 1972; Calcagno, 1986; Carlson, 1976; Carlson and Van Gerven, 1977; Carlson and Van Gerven, 1979; Greene, 1967; Greene, 1972; Greene, 1982; Schrader et al., 2014; Stynder et al., 2009; Van Gerven, 1982; Van Gerven et al., 1977). As these studies have not included sites from other regions, it is not clear whether these close affinities are meaningful in an inter-regional setting. This study includes collections from several different regions in Nubia, covering the Neolithic-Medieval periods. As such, this offers a unique opportunity to test whether this specific spatial patterning is apparent throughout Nubia.

Model-bound analysis can also be used to explore spatial patterning. The isolation by distance model predicts that biological distance will increase as geographical distance increases. A modified version of this isolation model, conceived by Konigsberg (1990), has been used to investigate spatial patterning in a small number of Nubian samples (four Lower and one Upper Nubian) (Godde, 2013). Although the correlation between biological and geographical distance was not significant, some results suggested that the patterning predicted by the model was evident (Godde, 2013). By comparing biological distance and geographical distance (both linear and river) for all Nubian samples in this current study, the relationship between the two variables on a regional level can be tested.

To test geographical patterning in Lower and Upper Nubia, both model-based and model-free analysis will be used. Firstly, a model-free hypothesis, using the biodistance results, will be used to further investigate whether the previously reported regional patterning is applicable to Nubia as a whole. Therefore, the following Null and Alternative hypotheses will be used, Ho: there is no difference between regional groups, versus Ha: inter-regional differences are greater than intra-regional differences. Secondly, the isolation by distance model will be used to investigate whether biological and geographical distances are correlated when Ho:

There is no strong correlation and Ha: there is a strong positive correlation between biological and geographical distances.

4.3 Is there evidence of temporal patterning in Nubia (Neolithic – Medieval)? Are biological changes in the population correlated with diachronic shifts changes in social and cultural practices?

Although many studies observed Neolithic to Medieval biological continuity, a few inter-sample differences have been noted from consecutive periods (Galland et al., 2016; Irish, 2005). These differences are suggestive of migration. Additionally, previous research has identified the presence of non-locals in Nubian collections (Buzon and Simonetti, 2013; Buzon et al., 2007; Buzon et al., 2016). Often studies have focused on specific regions or certain periods, so it is unclear if the temporal patterns observed are mirrored across Nubia as a whole.

Archaeologists have identified several periods which could be associated with an influx of people (such as the C-Group (Williams, 2014), New Kingdom (Buzon, 2008), post-Meroitic (Phillipson, 2012). Although these periods may have involved changes in cultural material/practices, they are not always accompanied by a substantive change in the population or the movement of people. It is important to investigate such shifts with bioarchaeological research to directly test for biological as well as cultural exchange.

Another element to Konigsberg's (1990) isolation model investigated the relationship between temporal and biological distances. The model (based on the island model of Wright, 1943) suggests that two contemporaneous samples will be less similar than two temporally distant samples because of the homogenising effect of genetic interactions between groups. Therefore, as temporal distance increases, biological distance decreases. Goode (2013) found temporal and biological distance were negatively correlated, although the correlations were weak and not significant. The study only included five samples dating from Kerma to Medieval period. As the range of samples is much larger in the current study, an opportunity is presented to understand whether this patterning is observed across Nubia, including samples from a more comprehensive date range. An assumption for the model is that a stable rate of migration extended throughout the period. Consequently, if major migration events occurred during the periods studied, the model would not work.

To test temporal patterning in Lower and Upper Nubia, both model-free and model-bound analysis will be used. Firstly, to further investigate whether shifts in cultural practice are accompanied by changes in biological affinities, the biodistance results will be used to test the following hypotheses, Ho: there is no difference, as opposed to Ha: there are significant differences between samples from different periods. Secondly, Konigsberg's (1990) model will be used to determine if temporal patterning can be discerned. As such, biological and temporal distances will be assessed for correlation as Ho: there is no strong correlation and Ha: there is a strong negative correlation between these distances.

To contextualise the Nubian findings and investigate potential extra-regional influence, the last two research questions include data from sub-Saharan Africa, Egypt, the Near East, and the southern Mediterranean. Additionally, the data from these regions will provide a wider context for geographical and temporal patterning addressed by the preceding three research questions.

4.4 What influence did sub-Saharan gene flow have in Nubia? Is there evidence of human migration from sub-Saharan Africa to Nubia?

Nubia is often thought of as the corridor between sub-Saharan Africa to the south and Egypt and Eurasia to the north. Although most research has focused on the relationship between Nubia and Egypt, less attention has been given to genetic influence from the south.

Immigration from sub-Saharan Africa has been proposed by researchers for several periods, such as C-Group (Bietak, 1986) and post-Meroitic (Williams, 1991). Biodistance studies have provided some evidence to support these theories. Differences were found between the C-Group and A-Group (the preceding culture in Lower Nubia) that may indicate non-Nubian influence (Irish, 2005). Preliminary dental nonmetric trait research indicated that sub-Saharan gene flow was more prevalent in post-Meroitic and Medieval than Meroitic groups (Phillips et al., 2020; Phillips et al., 2021). Additionally, Krings (1999) identified a two-way migration along the Nile from DNA data in living Egyptians, Nubians, and Sudanese. The above research suggests that biological affinities between sub-Saharan Africans and Nubians may have shifted between periods.

DNA research identified sub-Saharan admixture in individuals from both Upper and Lower Nubia (Breidenstein, 2019; Cherifi and Amrani, 2020; Fox, 1997). Biodistance studies also identified such affinities (Irish, 1997; Irish and Turner, 1990; Phillips et al., 2020; Phillips et al., 2021). The results indicated that there is an element of geographical patterning to these relationships, where Upper Nubians share a closer affinity to sub-Saharan groups than do Lower Nubians (Phillips et al., 2020; Phillips et al., 2021). Krings (1999) also reported a cline from south to north, with southern groups having more sub-Saharan DNA than those to the north.

To further explore these relationships, both regional and temporal patterning will be tested. Firstly, spatial patterning will be investigated to understand whether sub-Saharan affinities reported in the previous research are mirrored across Nubia via biodistance results as follows, Ho: there is no difference and Ha: sub-Saharan groups are different from Upper Nubians and/or Ha: sub-Saharan groups are different from Lower Nubian samples. Secondly, previous data are suggestive of an influx of sub-Saharan peoples at different periods in Nubian history. To fully understand if pertinent biological distances follow temporal patterning, the following hypothesis will be used, Ho: there is no difference and Ha: there are significant differences between sub-Saharan African and Nubian samples (when separated by period).

4.5 What was the genetic relationship between Nubia and Egypt or Eurasia? Is admixture due to invasion or long-term biological diffusion?

Egypt and Nubia have a long and complex history. Conquests of Nubia by Egypt (Middle and New Kingdom) and then Egypt by Nubia (Napatan) have been associated with the movement of people back and forth (Morkot, 2000; Spencer, 2019; Török, 2008). Bioarchaeological data from the New Kingdom confirmed the presence of Egyptians and those of mixed heritage in Nubia at this time (Buzon, 2006; Buzon, 2008; Buzon et al., 2007; Irish and Friedman, 2010; Schrader et al., 2014). When looking at Nile valley groups, a study using DNA from living individuals found evidence of migration from north to south, (Krings, 1999).

In addition to the major migration events described above, Nubians and Egyptians were trading and interacting with each other for thousands of years (Buzon, 2008; Buzon et al., 2016; Spencer, 2014; Spencer et al., 2017). This long association is evident in bioarchaeological research. Isotopic evidence of non-locals, potentially from Egypt, has been found in Nubian towns from the Kerma – Napatan periods (Buzon and Simonetti, 2013). DNA research found similar levels of admixture in Egyptian and Nubian individuals, which is suggestive of the long history of interactions (Krings, 1999). Sirak and colleagues (2021) also found that Eurasian admixture identified in medieval individuals was potentially ongoing from the Meroitic period, suggesting frequent interactions between Nubians and Egyptians.

The effect of geography on the affinities between Nubians and Egyptians is unclear. Several studies looked at the relationship between Egypt and Lower Nubian samples, in whom close affinities are apparent (Godde, 2009; Irish, 1993; Irish, 1997; Irish, 2005; Irish and Friedman, 2010). Although studies have included both Upper Nubian and Egyptian groups, biological affinities between the two groups were not the focus of the study (Irish and Friedman, 2010; Schrader et al., 2014). It is assumed that, due to proximity, Lower Nubians would share a higher affinity with Egyptians than would Upper Nubians.

To investigate the relationship between Egypt (and Eurasia) and Nubia, two hypotheses are tested. Firstly, to determine whether affinities between Egypt and Nubia remained stable or that major immigration events occurred, the following null and alternative statistical hypotheses will be used, Ho: there is no difference and Ha: there are significant differences between Egyptian (and Eurasian) and Nubian samples (pooled by period)). Secondly, to discern if geographical patterning is evident in the relationship between Nubians and Egyptians, the following hypotheses will be used, Ho: there is no difference, vs. Ha: Egyptian (and Eurasian) groups are different from Lower Nubians and/or Ha: Egyptian (and Eurasian) groups are different than Upper Nubians.

4.6 Summary

The research questions and hypotheses laid out in this chapter will be used as the basis for this study. The results and discussion sections will mirror the above pattern of in focusing on the 4th Cataract region, then widening to Nubia, and finally adding external regions. The next chapter describes the collections and methods used.

5. Materials and Methods

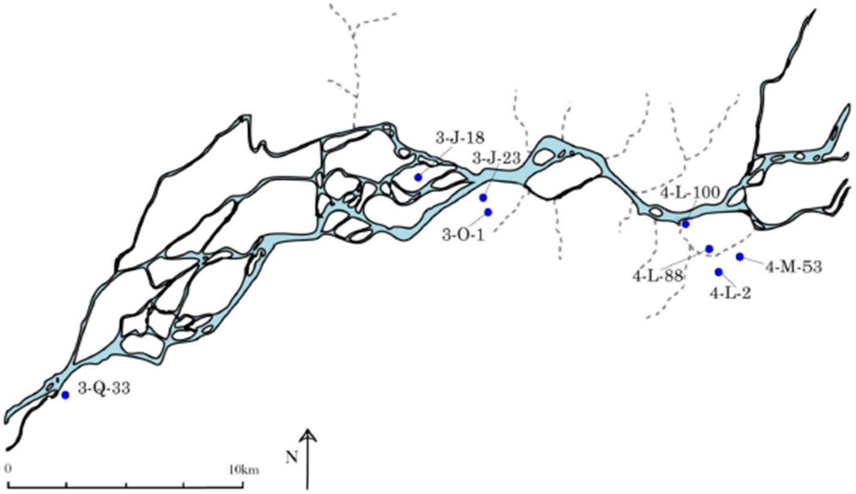
This chapter details the skeletal collections and methods used in this study. The collections (sections 5.1-5.5) were chosen to be representative samples of the whole of Nubia (Upper and Lower), and of each time period. The core data (17 collections, 1138 individuals) were collected as part of this project and where appropriate, this was supplemented by previously published data. The methods (section 5.6) are outlined below, including: dental nonmetric trait recording, inclusion in study, inter- and intra-observer error tests, model-free analysis, and model-bound analysis.

5.1 Materials

An overview of all collections included in this study are in Table 5.1. This table details cultural affiliation, time period, curation, and region where applicable. Further details on each of the collections are provided below. Additionally, Table 5.2 gives brief details on the individuals (females, males, and sub-adults) included from the collections. Table 5.3 presents information on previously published data included this research project. Maps where each sample is located.

5.2 Fourth Cataract

Skeletal material from the British Museum's 4th Cataract collection was used as the basis for this project. The collection was excavated as part of the rescue archaeology mission associated with the building of the Merowe Dam project. The individual sites are described below. The skeletal assemblages include individuals from the Kerma, Meroitic, Post-Meroitic, and Medieval periods (Jakob, 2007). Each site had a varied distribution of sexes, all contained sub-adults. Due to the nature of rescue archaeology, numerous sites were excavated in a short time period. Thus, there are varying levels of information available for each site. Further details on demography have been summarised in Table 5.2. Figure 5.1 is a map detailing the position of the 4th Cataract sites.



Original map image copyright of A. Davies-Barrett.

Figure 5.1. Position of Fourth Cataract sites

5.2.1 4-L-2

Main sites from the Kerma period were found in the same area, see (Figure 5.1). Site 4-L-2 was excavated between 2005 and 2007 (Welsby, 2010). There was evidence that the graves had been robbed, many quite extensively (Welsby, 2010). The low Tumuli that covered the graves were mostly sub-circular or sub-oval in shape, as were the grave cuts themselves, averaging around 1.5m in diameter. The tumuli were positioned very close to each other (Welsby, 2010). All except one individual was interred in a flexed position. The skeletons were mostly orient

		SAMPLE NAME	SITE(S)/REGION	PERIOD/CULTURE	DATES	NUMBER OF INDIVIDUALS	CURATION
UPPER NUBIA	4TH CATARACT	4th Cataract Kerma (4CKM)	4-L-2, 4-L-88, 4-L-100 / 4th Cataract	Kerma Classique	1750–1500 BCE	86	BM
		3-Q-33 (3Q33)	3-Q-33 / 4th Cataract	Meroitic	300 BCE–350 CE	29	BM
		4th Cataract post-Meroitic (4CPM)	3-Q-33, 3-O-1, 4-M-53 / 4th Cataract	post-Meroitic	350–550 CE	32	BM
		3-J-23 (3J23)	3-J-23 / 4th Cataract	Medieval	655-775 CE	110	BM
		3-J-18 (3J18)	3-J-18 / 4th Cataract	Medieval	1150–1400 CE	145	BM
	DONGOLA REACH	R12 (R12)	R12 / North Dongola Reach	Neolithic	5000–4000 BCE	91	BM
		H29 (H29)	H29 / North Dongola Reach	Kerma Ancien	2500–2050 BCE	73	BM
		P37 (P37)	P37, O16 / North Dongola Reach	Kerma Ancien - Moyen	2500–1750 BCE	21	BM
		Kerma Classique (KMC)	Kerma / North Dongola Reach	Kerma Classique	1750–1500 BCE	63	CAM
		Soleb (SOL)	Soleb /Between the 2nd and 3rd Cataracts	New Kingdom	1550–1070 BCE	32	MH
		Amara West New Kingdom (NK)	Amara West /Between the 2nd and 3rd Cataracts	New Kingdom	1294–1069 BCE	53	BM
		Tombos (TOM)	Tombos /Between the 2nd and 3rd Cataracts	post-New Kingdom	1212–1069 BCE	147	PUR
		Amara West post-New Kingdom (PNK)	Amara West /Between the 2nd and 3rd Cataracts	post-New Kingdom	900–700 BCE	101	BM
		Kawa (KAW)	Kawa / North Dongola Reach	Meroitic	300 BCE–350 CE	91	BM
	6TH CATARACT	Ghaba (GHB)	Ghaba / near 6th Cataract	Neolithic	5000–4000 BCE	119	LJMU
		Al Khiday Neolithic (AKN)	Al Khiday / near Khartoum	Neolithic	5000–4300 BCE	2	UP
		Gabati Merotic (GABMER)	Gabati / near Meroe	Meroitic	200 BCE–200 BC	84	BM
		Gabati post-Merotic/Medieval (GABPM)	Gabati / near Meroe	post-Meroitic - Medieval	550–700 BC	37	BM
		Soba (SBA)	Soba / near Khartoum	Medieval	700–1600 CE	50	BM
LOWER NUBIA		Gebel Ramlah (GRM)	Gebel Ramlah / Western Desert	Neolithic	4690–4340 BCE	82	GRS
		C-Group (CGR)	Faras to Gamai	Kerma Moyen / C-Group Ib -IIa	2000–1600 BCE	62	PAN
		Heirakonpolis C-Group (HKC)	Hierakonpolis	Kerma Moyen / C-Group Ib -IIa	2000–1600 BCE	56	HK
		Pharaonic (PHA)	Faras to Gamai	New Kingdom	1650–1350 BCE	38	PAN

	Meroitic (MER)	Semna, Faras to Gamai	Meroitic	100 BCE–350 CE	94	ASU, PAN
	X-Group (XGR)	Semna, Faras to Gamai	post-Meroitic / X-Group	350–550 CE	63	ASU, PAN
	Christian (CHR)	Semna, Faras to Gamai	Medieval	550–1350 CE	41	ASU, PAN
UPPER EGYPT	Abydos (ABY)	Abydos	Early Dynastic	3000–2686 BCE	54	BMNH, CAM
	Thebes (THE)	Thebes	Middle Kingdom	2055–1773 BCE	54	AMNH
	Qurneh (QUR)	Qurneh	New Kingdom	1295–1186 BCE	67	CAM
LOWER EGYPT	Saqqara (SAQ)	Saqqara	Old Kingdom	2613–2494 BCE	41	MH
	Lisht (LIS)	Lisht	Middle Kingdom	1985–1773 BCE	61	NMNH
	Giza (GIZ)	Giza	Late Dynastic	664–332 BCE	62	CAM
MIDDLE EAST	Lachish (LAC)	Lachish, Jericho	Iron Age II	1000–586 BCE	86	NHM
SUB-SAHARAN AFRICA	Ethiopia (ETH)	Ethiopia, Eritrea	Historical	19–20th century CE	40	MH
	Somalia (SOM)	Somalia, East Ethiopia	Historical	19–20th century CE	77	CAM
	Chad (CHA)	Chad	Historical	19–20th century CE	29	MH
	Kenya (KEN)	Kenya, Tanzania	Historical	19–20th century CE	114	AMNH, MH, NMNH
	Tanzania (TAN)	Tanzania, Zanzibar	Historical	19–20th century CE	45	AMNH, MH
REGIONAL COLLECTIONS	sub-Saharan Africa Central (SSC)	DRC, Republic of Congo, Gabon, Chad	Historical	19–20th century CE	325	AMNH, MH, NMNH, RBINS, UBL
	sub-Saharan Africa East (SSE)	Kenya, Tanzania, Zanzibar, Somalia, Ethiopia, Eritrea	Historical	19–20th century CE	637	AMNH, MH, NMNH, CAM
	sub-Saharan Africa South (SSS)	Botswana, South Africa	Historical	19–20th century CE	1064	AMNH, ASU, MH, NMNH, WUJ
	sub-Saharan Africa West (SSW)	Ghana, Benin, Senegal, Gambia, Cameroon, Nigeria, Togo	Historical	19–20th century CE	486	AMNH, MH, NHM
	North West Africa (NWA)	Morocco, Tunisia, Algeria, Canary Islands	Historical (except Canary Islands)	19–20th century CE (400–900 CE)	245	IPH, MH, NHM, NMNH, UM
	South Eastern Mediterranean (SEM)	Isreal, Turkey, Greece, Italy	Iron Age to Historical	1000 BCE - 20th century CE	293	AMNH, NHM

ASU -Arizona State University; BM- British Museum; CAM - Cambridge University; GRM,- Gebel Ramlah archaeological site, Egypt; MH -Muse´e de l'Homme; PAN -Panum Institute NHM - Natural History Museum, London, IPH - Institut de paléontologie humaine, PAN UM- University of Minnesota, RBINS - Royal Belgian Institute of Natural Sciences in Brussels, ULB - Université libre de Bruxelles, WUJ - University of the Witwatersrand, Johannesburg, AMNH - American Museum of Natural History; NMNH, National Museum of Natural History; UM, University of Minnesota

Table 5.1 Details of samples used in study

NE-SW, typically the head was positioned in the NE end, but this was not done throughout the site (Welsby, 2010). Grave goods varied across the burials. All graves had some sort of pottery associated with them, and many had jewellery (mainly bracelets made of beads) (Welsby, 2010). There were four instances where individuals had been buried with goats. In all cases the goat was buried in front of the individual with a hand being placed near or on the goat skull (Welsby, 2010). Where individuals were buried with goats, there was a richer array of funerary goods, including ceramic jars, ochre, red ochre, jewellery (scarab amulet in one instance), bed of leather, lithics and one example of a metal knife in one grave (Welsby, 2010). Additionally, one of the burials contained two individuals and two goats. The site has been dated to the Kerma Classique period (Welsby, 2010). Ceramics found in the graves were predominately of a Kerma Classique origin, but some of the vessels revealed links to the Pan-Grave culture (primarily in the adornment of several pots) (I Welsby Sjöström, personal communication, email 2nd March 2022). Dental preservation is relatively poor in this collection.

5.2.2 4-L-88

Another Kerma Classique site, 4-L-88, was found on the lower slopes of the gebel (i.e., hill), adjacent to the wadi (Welsby, 2010). Tumuli were similar in shape and size to those found at 4-L-2, with the max length ranging from 1.33m to 2.32m. The site was totally excavated, with 23 individuals exhumed (Welsby, 2010). Preservation levels are also low in this assemblage and reliable sexing of individuals could not be performed. The assemblage included three sub-adults. As this site has yet to be published, we do not have many details on grave goods or grave shape or orientation (Welsby, 2010). The ceramics from this site were classified as typical of the Kerma Classique period (I Welsby Sjöström, personal communication, email 2nd March 2022). Dental preservation is also poor, with most individuals having under 25% of teeth available for examination.

	COLLECTION	FEMALES	MALES	UNKNOWN	SUB-ADULTS	TOTAL
4TH CATARACT	4-L-2	8	9	18	14	49
	4-L-88	0	1	12	3	16
	4-L-100	0	0	13	4	17
	3-Q-33	15	10	2	10	37
	4-M-53	2	2	3	1	8
	3-O-16	7	5	4	0	16
	3-J-23	26	42	8	34	110
	3-J-18	53	44	19	29	145
UPPER NUBIA	Ghaba	1	1	98	15	115
	R12	5	4	64	18	91
	H29	0	2	52	19	73
	O16	0	1	6	0	7
	P37	7	7	20	4	38
	Amara West	22	18	92	22	154
	Kawa	15	14	41	21	91
	Gabati	30	25	52	14	121
	Soba	4	6	30	10	50
	Totals	195	191	534	218	1138

Table 5.2 Details of individuals included in data collection

5.2.3 4-L-100

This burial complex was not fully excavated, with only the central part of the cemetery excavated. This site is located high up in a wide flat expanse, halfway up the gebel (Welsby, 2010). Graves had been widely robbed, some of which occurred shortly before excavation took place. Most of the tumuli were badly preserved, with only the lower levels of stones remaining (Welsby, 2010). Graves were positioned closely together, some of the earlier tumuli being impaired by the construction of later ones. Like the other two sites from the 4-L grid square mentioned above, the tumuli were sub-circular or sub-oval in shape. The graves in this cemetery were mainly sub-rectangular in shape, often lined with stone slabs. The lining of the graves varied, with some even having roofing slabs (Welsby, 2010). Individuals had mostly been buried in the flexed position, orientated NE-SW, facing west. Due to the severe nature of the disturbance, many skeletons had been displaced or removed. Where grave goods remained, these would include, ceramics, jewellery (mainly beaded bracelets) and ochre. The pottery assemblage contained vessels belonging to the Kerma Classique, Pan-Grave and Egyptian New Kingdom cultures designs (I Welsby Sjöström, personal communication, email 2nd March 2022). Preservation rates for both dental and skeletal elements are very low, and only fragmentary remains were recovered. As such, no individuals could be reliably sexed. The assemblage did contain sub-adults (Welsby, 2010). Again, dental preservation is poor with similar levels to that found in 4-L-88.

5.2.4 3-Q-33

Test excavations at site 3-Q-33 began in the 2004/05 season. There is evidence of modern disturbance and grave robbing. The burial complex was located beside a small paleo channel (Wolf and Nowotnick, 2006). The cemetery was comprised of two distinct areas, one containing Meroitic burials and the other containing later post-Meroitic inhumations. The Meroitic section was in the east of the complex and contained sporadic remains of superstructures. Due to preservation, these were not always identified. The graves were densely distributed and often covered by circular tumuli (Wolf and Nowotnick, 2005). Grave type varied across the site with instances of lateral niche burials, narrow burial pits and one transverse chamber. The graves were frequently sealed by granite slabs. Some sort of zoning was also evident within the Meroitic area, with graves in the northern area aligned Northeast-Southwest and those in the southern area aligned East-West, with the head generally positioned at the western or south-western parts of the grave. Skeletons were mostly interred in an extended supine position, with the hands resting on the pelvis. In a few examples, individuals had been laid in their side in a slightly flexed position. There were four examples of multiple burials. All were primary inhumations except one instance where a grave was reopened to include the secondary burial (Wolf and Nowotnick, 2006). Some individuals had been wrapped in textile and often leather remains were found under the skeleton. Mostly ceramics and jewellery were included as grave goods, but due to disturbance much has been lost. Additionally, a grave was found on the edges of the Meroitic area which had many of the characteristics of a post-Meroitic burial. This could be a transitional grave, which represents the time where burial rights are changing and incorporates elements from the proceeding and preceding periods. Dental preservation is generally good in this assemblage.

Eight tumuli dating to the post-Meroitic era were also found in the cemetery at 3-Q-33. All tumuli had been disturbed. The tumuli consisted of sub-circular or sub-oval stone kerbs that contained flat gravel mounds within. Graves consisted of circular shafts with adjoining oval shaped side chambers. The side chambers had sloping roofs and were set to the south or south-west of the shaft. Large stone slabs had been used to seal the side chambers, but often these had been removed due to looting. Much of the grave goods have been lost, with only two graves remained intact (Wolf and Nowotnick, 2006). One contained a female and infant. The adult was wearing jewelry (bracelets, necklaces and alloy rings). Ceramic jars and pots, and a bag containing a necklace, were also found near the skeleton. A burial of a male was also found undisturbed. The grave contained funerary items linked to archery (stone archers loose, leather quiver and 4 iron arrowheads). Beads were also found around the ankle/leg (Wolf and Nowotnick, 2006). All dentitions could be examined, and preservation is at a good level.

5.2.5 4-M-53

Excavations in the post-Meroitic cemetery at 4-M-53 began in 2006/07, but had to be abandoned (Welsby, 2015). This meant that out of the 100 potential graves, only 9 were excavated. Dental preservation of the individuals varies widely. The cemetery was situated on wide plain with rocky outcrops and had been severely looted and many of the burials had been disturbed. Graves were covered by tumuli, which differed in type and size. Of the graves that were excavated, the grave pits were circular/sub-circular shafts with burial chamber leading at end of the shaft. Where skeletons had been left in-situ, they were usually aligned South-Northwest, in a flexed position on their left side. The head was placed at the southeast end. Two of the graves were richly furnished with jewellery and other grave goods, but the paucity of goods in the other graves is probably due to looting (Welsby, 2015). Dental preservation is varied in this small collection, with only half of the individuals have 50% of teeth available for analysis.

5.2.6 3-O-1

Initially five tumuli were excavated in 2002/3. The cemetery was fully excavated in 2007. The site, dated to the post-Meroitic, had been disturbed and the graves had been robbed (Welsby, 2013). The tumuli which covered the graves varied in shape and size, with many being circular and some having an egg-like shape. Vertical entrances led to burial chambers which widened out below the initial opening.

Chambers were mostly aligned North-South, as were the individuals interred (Welsby, 2013). The graves were capped with stones, and in some cases these were still in-situ. Individuals were placed in a flexed position, and there was some evidence of shrouds or other organic material coverings (Welsby, 2013). Grave goods differed, but where the graves had not been disturbed, they were richly furnished. Jewellery (beaded necklaces and bracelets made of stone, faience or shell), pottery, organic material (leather, textile and animal bone), metal work and baskets, were all recovered from graves (Welsby, 2013). The dentition are well preserved.

5.2.7 3-J-23

Cemetery was situated east of el-Tereif, on a low mound alongside the Nile. The cemetery was fully excavated in two phases, 47 graves initially and 131 graves at a later stage. Mainly Medieval/Christian burials were found, with some graves dated to the post-Meroitic period. Post-Meroitic burials made up around 4% of the assemblage and were all similar in shape and style. The cemetery has been dated to the early Medieval period (AD 655-775) (Vandenbeusch and Antoine, 2015). The post-Meroitic graves were trapezoidal in shape, with an associated descendary, leading to an oval burial chamber. Individuals were supine or slightly flexed and orientated West-East. Grave furnishings included beads and pottery, although most burials had been disturbed (Carpio and Guillen, 2005). A grave, located at the highest point of the cemetery and at its centre, had no other burials surrounding it for at least 3m. The lack of burials close to this grave could indicate the presence of a lost tumulus (Welsby, 2016).

Graves dated to the Christian period comprised ovoid burial chambers often marked by box grave monuments (max height 650mm), although many had no monument. Those interred were in a supine position, legs together and hands placed over the pelvic area. Bodies were orientated West-East (head to the west) and covered in shrouds. Two infant burials were found where the bodies were orientated with the head placed in the eastern end of the grave. Another two infants had been placed inside niches in the main grave of an adult. A few of the graves had stone slabs completely or partially covering the body. Grave goods were generally rare, metal and stone crosses and rings were found. Preservation was extremely good at this site, with 20 natural mummies being recovered, skin, and textiles still remained (Carpio and Guillen 2005). Tattoos, related to Christian iconography, were discovered on one of the mummified individuals (Vandenbeusch and Antoine, 2015). A high level of dental preservation was observed.

5.2.8 3-J-18

This cemetery was discovered on Mis Island, alongside the associated church. This church was dated to the later Medieval period (c.1150-1400 AD, typology by Adams, 1965). Both the church and cemetery were found near the center of the island, surrounded by bedrock. Males and females were quite evenly distributed in the cemetery, with sub-adults buried in the same complex. The skeletal and dental preservation of the collection is very good, with several natural mummies included in the assemblage. The cemetery has been split into three phases. A few graves were found beneath the church, and pre-date it's construction. They were aligned NW-SE. Undisturbed graves were covered by stone slabs and contained pottery (Ginns, 2010a).

The main phase of the cemetery relates to around 80% of the burials. These internments are thought to synchronous with the use of the church (Ginns, 2010a). Graves from this phase covered the whole of the cemetery, with some graves being cut into by later burials. A variety of monuments marked the graves, although these had often been lost due to erosion, disturbance or later burials. Even with the loss of monuments, some zoning could be ascertained in the cemetery(Ginns, 2010a). Firebrick monuments were widely spread across the complex, but most common near the church. Mudbrick monuments were found in groups at the northern end of the cemetery and also by the southwestern edge of the church (Ginns, 2010a). There were also a few examples of monuments containing both mudbrick and firebrick. These were found in the northern end of the cemetery. Stone monuments were found sporadically throughout the cemetery, although a grouping can be seen at the eastern edge of the church (Ginns, 2010a). Finally, there were graves which had no evidence of monuments. Often, these had been cut into by later graves, indicating that perhaps the monument had been lost. Elsewhere, graves with no monument were positioned next to graves with monuments and seemed to be contemporaneous (Ginns, 2010a). This could indicate that another type of monument was used or a different burial right. Individuals had been interred in various positions, with nearly equal numbers of those in a supine position, on left side or on right side. Some graves were found to contain stone slabs covering the head (Ginns, 2010a). Two individuals were buried under the western wall of the church (whilst in use). One of these individuals was buried covered with high quality fabrics and lain on a dyed fleece and woven blanket. The two individuals' association with the church, coupled with the high-status burial goods, suggest they may have been local leaders or priests (Ginns, 2010b).

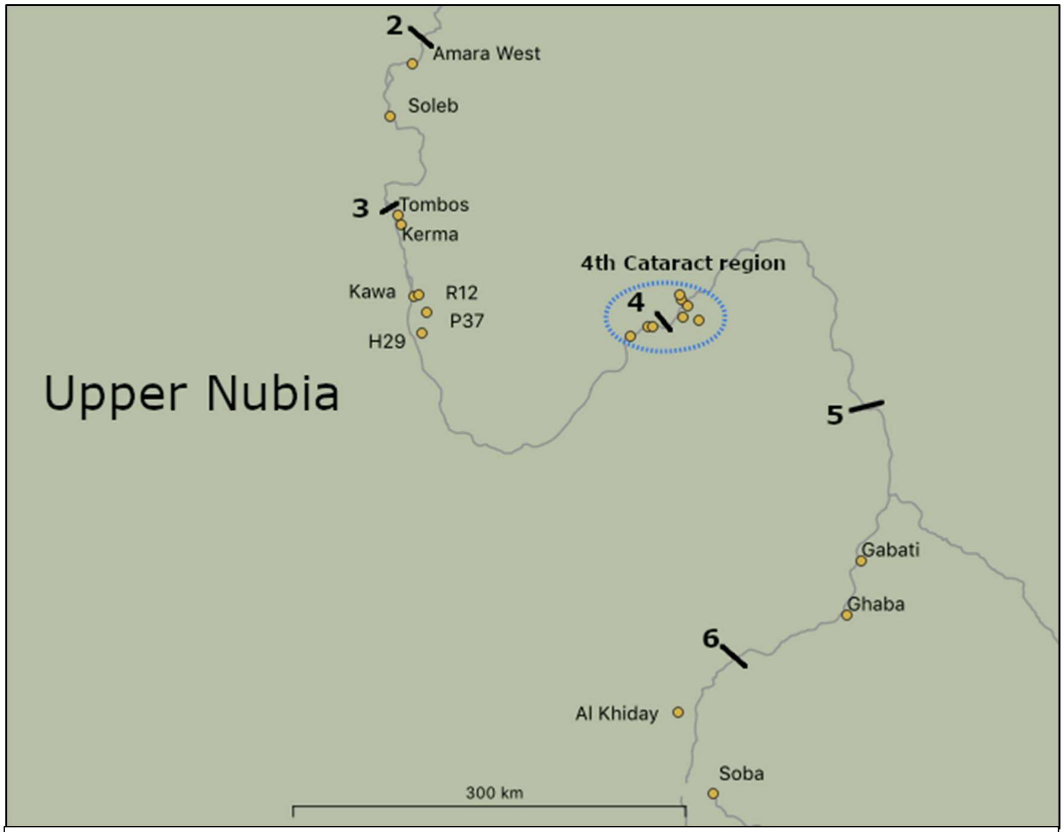
The burials in the last phase of the cemetery are thought to be associated with the time after the church collapsed. Most of these graves can be found in the northern part of the cemetery. Stone monuments marked all graves from this period. Bodies were found in various positions, including two which were prone. A small number of the graves contained stone head coverings (Ginns, 2010).

5.3 Upper Nubia

In addition to the 4th Cataract Collection, the British Museum curates several other skeletal assemblages from Upper Nubia. Assemblages used in this study include: six sites identified as part of the of the Northern Dongola Reach Survey SARS concession (1993-1997), two cemeteries from Amara West, and two sites from further south (6th Cataract region). Additionally, the el Ghaba collection (referred to as Ghaba) was included in the study, this collection is curated at Liverpool John Moores University. These additional assemblages were used to provide complementary data and contextualise the project. Figure 5.2 shows the position of the Upper Nubian sites, including the collections mentioned in the following section (5.4 Published Data). Table 5.2 details the individuals used in this study

5.3.1 Ghaba

The cemetery is located on the eastern bank of the Nile, 14km north-east of Shendi on the edge of the el-Ghaba village. It is thought the cemetery was in use for around 1300 years from the beginning of the fifth to end of fourth millennium BC (Salvatori et al., 2016). This period is associated with the Early Neolithic in southern Nubia but shares cultural links with the middle Neolithic in Upper Nubia. The site was first excavated in 1980 and skeletal preservation is poor, with little information on sex, age or pathology (Irish and DeGroote, 2016). The dentition was better preserved. Inhumations from 265 Neolithic graves were excavated, and 167 individuals were available for analysis. When it was possible to determine body position, individuals were buried in a flexed position, the degree of constriction varied between burials.



Dotted blue line = 4th Cataract region. Lines and numbers = Cataracts of the Nile. Yellow dots = collections used in study.

Figure 5.2 Map of Upper Nubia

Arms were bent and close to the face. Individuals were either placed on the left (35%) or right (36%) side. In 29% of burials, the side could not be determined (Salvatori et al., 2016). Both left and right sided depositions were homogenous, with no criteria found that could indicate why a specific side was chosen. Grave goods were found in 69% of the burials. These were most commonly shells, animal bone, ivory bracelets, bucrania, and stone axes. Pillows of vegetal material were found under the heads of several individuals. Red and yellow ochre was used in burial rite for some graves. Malachite was also used in several graves, staining the teeth of the interred individuals green. This staining of the teeth is so far unique to Ghaba. The remains of both domesticated and wild grains were recovered from the site (Salvatori et al., 2016).

5.3.2 R12

The site was excavated between 2000 – 2003 (Salvatori and Usai, 2008). Established on a mound, the cemetery is similar to other Neolithic burial grounds from the area. It was in use for around 600 years. And includes 168 individuals (72% adults), excavated from 154 graves. The latter are not well preserved due to the harsh presservation conditions but there was no evidence that the burials had been disturbed due to robbing. No patterning based on sex or age was evident in the placement of the graves, which include an equal numbers of males and females. The presence of stone mace-heads in graves may be associated with males. Due to the circular shape of the graves, the orientation was not clear (Salvatori and Usai, 2008). Placement of the body varied, with 63% deposited on the left-side, 13% on the right-side, and 23% unknown orientation. Equal numbers of males and females were found in graves with left-side and right-side placements. Left-side interments were more richly furnished, with grave goods than those with individuals placed on their right-side. Is has been suggested that the body placement could indicate two different groups, with possible differences in status. Other Mesolithic and Neolithic sites from Nubia mostly have left-sided depositions (Salvatori and Usai, 2008). Dental preservation at the site varied but was mostly good.

5.3.3 H29

Excavated from December 2011 to February 2012, this site dated to the Kerma Ancien period. The cemetery was fully excavated, with 99 graves from two areas. These were mainly simple pits, circular or oval in shape (Welsby et al., 2018). Where possible to ascertain, the graves were aligned NW-SE. Most individuals had been placed on their right-side in a flexed position but there was variation in the degree of flexing. Individuals were often buried with head to the east, facing north. Sixty-four adults and 32 sub-adults were exhumed. Preservation of the skeletal remains is around 45%, with 65% of the dentition recovered (Welsby et al., 2018). Individuals were placed on red-ochre covered animal hide, some also had palm fronds placed at their feet. Pottery was not often part of the grave goods, whereas jewellery was often present (Welsby et al., 2018). No zoning in the cemetery was evident, based on either status or sex. Although H29 is very similar to other Kerma sites from the region, there were some differences. The absence of both shell hair-slides and copper-alloy mirrors was noted. These items are very common in Kerma Ancien burial assemblages. Additionally, remains from equids and birds were found in some of the graves, which is atypical (Welsby et al., 2018).

5.3.4 O16

Cemetery O16 was only partly excavated, with only nine graves investigated (Welsby et al., 2001). The graves had been adversely affected by wind erosion. Where articulation of the bodies was discernible, all were: flexed, placed on the right-side, head to the east, and face to the north. All individuals were adults and the site is dated to the Kerma Ancien period (Welsby et al., 2001). Dental preservation at the site is poor.

5.3.5 P37

Located close to O16, P37 is also a Kerma cemetery comprised of two moundsthat covers both the Kerma Ancien and Kerma Moyen periods (Welsby et al., 2001). The northern mound contained 56 graves, 34 of which were fully excavated. Individuals have varying levels of dental preservation. The graves from the northern mound were all circular/oval pits around 1m in diameter. Bodies were flexed. The burials had been subject to erosion and robbing. In the southern mound, 22 graves were identified, with 13 fully excavated (Welsby et al., 2001). The graves were all the same style, pits with no evidence of superstructure. Bodies were crouched, on the right-side, head to the east, and face to the north. Pottery found in the graves at P37 was typical of the period and includes local wares, C-Group style, Egyptian, and Pan-grave style vessels. The vessels often showed signs of use and repair. No patterning associated with sex was evident (Welsby et al., 2001).

5.3.6 Amara West

Amara West is situated between the second and third Cataracts of the Nile (Spencer, 2014). It was established as the administrative centre of Upper Nubia during Egyptian rule, replacing Soleb, in the reign of Seti 1 (c. 1294BC – 750BC). Two cemeteries, C and D, are associated with Amara West. Both contain burials dated to the New Kingdom and post-New Kingdom periods. Cemetery D, iconsidered the ‘Elite’ cemetery contains several Egyptian style pyramid and chapel tombs dated to the New Kingdom (Binder et al., 2010). Cemetery C includes Egyptian chamber tombs thought to be of lower status, and another richly furnished chamber tomb marked by a large Nubian style Tumulus dating to the New Kingdom (Binder, 2017). In both cemeteries tombs were reused in the post-New Kingdom era. Niche burials dating to the post-New Kingdom were also created in Cemetery C (Binder, 2011). Questions have been raised about the why the high-status Tumulus burial is located in Cemetery C, and if there was a separation of burials not only due to status, but ethnicity (Binder, 2017). Upon further analysis of the New Kingdom burials, local adaptations to standard Egyptian practices became evident. Some adaptions, like the lack of true mummification, mirror those in other New Kingdom settlements, while others show variations only seen in Amara West (Binder et al., 2017). The post-New Kingdom burials retain Egyptian features but become more Nubian in character. Flexed body position, tumuli and funerary beds became more popular (Binder, 2011). Preservation of both skeletal and dental elements is poor.

5.3.7 Kawa

The burials at Kawa date to the Meroitic period, although it was also an important town in both the New Kingdom and Napatan periods (Welsby, 2014). The cemetery was excavated over several seasons, with a total of 135 individuals recovered in total. The collection contains males, females and sub-adults (Antoine, 2014). Although dental preservation varied among individuals, there was generally a high level of preservation. Many of the graves consisted of long descendaries with an axial chamber. Some of the burials were less complicated and comprised of simple grave pits. Bodies were mainly orientated East-West, with head to the west. Often the remains of cartonnage coffins was evident in the graves. Some individuals were interred in an extended supine position, others were placed on their sides in a crouched position. In many cases, tombs were reused and contained multiple burials (Welsby, 2008). Additionally, some pyramid tombs were present. Three of these pyramids were constructed from dressed stone. The only other examples of dressed stone pyramids are found in royal cemeteries and the elite cemetery at Meroe (Welsby, 2009). Pyramid tomb three, the least disturbed, contained seven individuals. The bodies were orientated South-North, except one where the orientation was reversed. Most individuals were in an extended supine position (except for the two that were flexed). The tomb seems to have been only used once, with all seven individuals buried at the same time. Only a few grave goods were associated with the burial. (Welsby, 2011). The burials, even those undisturbed, contained few grave goods. One area of the cemetery appeared to be an exception (area JH3), where the graves were richly furnished (Welsby, 2011).

5.3.8 Gabati

Discovered in 1993 the cemetery was part of a survey undertaken by the Sudan Archaeological Research Society near the village of Gabati in central Sudan (Edwards, 1998). The main part of the cemetery has been dated to the Meroitic period. A total of 64 graves out of 74 were excavated and approximately 142 individuals were recovered (Edwards and Judd, 2012). Most of the graves were oval chambers, oriented North-South. A few graves were rectangular and orientated East-West. All graves had East-West shafts. Body orientation matched the orientation of the grave chamber. Those individuals in East-West graves were in a contracted position, whereas those in North-South tombs were extended. Most were single burials (41.9%), but some were double (29%) or multiple (25.8%) burials.

Another 50 graves were excavated, consisting of 54 individuals, and dated to the post-Meroitic (36 individuals) and Medieval periods (18 individuals) (Judd, 2012). The post-Meroitic burials are marked by stone clad tumuli, with oval/semi-circular graves. Most bodies were contracted, oriented East-West. The Medieval burials are varied in form, both super- and sub-structure, except for 4 graves which are Christian in style (extended, head to the west). The skeletal collection contains males, females and sub-adults. Dental preservation at the site varied depending on time period, with only 16.8% of teeth recovered from the Meroitic individuals compared with 75%/73% in the post-Meroitic/Medieval periods (Judd, 2012).

5.3.9 Soba East

Soba was the capital of the medieval kingdom of Alwa, although it was an urban centre from the post-Meroitic period (c. 6th Century). Three different cemeteries (Mound B, Area UA3, Mound Z) were partially excavated, with all the burials dating to the Christian period or later (Welsby, 1998). A total of 66 individuals were exhumed and available for analysis. Preservation of the skeletal remains is relatively poor, although the dental preservation is better.

Mound Z was located to the east of Building G. Most of the burials consisted of simple rectangular grave cuts with vaulted brick chambers, some with associated rectangular mud or red brick superstructures. In several burials evidence of wooden coffins was present. As is the Christian norm, graves and bodies were aligned East-

West. Individuals were interred in an extended supine position, with head placed to the west. Grave goods were rare. Additionally, a group of later burials, which cut into the earlier graves, were excavated at Mound Z. These burials had simple oval grave cuts, with a varied orientation. Individuals were mainly placed on their side, either in crouched or extended position. It has been suggested that these later burials could be from a different time period or a culture (Welsby, 1998).

Mound B was located near to Building A and Building B, it is thought that Building B was a church. All graves were long, narrow cuts with rounded ends (except for one oval cut). Graves were aligned east-west, with extended burials, head to the west.

A red brick tomb containing 17 individuals (16 adults and an unborn child) was excavated from Area UA3. Bodies were positioned in an extended position, placed closely together. Evidence suggests that the tomb was used only once indicating that all individuals died at the same time. Eight other graves were found outside the tomb, including seven sub-adult individuals. These additional graves are not thought to be contemporaneous with the tomb, but are also dated to the Christian period (Welsby, 1998).

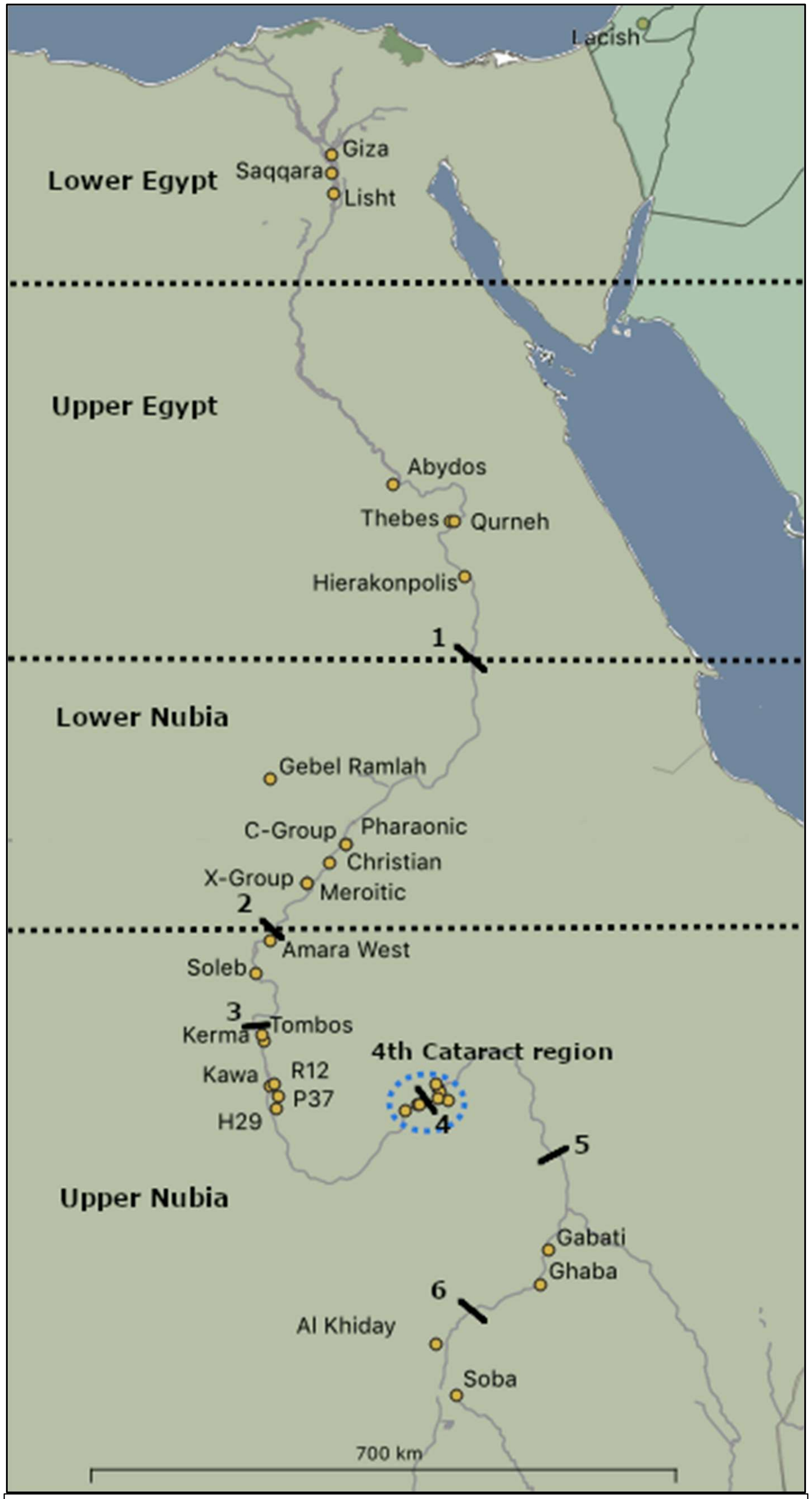
Some patterning within the cemeteries was observed. Firstly, males were more likely to be found in Mound B, females in Mound Z, and sub-adults in Mound Z and latter graves in Area UA3. Secondly, the grave cuts were different in Mound B and Mound Z. This was supplemented by differences in the types of textiles associated with the burials in the two areas. Burials in Mound B had remnants of cloth made from vegetation, probably flax. Whereas the burials in Mound Z contained textiles made from animal fibres, probably from sheep (Welsby, 1998).

SAMPLE	DETAILS OF PREVIOUSLY PUBLISHED WORKS
KERMA CLASSIQUE (KMC)	Reisner, 1923; Collett, 1933; Judd and Irish, 2009; Irish, 2005
SOLEB (SOL)	Billy and Chamla, 1981; Irish, 2005
TOMBOS (TOM)	Schrader et al., 2014; Buzon et al., 2016
AL KHIDAY NEOLITHIC (AKN)	Usai et al., 2010; Salvatori et al., 2018; Usai and Salvatori, 2019; Irish and Usai, 2021
GEBEL RAMLAH (GRM)	Schild et al., 2002; Irish et al., 2003
C-GROUP (CGR)	Nielsen, 1970; Irish, 2005
HEIRAKONPOLIS C-GROUP (HKC)	Irish and Friedman, 2010
PHARAONIC (PHA)	Nielsen, 1970; Irish, 2005
MEROITIC (MER)	Zabkar and Zabkar, 1982; Irish, 2005
X-GROUP (XGR)	Zabkar and Zabkar, 1982; Irish, 2005
CHRISTIAN (CHR)	Zabkar and Zabkar, 1982; Irish, 2005
ABYDOS (ABY)	Petrie, 1902,1922; Bard, 2000; Irish, 2006
THEBES (THE)	Callender, 2000; Irish, 2006
QURNEH (QUR)	Petrie, 1909; Irish, 2006
SAQQARA (SAQ)	Bayfield, 2000; Malek, 2000; Grajetzki and Quirke, 2001a; Irish, 2006
LISHT (LIS)	Baines and Malek, 1982; Irish, 2006
GIZA (GIZ)	Petrie, 1907; Pearson and Davin, 1924; Irish, 2006
LACHISH (LAC)	Ullinger et al., 2005; Horwarth et al., 2014
ETHIOPIA (ETH)	Irish, 1993, 1997; Irish and Konigsberg, 2007
SOMALIA (SOM)	Irish, 2010
CHAD (CHA)	Irish, 1993, 1997
KENYA (KEN)	Irish, 1993, 1997
TANZANIA (TAN)	Irish, 1993, 1997
SUB-SAHARAN AFRICA CENTRAL (SSC)	Irish , 2013
SUB-SAHARAN AFRICA EAST (SSE)	Irish , 2013
SUB-SAHARAN AFRICA SOUTH (SSS)	Irish , 2013
SUB-SAHARAN AFRICA WEST (SSW)	Irish , 2013
NORTH WEST AFRICA (NWA)	Irish , 2013
SOUTH EASTERN MEDITERRANEAN (SEM)	Ullinger et al., 2005; Horwarth et al., 2014; Irish et al., 2017

Table 5.3 Details of previously published work

5.4 Published data

Data previously recorded by Irish (eg., Irish, 1993, 1997, 2005, 2006, 2010) were included in the study. Several samples were selected to contextualise the data



Dotted blue line = 4th Cataract region. Lines and numbers = Cataracts of the Nile. Yellow dots = collections used in study.

Figure 5.3 Map of Nile valley

collected. Samples from sub-Saharan Africa, Egypt, Lower Nubia, and the Southeast Mediterranean were utilised. Table 5.3 contains details for each collection, including where the data and background has been previously published. Figure 5.3 is a map detailing the locations of samples from the Nile valley and Lachish.

5.5 Organisation of samples

Some samples in the analysis are an amalgamation of smaller collections from the same period and location. Combining some of the collections ensured that all data could be used in the analysis and helped create robust sample sizes. As preservation in two of the 4th Cataract collections from the Kerma period (4-L-88 and 4-L-100) is poor, all three Kerma collections were pooled to create a ‘Kerma 4th Cataract’ sample (referred to as 4CKM in figures). Individuals/collections associated with the post-Meroitic period in the 4th Cataract were combined due to the small sample size of the separate collections. As such, a ‘post-Meroitic 4th Cataract’ sample (4CPM) was created from the individuals in: 3-O-1, 4-M-53, and part of 3-Q-33. Additionally, as P37 and O16 had relatively small sample sizes and were positioned closely together, the collections were merged under ‘P37’.

To study geographical patterning in Nubia, samples were assigned to one of four regions. Upper Nubia was split into three areas: Dongola Reach, 4th Cataract, and 6th Cataract. The three regions (and the samples they are comprised of) can be found in Table 5.1. Collections from Lower Nubia were grouped together. The samples from Egypt were split into two groups, Upper and Lower Egypt; details can be found in Table 5.1.

5.6 Methods

5.6.1 Inclusion in the Study

Both sex and age were recorded to better understand the demography of the samples. During analysis both sex and age groups were pooled to create the largest possible data sets. The pooling of age/sex is standard practice in ASUDAS studies, as this has been shown to have little or no effect on trait expression and occurrence of dental nonmetric traits (Scott and Irish, 2017).

An individual was defined as an adult by using the presence of third molars. An individual had to have one fully erupted (i.e. in occlusion) third molar from both the upper and lower jaw to be considered adult. Where these data were not available, the fusion of the basioccipital basisphenoid synchondrosis (BOBSS) was used to distinguish between adults and sub-adults.

Morphological features of the pelvis were used to determine sex in the adults, as they are commonly considered the most reliable indicators in the human skeleton (Garvin, 2015, 241). Standard techniques (Buikstra and Ubelaker, 1994; Bruzek, 2002) were used to determine if the individual was male, male?, female, female?, or unknown.

Only the permanent dentition was analysed, as there are insufficient data on deciduous dental nonmetric traits for this level of analysis (Scott et al, 2018). All individuals with at least one permanent tooth available to score were included, ranging from approximately six years in age, when the first permanent molars have erupted, to adult (Hillson, 1996).

5.6.2 Dental non-metric trait recording

The Arizona State University Dental Anthropology System (ASUDAS) was used to score the dental nonmetric traits. The ASUDAS sets out procedures for the observation of morphological traits in the modern human permanent dentition. This approach has been successfully applied in bio-distance studies worldwide (Irish, 2005), and specifically in Nubia. Other scoring systems have been developed but the ASUDAS is by far the most widely used in anthropology and is seen as the 'gold standard' in this area (Irish, 2015; Irish and Scott, 2015). The system was developed at Arizona State University, building on previous work by other anthropologists, especially that by A.A. Dahlberg (Turner et al, 1991). Reference plaques, as well as detailed descriptions, are used to standardise scoring and reduce inter- and intra-observer error levels (Irish and Guatelli-Steinberg, 2003). This standardization has led to the system being used in multiple studies and has produced reliable results. As the ASUDAS has be successfully utilised by multiple authors, with low inter-observer error levels, as such published results from previous studies can be used for direct comparison (Scott and Irish, 2017).

Professor Joel Irish, who was trained at Arizona State University by the developer of the system, provided training to the author in the ASUDAS. This training included several in depth sessions to ensure correct identification of traits and insignificant inter-observer error tests. Thorough training guarantees that the data collected are comparable to other studies. To ensure that trait scoring was maintained at a high standard, regular intra-observer error tests were also completed (see below section 5.6.3). Data were input periodically to confirm the trait frequencies and numbers for each collection. Inputting the data in this manner allowed for any inconsistencies /

outliers to be investigated. To help achieve repeatable scoring, all dentitions were recorded in the same labs at the British Museum and LJMU. Where possible the same desk and lighting were used. In addition, all teeth and jaws were cleaned when necessary to ensure any visible traits could be scored correctly. Each individual was recorded using the standard ASUDAS recording sheet (see Appendix 4). It allows for each antimere to be observed, and the degree to which the trait is found to be present is scored. Each trait has a different grading system based on the iterations observed, which are denoted on an ordinal- or rank-scale (Scott and Irish, 2017).

The individual count method was used for antimere selection. This entails recording both antimeres, but only the tooth showing the highest degree of expression for the particular trait is counted (Turner and Scott, 1977). This method has a threefold advantage. Firstly, it ensures that the phenotype is best represented through the recording of the maximum expression for the individual. Secondly, it maximises sample size, as often not all 32 teeth were present. Lastly, it handles the issue of fluctuating asymmetry, see Figure 5.4 (Irish, 2005). This method is widely used in ASUDAS studies (Irish, 2005).

Wear was scored using the guidelines laid out in Turner et al. (1991). This method includes six levels of wear varying from no visible wear, to only roots remaining (see Figure 5.5). Tooth wear can adversely affect the ability to correctly score crown traits (Burnett et al, 2013). To ensure reliable scoring, only crown traits which could be fully observed were scored. Depending on the type of wear, this was often around the level 3 or 4. Some crown traits were also more affected by wear as they are expressed in the enamel only and have no presence in the dentine below. As such,

a – Slight asymmetry in expression of tuberculum dentale on UI2. b – Slight asymmetry in expression of Carabelli's trait on the UM1. c – Marked asymmetry in expression of protostylid on LM3. d – Marked asymmetry in expression of Tomes' root on LP1

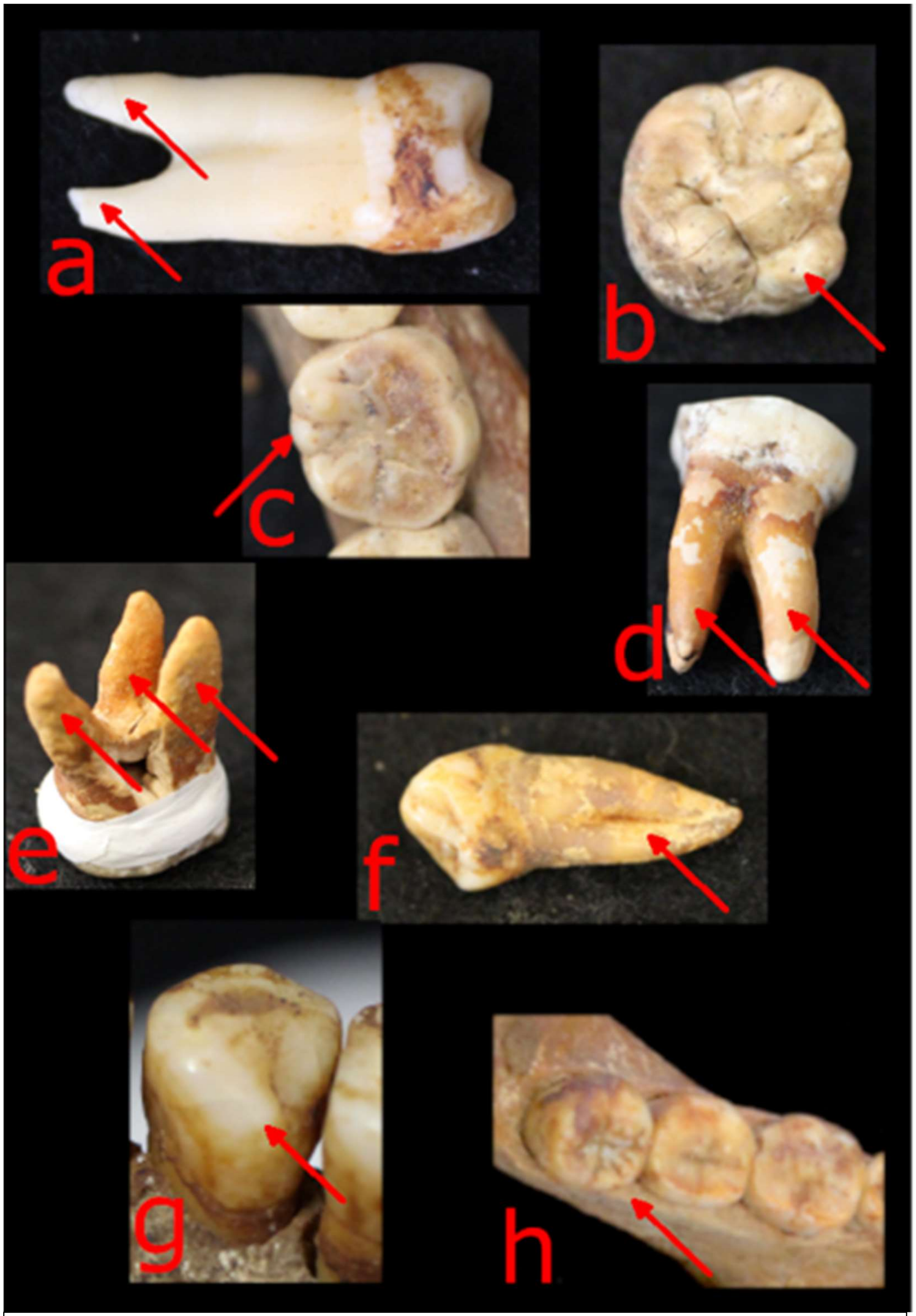
Figure 5.4 Asymmetry in nonmetric trait expression

Individual a exhibits low levels of wear on lower dentition. Individual b exhibits high levels of wear on lower dentitions.

Figure 5.5 Differing levels of wear

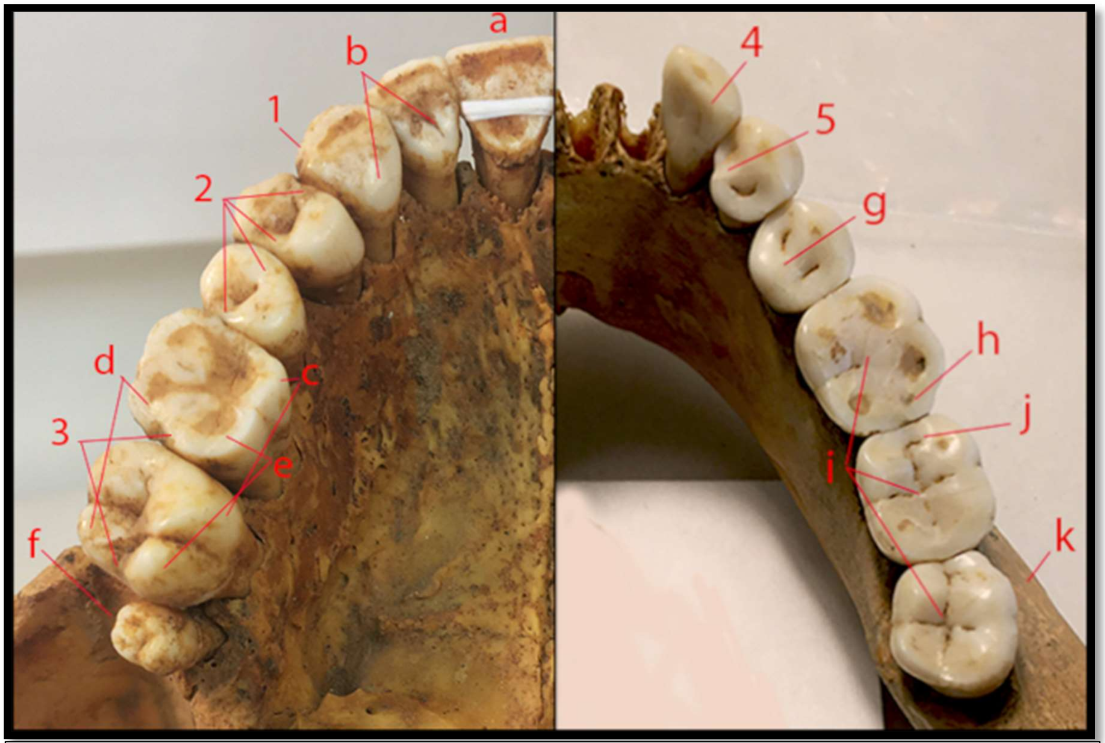
traits like Upper Premolar Accessory Cusps are affected by minimal wear, whereas Lower Molar Cusp Number can be identified on more severely worn teeth (Burnett et al, 2013).

Of the many non-metric variations seen in the dentition and jaw of modern humans, 42 traits comprise the ASUDAS (Scott and Irish, 2017). The entire suite of ASUDAS traits is not always used in each study. Traits can differ between published data. Irish identified 11 traits, nine high frequency and two low frequency, that make up the 'sub-Saharan dental complex' (Irish, 1998), now termed Afridonty (Irish, 2013). The nine high frequency traits are mass-additive in nature including, upper canine mesial ridge, two-rooted premolar (UP1), Carabelli's trait (UM1), three-rooted molar (UM2), cusp 7 (LM1), Tome's root (LP1), Y-groove pattern (LM2), two-rooted (LM2), and presence of UM3 (see Figure 5.6). Double shovelling (UI1) and enamel extension (UM1) are the low frequency traits. Afridonty is just one of the recognised dental complexes that have been identified worldwide, these include Eurodonty (Scott et al, 2013), Indodonty (Hawkey, 1998, 2004), Sinodonty (Turner, 1985), Sundadonty (Turner, 1987). Afridonty is seen as being indicative of peoples from sub-Saharan Africa and distinct from peoples of North Africa. Although all African populations share a level of homogeneity, North African dentitions share similarities with European dentitions, notably in the presence of mass-reduced dental traits (e.g., M3 agenesis, peg/reduction, molar cusp number etc.) (Irish, 1998). Irish, in previous studies of African collections (1997, 2005, 2006, etc.), used a suite of 36 traits comprising crown, root, and inter-oral osseous features (see Figure 5.7 and Appendix 3). This suite of traits includes many of the widely found variations in the dentition and have been used in multiple studies of populations around the world (including but not limited to Africa (Irish, 1998a; Irish, 1997; 1998b; Irish and Guatelli-Steinberg, 2003; Irish and Turner, 1990), the Americas (Aguirre et al, 2006;



a- two rooted UP1, b- Carabelli's trait, c- LM1 cusp 7 , d- two rooted LM2, e- three rooted UM2, f- tomes root LP1, g- canine mesial ridge, h- presence of M3

Figure 5.6 Afridonty nine high frequency traits



Letters indicate trait is present, numbers indicate where traits are absent, not all 36 traits are depicted. a- labial curvature, b- tuberculum dentale, c- Carabelli's trait, d- metacone, e- hypocone, f- reduced 3rd molar, g- multiple LP2 lingual cusps, h- LM cusp 5, i- LM groove patter (M1 and M2 = Y, M3 = X), j- anterior fovea, k- torsomolar angle (buccal direction). 1- double shoveling and distal accessory ridge, 2- Premolar accessory cusps, 3- UM cusp 5, 4- distal accessory ridge, 5- LP1 lingual cusp. Detailed figures for all 36 traits can be found in Scott and Irish, 2017.

5.7 Arizona State University Dental Anthropology System traits.

LeBlanc et al, 2008; Willermet et al, 2013), Asia (Kaburagi et al, 2010; Matsumura, 2006; Peiris et al, 2011; Ullinger et al, 2005), Europe (Coppa et al, 2007; Scott et al., 2013; Horwath et al, 2014; Khudaverdyan, 2014), and Oceania (Ichikawa and Matsuno, 2008; Itou and Matsuno, 2011)). As such, the same 36 traits were used in this study and the data is directly comparable to the published data used in other studies.

Once the traits for each individual were recorded, the ordinal results for each trait were dichotomised into categories of present or absent. The dichotomisation of the traits has been questioned by some researchers. As many are quasicontinuous in nature (Scott et al., 1983; Scott and Turner, 1988), it has been suggested that the nuances of trait expression are lost via the dichotomisation process (Carson, 2006; Hauser and De Stefano, 1989). The advantages of dichotomising are: less intra/inter-observer error (Hubbard et al, 2015), higher heritability estimates (Stojanowski et al, 2019), and decreased environmental effects (Ricaut et al, 2010). Standardised breakpoints are used to determine presence/absence. These thresholds should be representative of the degree of expression of the traits in the specific assemblages being studied. This means that if a trait is common in certain population, the breakpoint may need to be moved to ensure that normal distribution is achieved (Scott et al, 2016). The dichotomisation of the traits is performed to allow basic comparisons between assemblages and to further explore the data in quantitative analyses (Scott and Irish, 2017). Once the data are dichotomised, it is possible to observe where there are differences in trait frequencies between samples, especially when converted into percentages, to remove the issue of comparing samples of different sizes (Irish, 2005). Although the basic review of results (above) is useful, it can be hard to interpret due to the large amount of data across all 36 traits. Model-free and model-bound analyses can be used to further illustrate the relationships between assemblages (see sections 5.6.4 and 5.6.5).

5.6.3 Inter- and Intra-observer Tests

To test the reliability and repeatability of scoring traits from the ASUDAS, the Ghaba collection was used, because it had previously been scored by Irish (Irish and Degroote, 2016). The collection consists of 115 individuals with varying degrees of preservation; as such it provided a good a basis to test scoring methods. Fisher’s exact test was used to compare presence and absence in all 36 traits. Comparing both presence and absence provided a chance to examine whether both researchers identified the trait and whether the site/tooth was available for scoring.

In addition, tests on the reliability of the author's scoring were completed throughout the data collection process. Individuals from various sites were re-scored, with always a minimum of 30 days between scoring dates. Where possible the same lab and lighting conditions were used to standardise the scoring conditions. Cohen's Kappa Coefficient (in SPSS) was used to test intra-observer reliability.

5.6.4 Model-free analyses

An efficient way to reveal relationships between assemblages is by using distance analyses. Distance statistics such as the mean measure of divergence (MMD) (Sjøvold, 1977), Gower Distance (Gower, 1966), and pseudo-Mahalanobis D2 (D2) (Konigsberg, 1990) have been used to reveal phenetic distances between samples with non-metric data. Previously, there has been much discussion about which statistic is the best to use, especially with regards to D2 and MMD—the two most widely used biodistance methods (Irish, 2010). The MMD was chosen for this study for several reasons. Firstly, it uses trait frequencies at a group level rather than at the individual level (as D2 does), allowing data from the entire group to be included even if some traits in certain individuals are missing. Secondly, it can handle small sample sizes if the relevant correction is applied. Both of the aforementioned issues occur often when studying archaeological material. Thirdly, it has been used successfully in previous projects and has been shown to produce results that are comparable to D2. Finally, it produces high correlations with geographical data (Irish, 2010). The MMD equation used in this study is presented below, taken from

Harris and Sjøvold (2004). This includes the Freeman and Tuckey (1950) angular transformation to correct for low (≤0.05) or high (≥0.95) trait frequencies, as well as small sample sizes.

$$MMD = \frac{\sum_{i=1}^{r} (\theta_{1i} - \theta_{2i})^2 - (1/(n_{1i} + 1/2) + 1/(n_{2i} + 1/2))}{r}$$

The MMD statistic was run in R (R_Core_Team, 2017), using the script written by Sołtysiak (2011). The MMD script in R produces a distance matrix that reveals whether two assemblages are phenetically similar to one another (Harris and Sjøvold, 2004). As the MMD is a dissimilarity statistic, the closer the MMD value is to zero the higher the affinity between samples. The standard deviation and statistical significance for each MMD value were also calculated. Significant differences are assessed by comparing the MMD distance with its standard deviation (using Sjøvold's formula (1973)). The R script uses two-sided Z-scores (counted as MMD/SD) to calculate the p-value for each MMD value (Sołtysiak, 2011). Significance was set at the 0.025 alpha level (Sjøvold, 1977). Alternative formulae and approaches have been used in the past (Constandse-Westermann, 1972; Harris and Sjøvold, 2004; Sjøvold, 1977; Suchey, 1975).

To get the best results from the MMD, all dichotomised data need to be edited before application (Harris and Sjøvold, 2004). The editing process is three-fold and was completed for each data set described in the following chapter. First, any traits where sample size was consistently under 10 were removed, as distance statistics are less likely to produce reliable results (Green et al, 1979). Second, traits that are found to be nondiscriminatory are removed. These were identified via principal component analysis (PCA), using SPSS 26.0 (IBM_Corp, 2019). PCA identified the traits that were most influential in producing variation between the samples and those which were least influential. The results of the PCA analysis were plotted on a 3D-graph, to demonstrate the relationship between the PCA loadings and the sample distribution (Irish, 2010). The number of principal components used in each analysis was determined by reviewing a scree plot of the eigen values. The scree plot was used to identify the point at which the proportion of variance reduces, this indicates the optimal number of principal components to use in the analysis whilst still including a high level of variance. Additionally, the combined total variance had to be at least 60% from the chosen principal components. Any trait with loadings of less than 0.4 across all the relevant principal components were removed (Dunteman, 1989). Third, any correlated traits were removed before the MMD distance statistic can be run, as their inclusion can produce inaccurate results (Sjøvold, 1977). Kendall's tau-b test in SPSS, was used to determine which traits are inter-correlated (Irish, 2010). Any trait pairing with a correlation of 0.6 and above was identified and at least one of the traits removed.

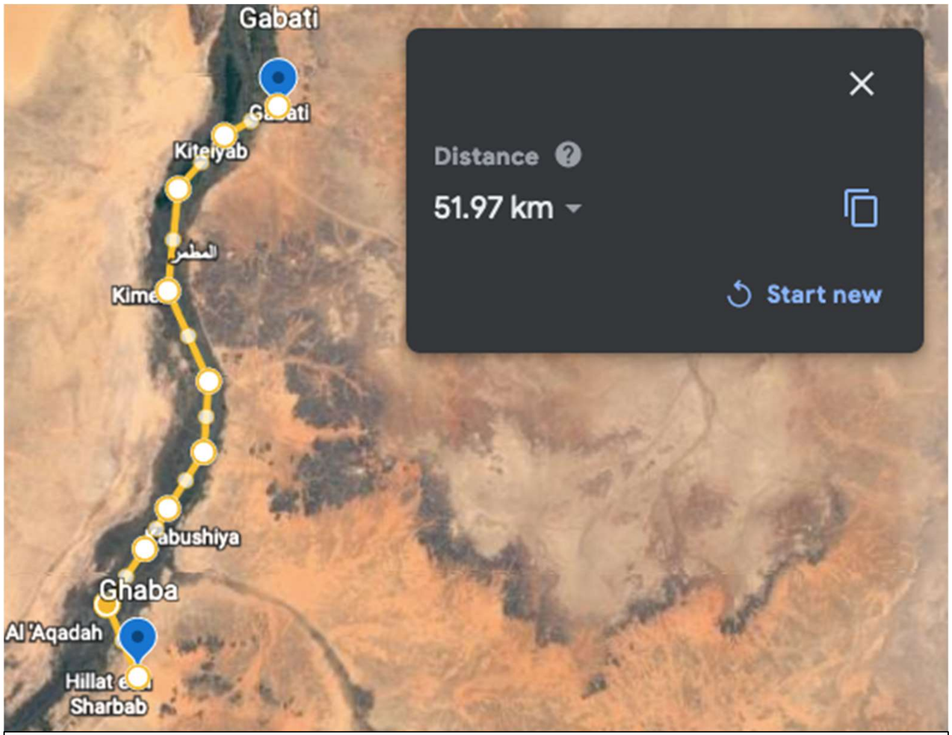
MMD analysis was run on the full 36-trait data and the edited suite of traits. The resulting distance matrices were submitted to multidimensional scaling (MDS). MDS converts the distance values into a graphic representation, illustrating proximities of samples to one another (Kruskal and Wish, 1978). MDS creates vectors in n-dimensional space based on the distance matrix and calculates the Euclidean distance between said vectors. A matrix based on the Euclidean distances between the different paired points is created. The Euclidean distance matrix is compared to the original distance matrix. The vectors are modified multiple times until the iteration with minimum stress and maximum r2 is obtained (Borg and Groenen, 1997; Borgatti, 1997; Cox and Cox, 1994; Kruskal and Wish, 1978). Stress was calculated using Kruskal's stress formula 1. In this study a stress value of under 0.15 was targeted (Borgatti, 1997), anything above this level was noted in the results. If MDS produces high levels stress this means that the graphical distance depicted may not represent the true relationship between the samples. The ALSCAL program is SPSS was used to convert the distance matrix. ALSCAL uses a sum of squares algorithm to create the optimally scaled Euclidean distance for each sample-pairing (IBM_Corp, 2019). As such, a close spatial relationship between two points on the MDS plot suggests a close relationship between the two relevant samples (Irish, 2010).

5.6.5 Model-bound analyses

The relationship between geographical distance, temporal distance, and biological affinity was tested using a model constructed by Konigsberg (1990). Konigsberg's model (1990) is based on elements of three prior models: Wright's (1951) Island Model (temporal isolation), Kimura and Weiss's (1964) Unidimensional Stepping-Stone Model (a modified version of the Isolation by Distance Model (Wright, 1943)), and a migration matrix (e.g. Harpending and Ward, 1982). The model compares biological distance with temporal distance (accounting for geographical distance) and biological distance with geographical distance (accounting for temporal distance). Distance (temporal/geographical/biological) data between samples is inputed into a matrix and then compared to ascertain if they are correlated. The expectations of the model are as follows: as geographic distance increases so does biological distance (positively correlated), and as temporal distance increases biological distance decreases (negatively correlated). Konigsberg's model (1990) has been used by various authors to investigate archaeological samples which are often separated by both time and space (Steadman, 2001; Zakrzewski, 2007; Godde, 2009, 2013; Godde and Jantz, 2017).

Following Konigsberg (1990), three distance matrices were created. A temporal matrix was generated using the median of the date range for each sample. The date range was based on a date range assigned by cultural association rather than radiocarbon dates as these were not available (Godde, 2013). This median date was used to calculate the differences in time between each sample. Straight-line geographical distances were calculated by inputting the geo-coordinates for the sites into the Geographic Distance Matrix Generator (Ersts, no date). This program produced a straight-line geographic distance matrix. Geo-coordinates were obtained from the site reports where possible, or via Google Earth if they were not listed in the reports. The distance between the sites, following the route of the Nile, was also created. River distances have been shown to produce stronger correlations with biological affinity than straight-line distances (Buikstra, 1980). The river distances were measured using the ruler tool in Google Earth (see Figure 5.8). For biological distance the MMD values (both 36 trait and edited versions) were used to create the matrices (MMD equation can be found in section 5.6.4).

Vecchyo and Slatkin (2018) found that when comparing pairwise F_{ST} values from historical and modern samples, a stepping-stone model can explain both isolation by time and geographical distance. Vecchyo and Slatkin (2018) proffered that at short distances an isolation by time model is observed, and that an isolation by distance model is observed at long distances. To test whether the above patterning also applies to phenetic data, the relationship between biological distance and time/geography was tested without accounting for the third variable.



Example of ruler tool in Google Earth

Figure 5.8 Google Earth distance calculation

Mantel tests (Mantel, 1967) were used to ascertain whether the matrices are correlated. As in the original model (Konigsberg, 1990), a partial (3-way) Mantel test (Smouse et al., 1986) was used to determine the relationship between the geographical, temporal and biological distance matrices. Additionally simple Mantel tests were conducted between the geographical/temporal distance matrices and the biological distance matrices. Simple and partial Mantel tests were performed on PAST 4 (version 4.09) (Hammer et al., 2001). Pearson’s correlation coefficient was used to calculate the r value, the significance test was one tailed. Mantel tests are widely used to compare matrices as they are easy to interpret and simple to perform.

The use of Mantel tests in other studies offers opportunities to compare results on a like for like basis. The tests have come under criticism in recent years over its efficacy with regards to power and type I error (Peres-Neto and Jackson, 2000; Legendre and Fortin, 2010; Guillot and Rousset, 2013). Even with these criticisms, Mantel tests have proven to be robust (Séré et al., 2017) and produce comparable results to alternative methods (Peres-Neto and Jackson, 2000; Diniz-Filho et al., 2013; Godde and Jantz, 2017).

5.7 Summary

The skeletal assemblages presented in sections 5.1-5.5 were selected to represent past populations from Nubia and the surrounding region. Although this study includes a broad and comprehensive array of collections (ranging from the geographically focused 4th Cataract to the expansive regional collections) there are still gaps. For example, no skeletal collections from the Napatan period were available. Additionally, some periods are not represented in certain regions (i.e., Neolithic in the 4th Cataract). Due to the nature of archaeology, it may never be possible to obtain truly representative data of past populations. With each new collection studied our understanding increases and provides further clarity on Nubia in the past. The methods listed above in section 5.6 will be implemented to allow further investigations into the relationships between samples. The methods have been chosen as they are known to produce reliable and robust results, both in Nubia and worldwide. Chapter 6 reports the results from these analyses. As the methods have been used multiple times in previous studies, the results from this current study will be readily comparable to other works.

6. Results

The results relayed in this chapter were produced using the methods described in Chapter 5. Firstly, intra- and inter-observer tests will be discussed. Next the results for the biodistance study will be reported. Finally, the Mantel test findings will be detailed.

6.1 Inter- and Intra-Observer error tests

6.1.1 Inter-Observer Error Test

Results for the Fisher's exact test found no significant differences in the scoring data for the 36 traits, providing p values ranging from 0.12 – 1.00 . Most of traits no differences were found, with 18 traits producing a p value of 1.00. Where differences were found these were random but mostly concerned with differences in assessing whether a site/tooth was visible for scoring (see Appendix 1)

6.1.2 Intra-Observer Error Test

For each error test Fisher's exact test was used to identify any differences in the scoring. Results revealed that no significant differences were found ($p = 0.05$) (see Appendix 2)

6.1.3 Summary of Inter- and Intra-Observer error tests

Inter- and Intra-observer error testing revealed that there were no significant differences in the scoring of the ASUDAS traits. These results indicate that not only was the ASUDAS technique applied correctly by the author, but that data collected by Professor Irish could be used in this study.

6.2 Biodistance results

Description of the results will be split five sections. Results for the samples from the geographically focused area of the 4th Cataract will be relayed first, then increasing in geographical scale to cover samples from Upper Nubia, Nubia (Upper and Lower), East Africa, and Lachish, and finally regional samples representing the African continent as a whole and the Southeast Mediterranean. Each section will cover the trait frequencies, MMD, and PCA results where relevant. The tags for each sample (used in the text, tables, and figures) are detailed in Table 5.1 from the previous chapter. This table also assigns the samples into the time periods and regions/groups referenced in the below text. Significant MMD values are shown in red on the relevant tables (p=0.025).

6.2.1 Fourth Cataract

Table 6.1 shows the trait percentages and sample sizes for the 4th Cataract samples. Although a level of homogeneity can be observed for the region, some between group variation is evident in the trait frequencies. Not all traits are present in all samples (i.e., enamel extension is not present in 3-Q-33, 4th Cataract Kerma (4CKM), and 4th Cataract post-Meroitic (4CPM)). Additionally, some traits show higher frequencies in several groups, like UI1 shovelling in 4CKM. The samples from the 4th Cataract exhibit several traits that contribute to complexity in both the crown and root, and are associated with the sub-Saharan dental complex, a.k.a., Afridonty (i.e., UI1 shovelling, Bushman Canine, UC distal accessory ridge, five-cusped LM2, LM1 deflecting wrinkle, LM1 cusp 7,

TRAITS AND BREAKPOINTS	4TH CATARACT KERMA (4CKM)	3-Q-33 (3Q33)	4TH CATARACT POST-MEROITIC (4CPM)	3-J-23 (3J23)	3-J-18 (3J18)
WINGING UI1	7.7[A]	9.1	0.0	8.9	5.4
(+ = ASU 1)[C]	13.0[B]	11.0	13.0	56.0	93.0
LABIAL CURVATURE UI1	46.2	11.1	30.0	35.0	20.5
(+ = ASU 2-4)	26.0	9.0	10.0	60.0	83.0
PALATINE TORUS	9.1	0.0	0.0	16.9	11.7
(+ = ASU 2-3)	11.0	24.0	12.0	77.0	94.0
SHOVELING UI1	75.0	0.0	22.2	39.5	53.9
(+ = ASU 2-6)	16.0	8.0	9.0	38.0	39.0
DOUBLE SHOVELING UI1	0.0	0.0	0.0	1.6	0.0
(+ = ASU 2-6)	22.0	10.0	12.0	61.0	78.0
INTERUPTION GROOVE UI2	38.9	33.3	30.0	28.0	9.9
(+ = ASU +)	18.0	12.0	10.0	50.0	71.0
TUBERCULUM DENTALE UI2	36.8	10.0	60.0	32.6	52.1
(+ = ASU 2-6)	19.0	10.0	10.0	46.0	48.0
BUSHMAN CANINE UC	6.7	10.0	9.1	21.6	22.2
(+ = ASU 1-3)	15.0	10.0	11.0	37.0	54.0
DISTAL ACCESSORY RIDGE UC	41.7	22.2	37.5	44.4	27.3
(+ = ASU 2-5)	12.0	9.0	8.0	27.0	33.0
HYPOCONE UM2	93.6	84.2	100.0	87.5	83.5
(+ = ASU 3-5)	31.0	19.0	21.0	80.0	109.0
CUSP 5 UM1	30.0	33.3	0.0	31.8	16.2
(+ = ASU 2-5)	20.0	9.0	7.0	44.0	37.0
CARABELLI'S CUSP UM1	40.0	23.1	16.7	42.1	36.6
(+ = ASU 2-7)	20.0	13.0	12.0	57.0	71.0
PARASTYLE UM3	9.7	7.1	5.9	10.7	5.4
(+ = ASU 1-5)	31.0	14.0	17.0	56.0	74.0
ENAMEL EXTENSION UM1	0.0	0.0	0.0	18.6	12.1
(+ = ASU 1-3)	4.0	7.0	10.0	43.0	33.0
ROOT NUMBER UP1	50.0	63.2	82.4	52.9	75.3
(+ = ASU 2+)	38.0	19.0	17.0	51.0	81.0
ROOT NUMBER UM2	79.4	72.2	90.0	75.0	87.8
(+ = ASU 3+)	34.0	18.0	20.0	40.0	82.0
PEG-REDUCED UI2	3.5	11.1	4.8	1.4	0.0
(+ = ASU P OR R)	29.0	18.0	21.0	74.0	108.0
ODONTOME P1-P2	0.0	0.0	0.0	0.0	0.0
(+ = ASU +)	33.0	20.0	18.0	60.0	87.0
CONGENITAL ABSENCE UM3	2.8	4.0	11.1	8.0	18.9
(+ = ASU -)	36.0	25.0	27.0	75.0	122.0
MID LINE DIASTEMA UI1	16.7	14.3	0.0	18.0	29.2
(+ ≥ 0.5 MM)	6.0	14.0	7.0	50.0	65.0
LINGUAL CUSP LP2	90.9	81.0	91.3	93.0	94.4
(+ = ASU 2-9)	22.0	21.0	23.0	57.0	89.0

ANTERIOR FOVEA LM1	47.1	16.7	0.0	40.4	25.0
(+ = ASU 2-4)	17.0	12.0	8.0	47.0	32.0
MANDIBULAR TORUS	0.0	0.0	5.0	0.0	0.0
(+ = ASU 2-3)	14.0	20.0	20.0	64.0	97.0
GROOVE PATTERN LM2	24.0	37.5	30.4	52.9	48.1
(+ = ASU Y)	25.0	24.0	23.0	68.0	106.0
ROCKER JAW	18.2	10.5	5.0	16.1	29.4
(+ = ASU 1-2)	11.0	19.0	20.0	62.0	92.0
CUSP NUMBER LM1	15.4	0.0	6.3	10.8	4.4
(+ = ASU 6+)	26.0	20.0	16.0	74.0	92.0
CUSP NUMBER LM2	37.5	32.0	31.8	37.1	17.9
(+ = ASU 5+)	24.0	25.0	22.0	70.0	106.0
DEFLECTING WRINKLE LM1	38.9	25.0	20.0	44.2	33.3
(+ = ASU 2-3)	18.0	12.0	5.0	52.0	45.0
C1-C2 CREST LM1	0.0	0.0	0.0	8.7	12.2
(+ = ASU +)	14.0	11.0	4.0	46.0	41.0
PROTOSTYLID LM1	0.0	17.7	0.0	4.8	13.8
(+ = ASU 1-6)	14.0	17.0	15.0	62.0	80.0
CUSP 7 LM1*	12.5	15.0	6.3	13.9	5.6
(+ = ASU 2-4)	24.0	20.0	16.0	72.0	90.0
TOMES ROOT LP1	25.9	27.8	15.0	18.5	19.6
(+ = ASU 3-5)	27.0	18.0	20.0	54.0	97.0
ROOT NUMBER LC	0.0	0.0	0.0	0.0	0.0
(+ = ASU 2+)	45.0	24.0	22.0	71.0	125.0
ROOT NUMBER LM1	2.0	0.0	0.0	0.0	0.9
(+ = ASU 3+)	51.0	25.0	23.0	77.0	111.0
ROOT NUMBER LM2	92.9	79.2	82.4	90.2	92.0
(+ = ASU 2+)	42.0	24.0	17.0	41.0	75.0
TORSOMOLAR ANGLE LM3	21.4	10.0	15.4	21.9	23.6
(+ = ASU +)	28.0	20.0	26.0	64.0	89.0

A.Upper row for each trait is the frequency in %, B.,Lower row is the number of individuals scored, C. ASUDAS trait score used as breakpoint referenced in brackets.

Table 6.1 4th Cataract trait percentages and sample size

and LP1 Tome's root). In addition to these mass additive traits, others that result in a more simplified dentition, i.e., mass reduced, like UM3 agenesis and UI2 reduction are also discerned. To assess how the samples relate to each other, the MMD was applied to the 36-trait data, with results in Table 6.2. A high level of affinity can be seen across the groups indicated by low MMD values.. The average MMD value for the 4th Cataract sites is 0.029. There are a few exceptions, such as 4th Cataract post-Meroitic (4CPM) differs significantly from 3-J-23. Additionally, 3-J-18 is significantly different from 4th Cataract Kerma (4CKM), 3-Q-33, and 3-J-23. The MMD value between 3-J-23 and 3-J-18 is low (0.028), usually an indication of a close affinity between samples. Although low, the samples are significantly different from each other. This is due to a low standard deviation (SD), as both samples are relatively large which can reduce the SD.

	4TH CATARACT KERMA (4CKM)	3-Q-33 (3Q33)	4TH CATARACT POST-MEROITIC (4CPM)	3-J-23 (3J23)	3-J-18 (3J18)
4TH CATARACT KERMA (4CKM)	0.000	0.054	0.024	0.000	0.044
3-Q-33 (3Q33)	0.054	0.000	0.001	0.035	0.082
4TH CATARACT POST-MEROITIC (4CPM)	0.024	0.001	0.000	0.054	0.045
3-J-23 (3J23)	0.000	0.035	0.054	0.000	0.028
3-J-18 (3J18)	0.044	0.082	0.045	0.028	0.000

Red = significant at p ≤ 0.025 level

Table 6.2 4th Cataract 36-trait MMD values.

As discussed in Chapter 5, to increase the accuracy of the MMD analysis traits should first be edited, here in a three-step process. Table 6.1 was reviewed to identify traits where the frequencies are low (<10%) across samples. These are: UI1 winging, UI1 double shovelling, P1/P2 odontome, mandibular torus, LC root number, and LM1 root number. Principal component analysis was used to determine which traits were responsible for the most/least amount of variation between the samples.

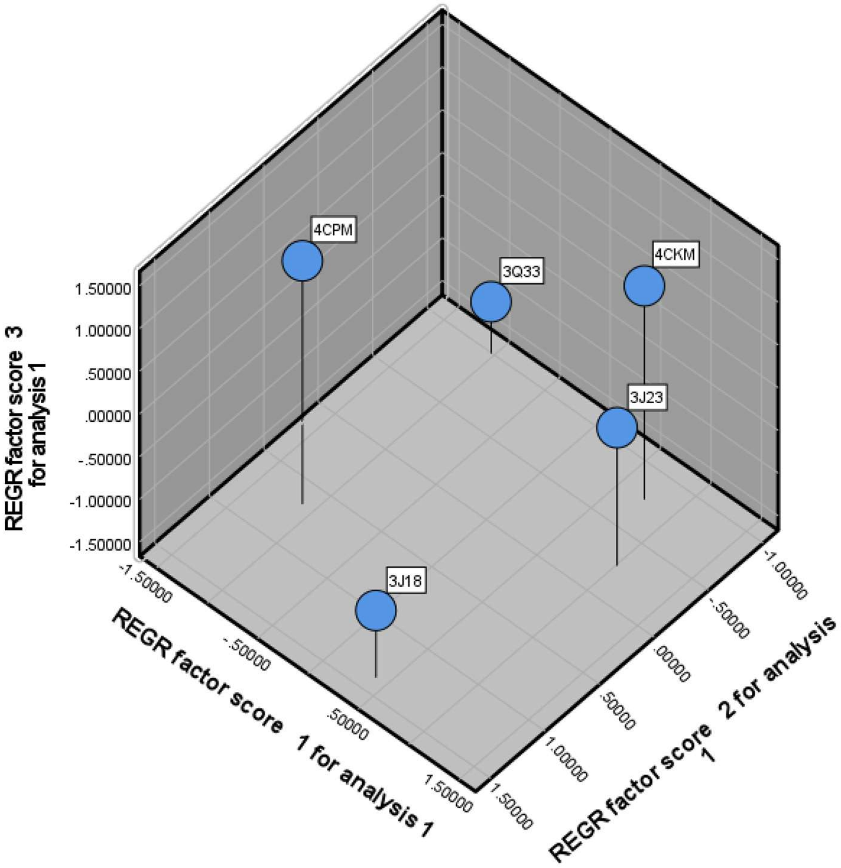


Figure 6.1 4th Cataract PCA loadings 3-D representation

The PCA results are detailed in Table 6.3. The first three components were used, producing 93% of the variation. The results were plotted on a 3-D graph (Figure 6.1) display how the trait loadings over the first three principal components were distributed across the five samples. The first prinicapal component separates the samples into two groups, 3-Q-33 and 4th Cataract post-Meroitic (4CPM) to the left and 3-J-18, 3-J-23, and 4th Cataract Kerma (4CKM) to the right. Differences in the frequencies of several traits, including maxillary torus, UM1 Carabelli's cusp, LM1 anterior fovea, LM1 deflecting wrinkle, LM2 root number, and LM3 torsomolar angle

	PRINCIPAL COMPONENT		
	1	**2**	**3**
LABIAL CURVATURE UI1	0.417	0.586	0.691
PALATINE TORUS	0.958	0.216	-0.115
SHOVELING UI1	0.728	0.262	0.386
INTERUPTION GROOVE UI2	-0.526	0.816	0.238
TUBERCULUM DENTALE UI2	0.318	-0.557	0.766
BUSHMAN CANINE UC	0.753	-0.399	-0.387
DISTAL ACCESSORY RIDGE UC	0.438	0.519	0.648
HYPOCONE UM2	-0.314	0.105	0.938
CUSP 5 UM1	0.165	0.717	-0.674
CARABELLI'S CUSP UM1	0.872	0.434	-0.181
PARASTYLE UM3	0.347	0.895	-0.023
ENAMEL EXTENSION UM1	0.82	-0.116	-0.283
ROOT NUMBER UP1	-0.297	-0.919	0.255
ROOT NUMBER UM2	0.127	-0.712	0.663
PEG-REDUCED UI2	-0.914	0.201	-0.351
CONGENITAL ABSENCE UM3	0.446	-0.894	0.049
MID LINE DIASTEMA UI1	0.699	-0.157	-0.621
LINGUAL CUSP LP2	0.812	-0.241	0.529
ANTERIOR FOVEA LM1	0.661	0.699	-0.159
GROOVE PATTERN LM2	0.569	-0.318	-0.549
ROCKER JAW	0.717	-0.485	-0.464
CUSP NUMBER LM1	0.508	0.64	0.567
CUSP NUMBER LM2	-0.225	0.878	0.248
DEFLECTING WRINKLE LM1	0.823	0.544	-0.154
C1-C2 CREST LM1	0.832	-0.436	-0.314
PROTOSTYLID LM1	-0.141	-0.358	-0.913
CUSP 7 LM1	-0.179	0.826	-0.499
TOMES ROOT LP1	-0.286	0.547	-0.568
ROOT NUMBER LM2	0.909	0.19	0.191
TORSOMOLAR ANGLE LM3	0.956	-0.004	0.248

Table 6.3 4th Cataract - Principal Component Analysis loadings. Graphical representation in Appendix 5.

have caused the groups to diverge. Samples 3-Q-33 and 4CPM have lower frequencies of the abovementioned traits than the others. Additionally, 3-J-18 is divergent from the other samples along the axis relating to component 2. Lower frequencies of UI2 interruption groove and LM1 cusp 7, paired with higher frequencies of UM3 congenital absence are responsible for the divergence. To complete the PCA editing process, any traits which had loadings lower than 0.4 were removed from the analysis. Finally, Kendall’s tau-b test identified correlations between the remaining traits. Those with a correlation of 0.6 or above were also deleted.

	4TH CATARACT	UPPER NUBIA	NUBIA	NORTH EAST AFRICA AND LACHISH	CONTINENTAL VIEW
WINGING UI1	*	*	*	*	*
LABIAL CURVATURE UI1					
PALATINE TORUS					
SHOVELING UI1	*				*
DOUBLE SHOVELING UI1	*	*	*	*	*
INTERUPTION GROOVE UI2	*	*	*	*	*
TUBERCULUM DENTALE UI2					
BUSHMAN CANINE UC			*	*	
DISTAL ACCESSORY RIDGE UC	*	*			*
HYPOCONE UM2					
CUSP 5 UM1	*			*	
CARABELLI'S CUSP UM1					
PARASTYLE UM3	*	*	*		*
ENAMEL EXTENSION UM1					
ROOT NUMBER UP1			*		
ROOT NUMBER UM2					
PEG-REDUCED UI2	*	*	*	*	*
ODONTOME P1-P2	*	*	*	*	*
CONGENITAL ABSENCE UM3				*	
MID LINE DIASTEMA UI1					
LINGUAL CUSP LP2					
ANTERIOR FOVEA LM1	*	*	*	*	
MANDIBULAR TORUS	*	*	*	*	*
GROOVE PATTERN LM2	*				*
ROCKER JAW					
CUSP NUMBER LM1		*		*	*
CUSP NUMBER LM2		*	*	*	
DEFLECTING WRINKLE LM1					*
C1-C2 CREST LM1		*	*	*	*
PROTOSTYLID LM1	*	*	*	*	*
CUSP 7 LM1	*		*		
TOMES ROOT LP1					
ROOT NUMBER LC	*	*	*	*	*
ROOT NUMBER LM1	*	*	*	*	*
ROOT NUMBER LM2					
TORSOMOLAR ANGLE LM3					

Table 6.4 Traits removed during the five separate editing processes

	4TH CATARACT KERMA (4CKM)	3-Q-33 (3Q33)	4TH CATARACT POST-MEROITIC (4CPM)	3-J-23 (3J23)	3-J-18 (3J18)
4TH CATARACT KERMA (4CKM)	0	0.000	0.000	0.000	0.037
3-Q-33 (3Q33)	0.000	0	0.000	0.033	0.065
4TH CATARACT POST-MEROITIC (4CPM)	0.000	0.000	0	0.042	0.035
3-J-23 (3J23)	0.000	0.033	0.042	0	0.030
3-J-18 (3J18)	0.037	0.065	0.035	0.030	0

Red = significant at p ≤ 0.025 level

Table 6.5 4th Cataract 36-trait MMD values.

After editing, 20 traits remained (details in Table 6.4). Table 6.5 lists the results of the 20-trait MMD analysis. The editing process increased affinities between most samples. The average MMD value for the group is now 0.019. Three samples, 3-Q-33, 4CKM, and 4CPM show no difference among them. The most distinct sample is still 3-J-18, showing a significant difference with 3-J-23 and 3-Q-33.

6.2.2 Upper Nubia

The Upper Nubian samples have been divided into three regions the 4th Cataract (as described above), Dongola Reach, and the 6th Cataract (see Table 5.1 for further details). Table 6.6 is the trait frequencies and numbers for the Dongola Reach and 6th Cataract. The samples from Upper Nubia and the 4th Cataract appear similar to one another. The Upper Nubian collections also contain a mixture of mass additive and mass reduced traits.

Table 6.7 reveals the 36-trait MMD results. Higher MMD values are seen between samples in the Dongola reach than in the 4th Cataract group. Several samples differ significantly from most others, namely: H29, Tombos, and Soleb. Alternatively, P37, R12, and Amara West post-New Kingdom are most similar to the others from the Dongola Reach. Close affinities can be observed between the 4th Cataract samples and those from the Dongola Reach, except for 3-J-23 and 3-J-18. The 6th Cataract samples show high levels of intra-group affinity, with only the Al Khiday sample showing significant differences from the others (both Gabati samples and Soba). The high level of affinity is reflected in the average group MMD value (MMD= 0.058). The 6th Cataract group shares affinities with both of the other two regions, although Al Khiday and Gabati post-Meroitic/medieval samples are significantly different from most other samples. Ghaba shows a high level of relatedness to all other samples from Upper Nubia.

Of the three Neolithic samples (R12, Ghaba, and Al Khiday), only R12 and Al Khiday produce a MMD value which is significantly different (p= 0.001). When compared to the Kerma period samples (4th Cataract Kerma (4CKM), H29, P37 and KermaClassique (KMC)), Ghaba shares a close affinity with all, R12 is only significantly different from H29 (p= 0.009), and Al Khiday is significantly different from all Kerma samples except Kerma Classique (KMC). The Kerma samples show a high level of affinity between the collections, except for H29 and KMC which differ significantly (p= 0.00). The H29 sample shares a greater affinity to 4CKM than to the other Kerma samples from the Dongola Reach. Both H29 and 4CKM are significantly different from all New-Kingdom/post-New Kingdom samples (Soleb (SOL), Amara West New Kingdom (NK), Tombos (TOM), Amara West post-New

Kingdom (PNK)). The KMC sample is similar to both Tombos and Soleb, but significantly different from both samples from Amara West. The opposite is true for P37. The New Kingdom/post-New Kingdom samples display a high level of dissimilarity from each other. Tombos is significantly different from all other samples, and Soleb and Amara West New Kingdom only share a close affinity to Amara West post-New Kingdom. The relationship with the Meroitic samples (3-Q-33, Kawa (KAW), and Gabati Meroitic (GABMER)) varies between regions. Kawa is significantly different from all samples bar Amara West post-New Kingdom (PNK). The Meroitic Gabati sample shares close affinities with the Amara West samples only. The 3-Q-33 sample is phenetically similar to all from the preceding period. There is a high level of affinity between the three Meroitic samples, with a significant difference only between 3-Q-33 and Kawa (p=0.00). Kawa and Gabati Meroitic produced an MMD of 0.00. The post-Meroitic samples (4th Cataract post-Meroitic (4CPM) and Gabati post-Meroitic (GABPM)) show varying levels of relatedness to the Meroitic. The 4th Cataract collection is only significantly different from Kawa (p= 0.002). However, GABPM only shares a close affinity with the other Gabati sample. When compared, the post-Meoritic samples create a significantly different MMD (p=0.009). Soba shows a high level of affinity with both post-Meroitic samples, whereas 3-J-23 is significantly different from both. The other medieval 4th Cataract collection, 3-J-18, is phenetically similar to 4CPM. When the medieval samples are compared with each other, 3-J-18 is distinct and does not share a close affinity to either of the other two samples from this period.

	Dongola Reach									6th Cataract				
TRAIT	R12 (R12)	H29 (H29)	P37 (P37)	Kerma Classique (KMC)	Soleb (SOL)	Amara West New Kingdom (NK)	Tombos (TOM)	Amara West post-New Kingdom (PNK)	Kawa (KAW)	Ghaba (GHB)	Al Khiday Neolithic (AKN)	Gabati Meroitic (GABMER)	Gabati post-Merotic/ Medieval (GABPM)	Soba (SBA)
WINGING UI1	0.0[A]	10.5	13.0	5.4	8.3	0.0	1.7	0.0	3.1	0.0	0.0	0.0	7.7	20.0
(+ = ASU 1)[C]	16.0[B]	19.0	23.0	56.0	24.0	8.0	115.0	16.0	32.0	3.0	16.0	19.0	26.0	15.0
LABIAL CURVATURE UI1	42.5	33.3	43.5	38.5	12.5	20.0	64.5	12.0	28.6	21.7	30.0	31.8	10.3	12.5
(+ = ASU 2-4)	40.0	57.0	23.0	13.0	8.0	15.0	31.0	25.0	56.0	23.0	20.0	22.0	29.0	24.0
PALATINE TORUS	0.0	0.0	0.0	1.8	10.3	0.0	0.9	10.0	16.7	0.0	0.0	7.4	10.7	16.7
(+ = ASU 2-3)	5.0	8.0	19.0	55.0	29.0	5.0	114.0	10.0	24.0	1.0	8.0	27.0	28.0	6.0
SHOVELING UI1	26.1	59.1	14.3	22.2	11.1	12.5	11.1	5.9	35.9	10.5	0.0	27.3	27.8	58.3
(+ = ASU 2-6)	23.0	44.0	14.0	9.0	9.0	8.0	27.0	17.0	39.0	19.0	16.0	11.0	18.0	12.0
DOUBLE SHOVELING UI1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(+ = ASU 2-6)	47.0	56.0	26.0	7.0	8.0	13.0	27.0	25.0	57.0	25.0	22.0	24.0	29.0	24.0
INTERUPTION GROOVE UI2	12.0	4.8	4.8	9.1	30.8	12.5	21.7	17.4	9.5	20.0	15.4	15.8	8.0	25.0
(+ = ASU +)	25.0	42.0	21.0	11.0	13.0	16.0	23.0	23.0	42.0	10.0	13.0	19.0	25.0	20.0
TUBERCULUM DENTALE UI2	25.0	54.8	31.8	8.3	25.0	6.3	30.4	31.6	39.5	26.3	15.4	66.7	22.7	17.4
(+ = ASU 2-6)	20.0	42.0	22.0	12.0	12.0	16.0	23.0	19.0	38.0	19.0	13.0	12.0	22.0	23.0
BUSHMAN CANINE UC	25.0	25.0	16.0	16.7	0.0	0.0	0.0	0.0	12.8	0.0	9.1	22.2	8.7	8.7
(+ = ASU 1-3)	24.0	44.0	25.0	18.0	11.0	12.0	23.0	24.0	47.0	30.0	11.0	9.0	23.0	23.0
DISTAL ACCESSORY RIDGE UC	35.0	42.9	10.0	18.2	0.0	0.0	15.4	25.0	41.7	45.0	10.0	25.0	23.5	21.4
(+ = ASU 2-5)	20.0	35.0	20.0	11.0	7.0	10.0	13.0	16.0	36.0	20.0	10.0	4.0	17.0	14.0
HYPOCONE UM2	90.6	94.0	86.7	91.7	79.0	78.3	91.7	81.8	92.9	93.4	80.0	79.4	79.4	78.8
(+ = ASU 3-5)	53.0	50.0	30.0	48.0	19.0	23.0	60.0	44.0	56.0	61.0	20.0	34.0	34.0	33.0
CUSP 5 UM1	3.6	29.0	18.2	24.1	14.3	0.0	17.2	8.7	14.7	17.1	5.6	8.3	0.0	14.3
(+ = ASU 2-5)	28.0	31.0	11.0	29.0	7.0	16.0	29.0	23.0	34.0	41.0	18.0	12.0	17.0	14.0
CARABELLI'S CUSP UM1	64.1	52.6	61.1	51.6	0.0	31.3	57.1	51.5	70.3	32.5	35.3	31.6	46.4	34.8
(+ = ASU 2-7)	39.0	38.0	18.0	31.0	8.0	16.0	35.0	33.0	37.0	40.0	17.0	19.0	28.0	23.0

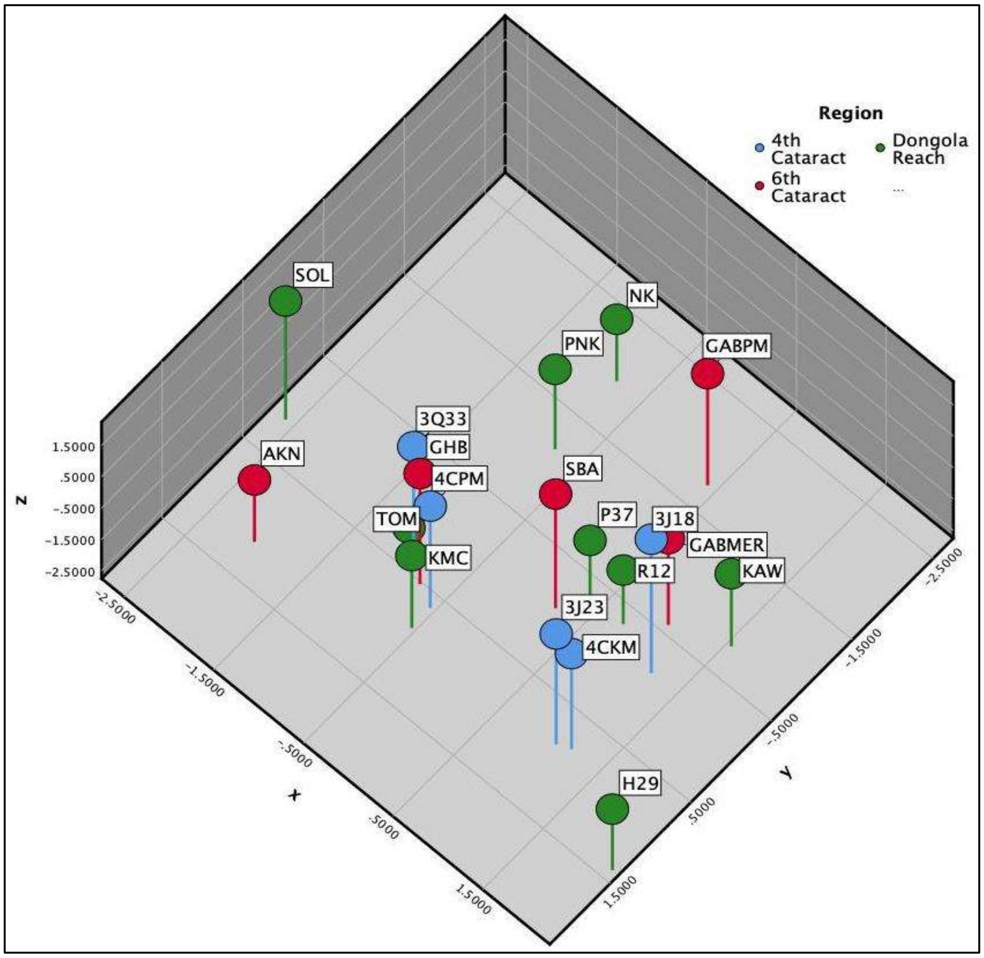
PARASTYLE UM3	0.0	2.3	7.1	5.4	0.0	0.0	4.0	7.3	0.0	1.6	0.0	2.7	7.4	0.0
(+ = ASU 1-5)	54.0	43.0	28.0	37.0	15.0	20.0	50.0	41.0	42.0	63.0	21.0	37.0	27.0	27.0
ENAMEL EXTENSION UM1	6.9	0.0	0.0	4.0	5.0	6.7	8.3	18.2	22.7	8.0	0.0	7.7	16.7	7.1
(+ = ASU 1-3)	29.0	20.0	13.0	50.0	20.0	15.0	60.0	11.0	44.0	25.0	16.0	13.0	24.0	14.0
ROOT NUMBER UP1	81.8	69.7	51.6	80.4	69.2	81.5	77.8	79.6	67.9	9.1	83.3	71.2	42.3	58.6
(+ = ASU 2+)	44.0	33.0	31.0	51.0	13.0	27.0	108.0	49.0	53.0	11.0	12.0	59.0	26.0	29.0
ROOT NUMBER UM2	81.0	74.3	69.0	90.2	90.9	64.3	79.0	65.6	72.1	81.8	92.9	79.0	57.1	84.0
(+ = ASU 3+)	42.0	35.0	29.0	41.0	11.0	14.0	76.0	32.0	43.0	22.0	14.0	57.0	28.0	25.0
PEG-REDUCED UI2	0.0	9.1	3.6	1.6	0.0	0.0	2.6	0.0	5.6	0.0	0.0	4.0	0.0	0.0
(+ = ASU P OR R)	48.0	55.0	28.0	63.0	24.0	23.0	115.0	28.0	54.0	28.0	21.0	25.0	28.0	23.0
ODONTOME P1-P2	2.6	6.8	4.8	0.0	0.0	4.0	6.1	2.3	2.0	0.0	0.0	0.0	6.9	0.0
(+ = ASU +)	39.0	44.0	21.0	41.0	12.0	25.0	66.0	44.0	50.0	86.0	21.0	31.0	29.0	31.0
CONGENITAL ABSENCE UM3	0.0	0.0	0.0	16.7	11.5	0.0	5.1	3.7	13.0	0.0	0.0	9.8	5.7	5.9
(+ = ASU -)	60.0	46.0	33.0	60.0	26.0	25.0	117.0	54.0	54.0	68.0	24.0	61.0	35.0	34.0
MID LINE DIASTEMA UI1	4.8	21.7	11.1	3.3	0.0	0.0	4.5	0.0	10.5	0.0	0.0	18.2	18.2	0.0
(+ ≥ 0.5 MM)	21.0	23.0	18.0	60.0	25.0	2.0	111.0	7.0	19.0	9.0	16.0	11.0	22.0	8.0
LINGUAL CUSP LP2	96.7	88.5	90.9	86.4	22.2	92.3	87.8	79.0	96.3	93.7	35.3	93.3	90.3	82.8
(+ = ASU 2-9)	61.0	52.0	22.0	22.0	9.0	13.0	41.0	19.0	54.0	63.0	17.0	30.0	31.0	29.0
ANTERIOR FOVEA LM1	42.3	69.7	44.4	43.8	40.0	33.3	28.6	36.8	64.0	32.4	50.0	45.5	29.4	36.8
(+ = ASU 2-4)	26.0	33.0	9.0	16.0	5.0	12.0	14.0	19.0	25.0	37.0	10.0	11.0	17.0	19.0
MANDIBULAR TORUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(+ = ASU 2-3)	22.0	19.0	29.0	60.0	31.0	7.0	131.0	16.0	39.0	10.0	22.0	39.0	30.0	19.0
GROOVE PATTERN LM2	17.2	34.1	18.5	41.3	52.9	0.0	28.0	12.2	11.5	52.2	68.2	12.8	11.8	25.0
(+ = ASU Y)	64.0	44.0	27.0	46.0	17.0	22.0	75.0	41.0	61.0	69.0	22.0	47.0	34.0	32.0
ROCKER JAW	9.1	5.3	13.3	5.3	10.7	0.0	3.3	13.3	25.7	0.0	5.9	38.1	44.8	25.0
(+ = ASU 1-2)	22.0	19.0	30.0	57.0	28.0	9.0	121.0	15.0	35.0	3.0	17.0	42.0	29.0	16.0
CUSP NUMBER LM1	13.1	10.9	17.7	0.0	0.0	21.4	0.0	14.3	12.0	3.7	5.6	9.4	6.1	7.4
(+ = ASU 6+)	61.0	46.0	17.0	28.0	8.0	14.0	34.0	28.0	50.0	54.0	18.0	32.0	33.0	27.0
CUSP NUMBER LM2	26.5	60.5	12.0	41.2	26.7	8.7	58.5	19.1	25.8	50.7	45.0	23.9	35.3	26.7

(+ = ASU 5+)	68.0	43.0	25.0	34.0	15.0	23.0	53.0	42.0	66.0	69.0	20.0	46.0	34.0	30.0
DEFLECTING WRINKLE LM1	28.6	60.7	28.6	11.1	0.0	20.0	21.7	20.8	23.1	13.5	16.7	40.0	23.1	33.3
(+ = ASU 2-3)	21.0	28.0	7.0	27.0	4.0	10.0	23.0	24.0	26.0	37.0	18.0	10.0	13.0	15.0
C1-C2 CREST LM1	15.0	13.3	14.3	0.0	0.0	37.5	4.4	10.5	8.3	6.3	0.0	22.2	0.0	0.0
(+ = ASU +)	20.0	30.0	7.0	27.0	4.0	8.0	23.0	19.0	24.0	32.0	17.0	9.0	11.0	14.0
PROTOSTYLID LM1	3.8	0.0	0.0	11.5	0.0	27.3	28.0	30.4	4.3	23.5	0.0	7.9	11.1	0.0
(+ = ASU 1-6)	53.0	39.0	17.0	26.0	7.0	11.0	25.0	23.0	47.0	51.0	20.0	38.0	27.0	24.0
CUSP 7 LM1*	20.0	21.4	10.0	17.1	0.0	8.3	10.6	3.5	14.3	12.0	8.3	11.8	6.7	22.2
(+ = ASU 2-4)	60.0	42.0	20.0	35.0	17.0	12.0	47.0	29.0	49.0	50.0	24.0	34.0	30.0	27.0
TOMES ROOT LP1	20.0	27.8	27.3	25.0	10.5	13.3	26.9	23.5	24.4	0.0	33.3	25.0	3.7	27.8
(+ = ASU 3-5)	30.0	18.0	22.0	52.0	19.0	15.0	108.0	34.0	41.0	5.0	12.0	32.0	27.0	18.0
ROOT NUMBER LC	0.0	3.6	0.0	1.9	5.6	0.0	1.9	2.2	3.3	0.0	5.6	1.9	0.0	3.6
(+ = ASU 2+)	55.0	28.0	33.0	52.0	18.0	26.0	105.0	46.0	60.0	22.0	18.0	53.0	32.0	28.0
ROOT NUMBER LM1	3.2	2.6	0.0	2.0	0.0	0.0	1.2	6.1	0.0	0.0	0.0	2.9	0.0	3.9
(+ = ASU 3+)	63.0	39.0	29.0	49.0	16.0	26.0	83.0	33.0	49.0	40.0	17.0	68.0	30.0	26.0
ROOT NUMBER LM2	87.5	96.8	88.0	94.0	80.0	89.5	87.1	84.4	85.4	100.0	90.9	96.5	71.4	86.7
(+ = ASU 2+)	56.0	31.0	25.0	50.0	20.0	19.0	101.0	32.0	48.0	30.0	11.0	57.0	28.0	30.0
TORSOMOLAR ANGLE LM3	24.4	20.0	22.7	15.7	5.3	27.3	7.8	18.8	30.8	0.0	4.6	32.4	40.7	35.7
(+ = ASU +)	41.0	25.0	22.0	51.0	19.0	11.0	102.0	16.0	39.0	1.0	22.0	37.0	27.0	14.0

A.Upper row for each trait is the frequency in %, B.,Lower row is the number of individuals scored,C. ASUDAS score used as breakpoint referenced in brackets.

Table 6.6 Dongola Reach and 6th Cataract trait percentages and sample sizes

A MDS plot of the 36-Trait MMD results can be seen in Figure 6.2. It provides a graphical representation of the relationship between the samples included in the analysis. Figure 6.2 is a good representation of the distance matrix, with an r^2 value of 0.854 and Kruskal's stress formula 1 value of 0.137. A high level of relatedness between samples is visible. There is some regional grouping evident, with the 4th cataract samples placed closely together, except 3-J-18. Additionally, many Dongola Reach samples are clustered together, except H29 and Soleb.



r^2 =0.854, Kruskal's stress formula 1 = 0.137

Figure 6.2 Multidimensional scaling of Upper Nubia 36-trait MMD data

		Dongola Reach									6th Cataract				
		R12 (R12)	H29 (H29)	P37 (P37)	Kerma Classique (KMC)	Soleb (SOL)	Amara West New Kingdom (NK)	Tombos (TOM)	Amara West post-New Kingdom (PNK)	Kawa (KAW)	Ghaba (GHB)	Al Khiday Neolithic (AKN)	Gabati Merotic (GABMER)	Gabati post-Merotic/ Medieval (GABPM)	Soba (SBA)
4th Cataract	4th Cataract Kerma (4CKM)	0.034	0.001	0.017	0.04	0.145	0.14	0.086	0.092	0.024	0.031	0.148	0.013	0.076	0
	3-Q-33 (3Q33)	0.069	0.13	0.016	0	0.019	0.061	0.023	0.015	0.103	0	0.016	0.058	0.056	0.031
	4th Cataract post-Meroitic (4CPM)	0.021	0.114	0.048	0.031	0.06	0.084	0.042	0.046	0.088	0.036	0.066	0.017	0.083	0.044
	3-J-23 (3J23)	0.049	0.054	0.039	0.048	0.148	0.156	0.102	0.084	0.04	0.02	0.137	0.02	0.071	0.016
	3-J-18 (3J18)	0.066	0.108	0.07	0.07	0.15	0.135	0.138	0.085	0.06	0.097	0.177	0	0.071	0.042
Dongola Reach	R12 (R12)	0	0.052	0	0.024	0.184	0.014	0.052	0.026	0.003	0.066	0.088	0	0.061	0.031
	H29 (H29)	0.052	0	0.036	0.094	0.253	0.201	0.137	0.167	0.065	0.127	0.163	0.041	0.162	0.072
	P37 (P37)	0	0.036	0	0.034	0.127	0.005	0.06	0.029	0.019	0.055	0.075	0	0.042	0.027
	Kerma Classique (KMC)	0.024	0.094	0.034	0	0.061	0.094	0.006	0.052	0.06	0.031	0.015	0.068	0.103	0.025
	Soleb (SOL)	0.184	0.253	0.127	0.061	0	0.113	0.117	0.066	0.2	0.068	0	0.143	0.143	0.053
	Amara West New Kingdom (NK)	0.014	0.201	0.005	0.094	0.113	0	0.077	0	0.085	0.094	0.135	0.048	0.053	0.079
	Tombos (TOM)	0.052	0.137	0.06	0.006	0.117	0.077	0	0.038	0.104	0.038	0.064	0.094	0.133	0.12
	Amara West post-New Kingdom (PNK)	0.026	0.167	0.029	0.052	0.066	0	0.038	0	0.033	0.035	0.073	0.02	0.024	0.044
	Kawa (KAW)	0.003	0.065	0.019	0.06	0.2	0.085	0.104	0.033	0	0.083	0.171	0	0.036	0.021
6th Cataract	Ghaba (GHB)	0.066	0.127	0.055	0.031	0.068	0.094	0.038	0.035	0.083	0	0.077	0.077	0.051	0.041
	Al Khiday Neolithic (AKN)	0.088	0.163	0.075	0.015	0	0.135	0.064	0.073	0.171	0.077	0	0.136	0.177	0.086
	Gabati Merotic (GABMER)	0	0.041	0	0.068	0.143	0.048	0.094	0.02	0	0.077	0.136	0	0.035	0.02
	Gabati post-Merotic/Medieval (GABPM)	0.061	0.162	0.042	0.103	0.143	0.053	0.133	0.024	0.036	0.051	0.177	0.035	0	0.018
	Soba (SBA)	0.031	0.072	0.027	0.025	0.053	0.079	0.12	0.044	0.021	0.041	0.086	0.02	0.018	0

Red = significant at $p \leq 0.025$ level

Table 6.7 4th Cataract 36-trait MMD values.

The traits were again edited via the process in Chapter 5. The data from Tables 6.1 and 6.6 were reviewed, and traits with consistently low frequencies (<10%) across samples were removed. Traits removed at this stage were: UI1 double shovelling, P1/P2 odontome, mandibular torus, LC root number, and LM1 root number. Principal component analysis (PCA) was then applied to identify any indiscriminate traits. The first five principal components were used in analysis, as they produced 66% of the variation. The loadings for these components are detailed in Table 6.8. Any trait with a loading of 0.4 or below across all five components was removed. To visualise how the trait loadings affected the samples, the results from the first three components were plotted on a 3-D graph (Figure 6.3). Most of the samples group together in the middle of the graph, but some are divergent. Component one is responsible for separating both Soleb and H29 at different ends of the x-axis. Although these two samples differ in several ways, high trait frequencies of Bushman canine and LM1 deflecting wrinkle in H29 and low levels of UC distal accessory ridge and LP1/2 cusp number in Soleb, are responsible for the separation from the other samples. New Kingdom Amara West sample (NK) is also distinct from the others on the z-axis, related to component three. High trait frequencies of LM1 C1C2 and low instances of rocker jaw caused the NK sample to diverge. Next, Kendall's tau-b was used to identify any correlated trait pairings. Any trait that had a correlation coefficient of 0.6 or above was removed from the analysis.

After the editing process 21 traits remained (see Table 6.4). The 21-trait MMD results are in Table 6.9. Higher levels of within group affinity can be observed among Dongola Reach samples, except Soleb which is now significantly different from all others in the group. Again, similarities are evident between the 4th Cataract samples

	PRINCIPAL COMPONENT				
	1	2	3	4	5
WINGING UI1	0.322	0.104	0.483	-0.265	-0.635
LABIAL CURVATURE UI1	0.3	0.456	-0.454	0.028	0.203
PALATINE TORUS	0.3	-0.371	0.695	-0.067	0.014
SHOVELING UI1	0.734	0.122	0.327	-0.095	0.004
INTERUPTION GROOVE UI2	-0.31	0.357	0.419	0.252	-0.225
TUBERCULUM DENTALE UI2	0.493	0.094	0.143	0.069	0.581
BUSHMAN CANINE UC	0.73	0.15	0.047	-0.328	0.27
DISTAL ACCESSORY RIDGE UC	0.617	0.316	0.121	0.494	0.2
HYPOCONE UM2	0.29	0.601	-0.216	0.446	0.276
CUSP 5 UM1	0.366	0.609	0.236	0.12	-0.379
CARABELLI'S CUSP UM1	0.592	-0.12	-0.445	0.053	0
PARASTYLE UM3	0.279	0.074	0.326	0.508	-0.158
ENAMEL EXTENSION UM1	0.203	-0.591	0.243	0.283	0.234
ROOT NUMBER UP1	-0.105	-0.067	-0.235	-0.55	0.359
ROOT NUMBER UM2	-0.312	0.634	0.203	-0.383	0.451
PEG-REDUCED UI2	0.37	0.405	-0.031	0.082	-0.229
CONGENITAL ABSENCE UM3	0.032	-0.044	0.595	-0.1	0.591
MID LINE DIASTEMA UI1	0.709	-0.021	0.339	0.046	0.099
LINGUAL CUSP LP2	0.68	-0.179	-0.24	0.508	0.112
ANTERIOR FOVEA LM1	0.471	0.08	-0.237	-0.446	-0.132
GROOVE PATTERN LM2	-0.335	0.67	0.348	-0.121	0.124
ROCKER JAW	0.388	-0.564	0.567	-0.11	0.126
CUSP NUMBER LM1	0.424	-0.458	-0.476	-0.054	-0.189
CUSP NUMBER LM2	0.044	0.721	-0.042	0.232	-0.009
DEFLECTING WRINKLE LM1	0.876	0.134	-0.022	-0.05	-0.117
C1-C2 CREST LM1	0.23	-0.499	-0.6	-0.101	0.128
PROTOSTYLID LM1	-0.314	-0.313	-0.335	0.53	0.017
CUSP 7 LM1	0.593	0.353	-0.213	-0.147	-0.285
TOMES ROOT LP1	0.312	0.322	-0.167	-0.556	-0.156
ROOT NUMBER LM2	0.309	0.435	-0.396	-0.08	0.255
TORSOMOLAR ANGLE LM3	0.618	-0.669	0.159	-0.155	-0.058

Table 6.8 Upper Nubia - principal component analysis loadings. Graphical representation in Appendix 5.

and those from the Dongola Reach. The exceptions are 3-J-23 and 3-J-18, which are both significantly different from all Dongola Reach samples. The 21-trait analysis

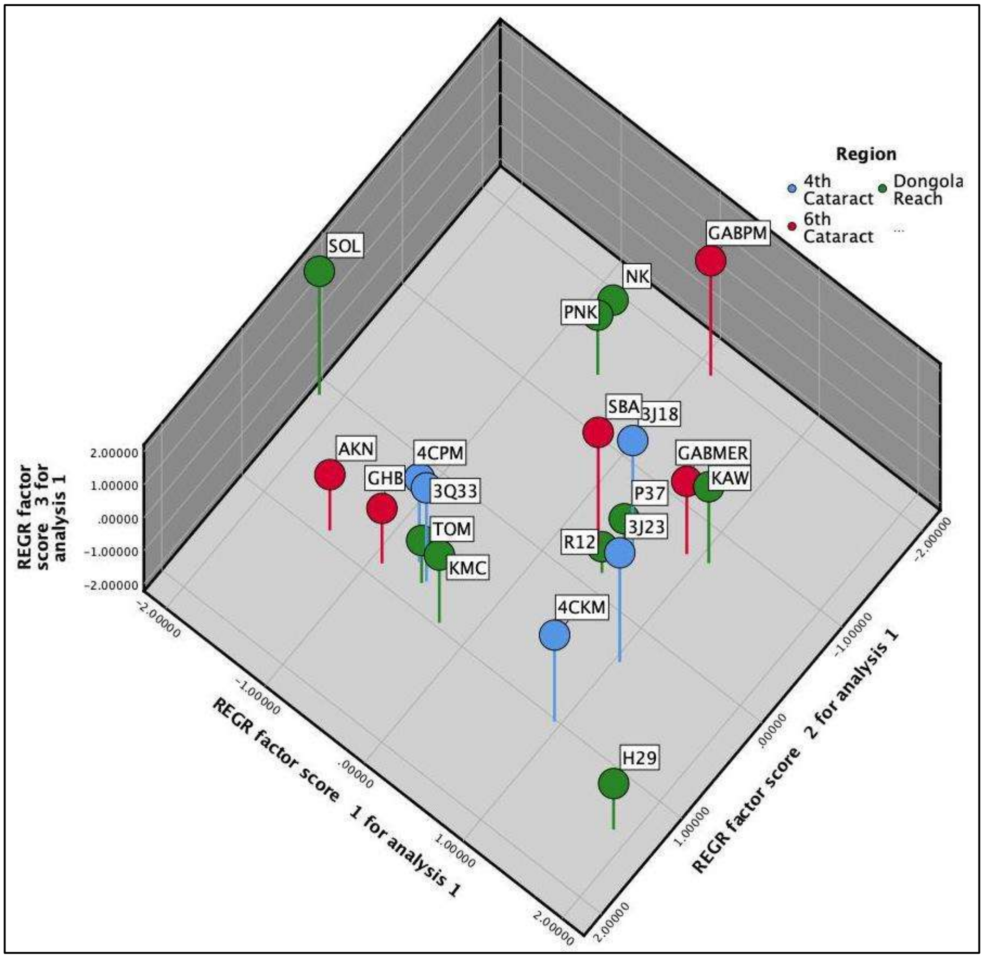
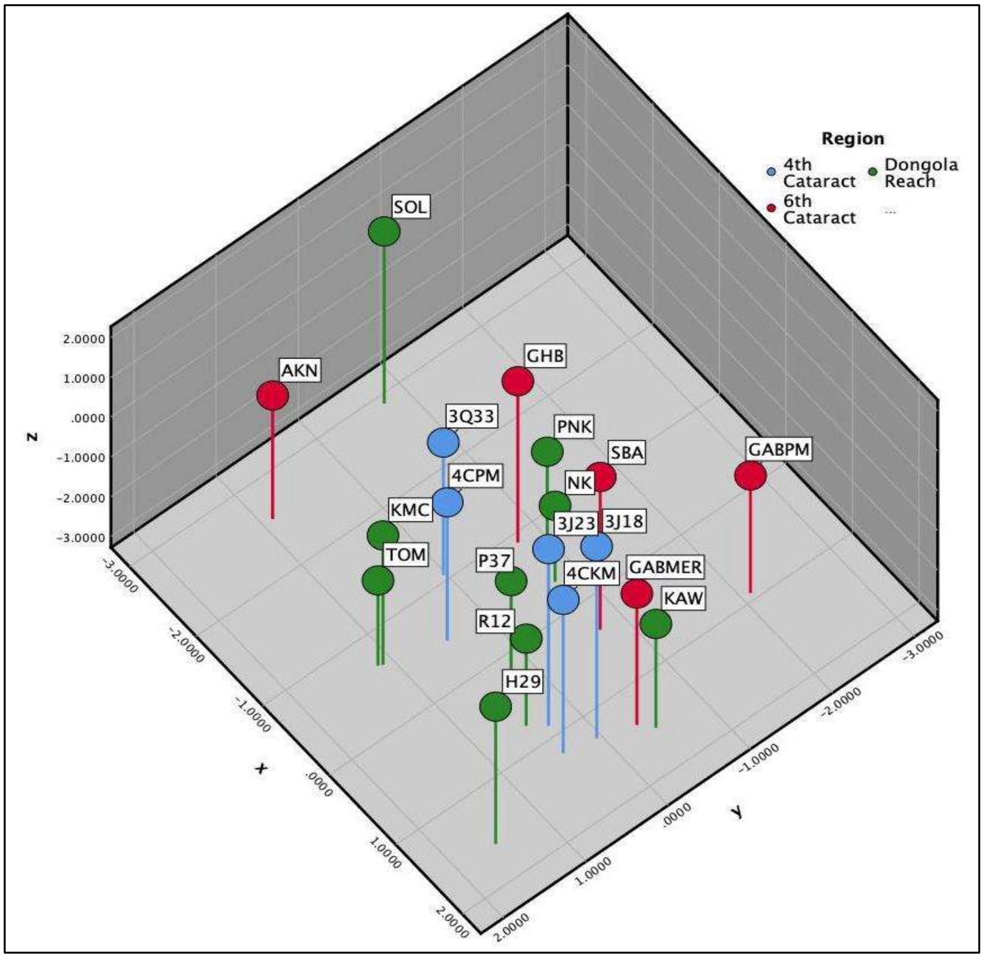


Figure 6.3 Upper Nubia PCA loadings 3-D representation

produces similar results for the 6th Cataract group, except that the Gabati samples are now showing a significant difference to each other (p= 0.035). Affinities between the 6th Cataract grouping and the two other regions are evident. As with the 36-trait analysis, Al Khiday and Gabati post-Meroitic/medieval samples are significantly different from most other samples. Again, Ghaba is not significantly different from any other sample from Upper Nubia. The Neolithic samples (R12, Ghaba, and Al Khiday), produce very similar results to the 21-trait analysis when compared with each other and the Kerma samples. There are slight changes in the MMD values, and R12 is no longer significantly different from H29. Although the relationship between the Kerma samples is the same in 21-trait MMD analysis (only H29 and KMC producing a significant difference (p=0.00)), how the samples compare to the New-Kingdom/post-New Kingdom samples has changed. Soleb is significantly different from all Kerma samples and H29 is significantly different from all New Kingdom/post-New Kingdom collections. The 4th Cataract collection (4CKM) exhibits similarities to Amara West New Kingdom (NK). P37 shows the highest level of relatedness to the New Kingdom/post-New Kingdom samples.

The trait editing decreased the distance between the New Kingdom/post-New Kingdom collections, with generally less significant differences among them. However, Soleb is now significantly different from all other samples. In the 21-trait analysis all affinities with the Meroitic assemblages change slightly, with Kawa now the most distinct (only showing an affinity with Amara post-New Kingdom (PNK)). 3-Q-33 is still phenetically similar to all samples from the preceding period. After trait editing, 3-Q-33 is significantly different from both the other Meroitic samples; Kawa and Gabati still show a high level of affinity (MMD= 0.013). All Meroitic samples are significantly different from GABPM, whereas the 4th Cataract collection (4CPM) is still only significantly different from Kawa (p= 0.035). Both Gabati assemblages are significantly different from each other (MMD= 0.064). Again, the post-Meroitic samples create a significantly different MMD when compared with each other. The relationship between the medieval and post-Meroitic samples is similar to the 36-trait MMD analysis. The 21-trait analysis between the medieval samples has increased the inter-sample affinities, with only 3-J-18 and 3-J-23 producing a significantly different MMD (p=0.015).

Figure 6.4 is the MDS plot of the 21-trait MMD data. The model is a good fit for the data with an r^2 of 0.884 and Kruskal's stress formula 1 of 0.128. The general patterning is similar to the 36-trait MDS. Al Khiday, Soleb and H29 are positioned away from the main grouping. Additionally, Gabati post-Meroitic is now distinct from the group. The 4th Cataract samples are generally grouped together in the middle of the graph. As per the 36-trait MDS there are two distinct clusters within this group, (1) 4CKM, 3-J-18 and 3-J-23, and (2) 3-Q-33 and 4CPM. Several Dongola Reach samples are in close proximity including: KMC, TOM, P37, R12, KAW, H29.



r^2 =0.884, Kruskal's stress formula 1 = 0.128

Figure 6.4 Multidimensional scaling of Upper Nubia 21-trait MMD data

		Dongola Reach									6th Cataract				
		R12 (R12)	H29 (H29)	P37 (P37)	Kerma Classique (KMC)	Soleb (SOL)	Amara West New Kingdom (NK)	Tombos (TOM)	Amara West post-New Kingdom (PNK)	Kawa (KAW)	Ghaba (GHB)	Al Khiday Neolithic (AKN)	Gabati Merotic (GABMER)	Gabati post-Merotic/ Medieval (GABPM)	Soba (SBA)
4th Cataract	**4th Cataract Kerma (4CKM)**	0.045	0	0.002	0.065	0.258	0.109	0.09	0.126	0.029	0.06	0.262	0.024	0.129	0
	3-Q-33 (3Q33)	0.075	0.122	0	0.012	0.068	0.028	0.057	0.021	0.125	0.032	0.013	0.096	0.12	0.058
	4th Cataract post-Meroitic (4CPM)	0.013	0.073	0.027	0.022	0.093	0.038	0.028	0.042	0.076	0.063	0.089	0.019	0.139	0.062
	3-J-23 (3J23)	0.073	0.042	0.036	0.072	0.246	0.167	0.126	0.12	0.049	0.051	0.218	0.043	0.121	0.021
	3-J-18 (3J18)	0.11	0.076	0.105	0.113	0.255	0.202	0.195	0.148	0.065	0.168	0.271	0.007	0.129	0.047
Dongola Reach	**R12 (R12)**	0	0.054	0	0.024	0.318	0	0.04	0.049	0.018	0.116	0.159	0.037	0.104	0.046
	H29 (H29)	0.054	0	0.019	0.114	0.376	0.18	0.139	0.19	0.105	0.167	0.258	0.047	0.231	0.076
	P37 (P37)	0	0.019	0	0.026	0.243	0.014	0.011	0.028	0.025	0.03	0.115	0.015	0.075	0.042
	Kerma Classique (KMC)	0.024	0.114	0.026	0	0.151	0.076	0.026	0.083	0.086	0.08	0.061	0.122	0.21	0.054
	Soleb (SOL)	0.318	0.376	0.243	0.151	0	0.191	0.208	0.111	0.332	0.117	0.006	0.273	0.272	0.154
	Amara West New Kingdom (NK)	0	0.18	0.014	0.076	0.191	0	0.054	0	0.072	0.088	0.158	0.09	0.041	0.045
	Tombos (TOM)	0.04	0.139	0.011	0.026	0.208	0.054	0	0.049	0.106	0.086	0.097	0.14	0.234	0.149
	Amara West post-New Kingdom (PNK)	0.049	0.19	0.028	0.083	0.111	0	0.049	0	0.031	0.069	0.099	0.068	0.049	0.04
	Kawa (KAW)	0.018	0.105	0.025	0.086	0.332	0.072	0.106	0.031	0	0.13	0.297	0.013	0.046	0.02
6th Cataract	**Ghaba (GHB)**	0.116	0.167	0.03	0.08	0.117	0.088	0.086	0.069	0.13	0	0.132	0.15	0.11	0.063
	Al Khiday Neolithic (AKN)	0.159	0.258	0.115	0.061	0.006	0.158	0.097	0.099	0.297	0.132	0	0.249	0.318	0.178
	Gabati Merotic (GABMER)	0.037	0.047	0.015	0.122	0.273	0.09	0.14	0.068	0.013	0.15	0.249	0	0.064	0.029
	Gabati post-Merotic/Medieval (GABPM)	0.104	0.231	0.075	0.21	0.272	0.041	0.234	0.049	0.046	0.11	0.318	0.064	0	0.038
	Soba (SBA)	0.046	0.076	0.042	0.054	0.154	0.045	0.149	0.04	0.02	0.063	0.178	0.029	0.038	0

Red = significant at p ≤ 0.025 level

Table 6.9 Upper Nubia 21-Trait MMD matrix

Samples from the 6th Cataract are again more dispersed across the graph. Some temporal patterning is discernible; the medieval samples sit closely together, as do the Kerma collections.

6.2.3 Nubia (Upper and Lower)

Published Lower Nubian data were added to the analysis to provide an overview across Nubia (trait frequencies can be found in Table 6.10). The Lower Nubian collections are comparable to the Upper Nubian samples in most traits. Two noticeable trait differences are UI1 double shovelling and LM1 protostylid, in which higher frequencies occur in the Lower Nubians. The 36-trait MMD results are contained in Table 6.11. When the Lower Nubian samples are compared to one another some temporal patterning is evident. The Pharaonic sample (PHA) shares affinities to all others from Lower Nubia, and the Hierakonpolis C-Group (HKC) is only significantly different from the Meroitic sample (MER) (p=0.00). The three later samples (Meroitic (MER), X-Group (XGR), and Christian (CHR)) are significantly different frm the two earliest samples, Gebel Ramlah (GRM) and C-Group (CGR).

When compared to the Upper Nubians, the MMD values are mainly significantly different. An exception is the Pharaonic sample (PHA), which shows a close affinity to most Upper Nubians; additionally, Ghaba is not significantly different from any Lower Nubian samples. Neolithic Gebel Ramlah fits with the patterning in Upper Nubian Neolithic samples. Apart from Ghaba, all Neolithic samples are significantly different from one another. Although not significantly different, Ghaba and Gebel Ramlah produce a relatively high MMD

	Lower Nubia						
TRAIT	Gebel Ramlah (GRM)	C-Group (CGR)	Heirakonpolis C-Group (HKC)	Pharaonic (PHA)	Meroitic (MER)	X-Group (XGR)	Christian (CHR)
WINGING UI1	0.0[A]	6.1	0.0	3.3	12.8	5.7	7.7
(+ = ASU 1)[C]	36.0[B]	49.0	29.0	30.0	39.0	35.0	26.0
LABIAL CURVATURE UI1	45.5	57.9	33.3	0.0	24.4	38.9	53.9
(+ = ASU 2-4)	44.0	19.0	18.0	5.0	41.0	18.0	13.0
PALATINE TORUS	0.0	0.0	0.0	0.0	10.7	10.2	8.8
(+ = ASU 2-3)	30.0	42.0	23.0	29.0	84.0	49.0	34.0
SHOVELING UI1	45.0	10.5	25.0	25.0	38.9	25.0	8.3
(+ = ASU 2-6)	40.0	19.0	16.0	4.0	36.0	12.0	12.0
DOUBLE SHOVELING UI1	4.6	0.0	0.0	0.0	4.6	6.7	15.4
(+ = ASU 2-6)	44.0	17.0	17.0	3.0	44.0	15.0	13.0
INTERUPTION GROOVE UI2	22.2	25.0	0.0	20.0	36.2	40.0	26.7
(+ = ASU +)	36.0	20.0	10.0	5.0	47.0	15.0	15.0
TUBERCULUM DENTALE UI2	54.1	35.0	27.3	20.0	40.5	42.9	21.4
(+ = ASU 2-6)	37.0	20.0	11.0	5.0	42.0	14.0	14.0
BUSHMAN CANINE UC	11.4	0.0	0.0	0.0	19.6	10.0	33.3
(+ = ASU 1-3)	35.0	26.0	11.0	8.0	51.0	20.0	12.0
DISTAL ACCESSORY RIDGE UC	46.4	12.5	11.1	50.0	31.0	21.4	22.2
(+ = ASU 2-5)	28.0	16.0	9.0	4.0	42.0	14.0	9.0
HYPOCONE UM2	93.8	76.1	90.5	83.3	78.5	85.7	72.7
(+ = ASU 3-5)	48.0	46.0	21.0	24.0	79.0	35.0	22.0
CUSP 5 UM1	16.7	40.0	37.5	16.7	10.9	21.2	25.0
(+ = ASU 2-5)	30.0	25.0	8.0	12.0	64.0	33.0	20.0
CARABELLI'S CUSP UM1	88.6	75.0	72.7	71.4	58.6	60.7	75.0
(+ = ASU 2-7)	35.0	24.0	11.0	14.0	58.0	28.0	16.0
PARASTYLE UM3	2.5	2.5	0.0	4.4	0.0	4.0	0.0
(+ = ASU 1-5)	40.0	40.0	16.0	23.0	58.0	25.0	20.0
ENAMEL EXTENSION UM1	7.9	2.3	9.1	0.0	13.5	6.7	4.2
(+ = ASU 1-3)	38.0	43.0	11.0	27.0	89.0	45.0	24.0
ROOT NUMBER UP1	69.1	83.0	84.2	72.0	53.9	70.7	73.1
(+ = ASU 2+)	42.0	47.0	19.0	25.0	78.0	41.0	26.0
ROOT NUMBER UM2	66.7	86.7	69.2	84.2	81.7	90.3	100.0
(+ = ASU 3+)	39.0	30.0	13.0	19.0	60.0	31.0	24.0
PEG-REDUCED UI2	6.1	0.0	3.7	11.1	1.9	4.8	0.0
(+ = ASU P OR R)	49.0	56.0	27.0	36.0	54.0	42.0	31.0
ODONTOME P1-P2	2.9	5.3	4.4	0.0	0.0	0.0	0.0

(+ = ASU +)	34.0	38.0	23.0	21.0	82.0	31.0	19.0
CONGENITAL ABSENCE UM3	11.5	7.1	3.7	3.0	5.0	17.8	9.4
(+ = ASU -)	52.0	56.0	27.0	33.0	80.0	45.0	32.0
MID LINE DIASTEMA UI1	10.8	0.0	3.9	3.0	8.7	3.6	0.0
(+ ≥ 0.5 MM)	37.0	52.0	26.0	33.0	23.0	28.0	23.0
LINGUAL CUSP LP2	64.3	72.4	75.0	50.0	86.0	100.0	83.3
(+ = ASU 2-9)	28.0	29.0	16.0	8.0	50.0	18.0	12.0
ANTERIOR FOVEA LM1	47.6	81.3	40.0	0.0	40.0	57.9	33.3
(+ = ASU 2-4)	21.0	16.0	10.0	2.0	35.0	19.0	9.0
MANDIBULAR TORUS	0.0	0.0	0.0	0.0	1.2	0.0	0.0
(+ = ASU 2-3)	47.0	50.0	31.0	24.0	81.0	52.0	39.0
GROOVE PATTERN LM2	64.4	50.0	50.0	25.0	10.5	29.0	33.3
(+ = ASU Y)	45.0	46.0	24.0	16.0	76.0	38.0	18.0
ROCKER JAW	18.2	27.3	15.2	11.1	22.0	13.2	25.6
(+ = ASU 1-2)	44.0	44.0	33.0	18.0	82.0	53.0	39.0
CUSP NUMBER LM1	11.8	5.7	5.9	0.0	6.9	5.7	9.1
(+ = ASU 6+)	34.0	35.0	17.0	9.0	72.0	35.0	11.0
CUSP NUMBER LM2	79.0	56.3	47.4	25.0	33.3	33.3	33.3
(+ = ASU 5+)	38.0	32.0	19.0	16.0	75.0	33.0	18.0
DEFLECTING WRINKLE LM1	34.8	36.4	38.5	50.0	7.0	11.1	0.0
(+ = ASU 2-3)	23.0	22.0	13.0	6.0	57.0	27.0	8.0
C1-C2 CREST LM1	0.0	0.0	0.0	0.0	4.9	0.0	0.0
(+ = ASU +)	28.0	26.0	13.0	8.0	61.0	28.0	8.0
PROTOSTYLID LM1	29.4	32.3	44.4	14.3	49.3	27.5	28.6
(+ = ASU 1-6)	34.0	31.0	18.0	7.0	69.0	40.0	14.0
CUSP 7 LM1	6.8	11.6	12.5	0.0	3.5	14.6	0.0
(+ = ASU 2-4)	44.0	43.0	24.0	12.0	85.0	48.0	17.0
TOMES ROOT LP1	9.3	19.6	19.4	8.7	6.0	2.9	17.2
(+ = ASU 3-5)	43.0	46.0	31.0	23.0	50.0	35.0	29.0
ROOT NUMBER LC	3.9	8.2	6.1	4.2	1.5	0.0	0.0
(+ = ASU 2+)	51.0	49.0	33.0	24.0	65.0	43.0	33.0
ROOT NUMBER LM1	0.0	2.6	0.0	0.0	0.0	0.0	0.0
(+ = ASU 3+)	51.0	39.0	23.0	15.0	45.0	29.0	17.0
ROOT NUMBER LM2	82.0	91.2	92.3	91.7	89.6	92.0	89.5
(+ = ASU 2+)	50.0	34.0	26.0	12.0	48.0	25.0	19.0
TORSOMOLAR ANGLE LM3	7.7	4.8	14.3	0.0	16.7	16.7	11.1
(+ = ASU +)	52.0	42.0	28.0	20.0	60.0	30.0	18.0

A.Upper row for each trait is the frequency in %, B.Lower row is the number of individuals scored, C. Breakpoint referenced in brackets.

Table 6.10 Lower Nubian trait percentages and sample size

		GEBEL RAMLAH (GRM)	C-GROUP (CGR)	HEIRAKONPOLIS C-GROUP (HKC)	PHA-RAONIC (PHA)	MEROITIC (MER)	X-GROUP (XGR)	CHRISTIAN (CHR)
4TH CATARACT	**4TH CATARACT KERMA (4CKM)**	0.09	0.129	0.081	0.052	0.071	0.029	0.11
	3-Q-33 (3Q33)	0.132	0.095	0.023	0	0.071	0.041	0.05
	4TH CATARACT POST-MEROITIC (4CPM)	0.127	0.189	0.096	0	0.096	0.048	0.087
	3-J-23 (3J23)	0.099	0.143	0.074	0.072	0.087	0.042	0.094
	3-J-18 (3J18)	0.154	0.195	0.088	0.082	0.088	0.069	0.108
DONGOLA REACH	**R12 (R12)**	0.128	0.128	0.054	0.069	0.075	0.045	0.059
	H29 (H29)	0.105	0.15	0.08	0.113	0.179	0.132	0.209
	P37 (P37)	0.15	0.108	0.042	0.056	0.091	0.061	0.069
	KERMA CLASSIQUE (KMC)	0.09	0.048	0	0.027	0.074	0.001	0
	SOLEB (SOL)	0.222	0.13	0.115	0.049	0.136	0.127	0.092
	AMARA WEST NEW KINGDOM (NK)	0.278	0.198	0.082	0.09	0.08	0.104	0.133
	TOMBOS (TOM)	0.079	0.037	0	0.045	0.096	0.041	0.058
	AMARA WEST POST-NEW KINGDOM (PNK)	0.139	0.092	0.011	0	0.04	0.048	0.061
	KAWA (KAW)	0.121	0.142	0.061	0.1	0.062	0.038	0.096
6TH CATARACT	**GHABA (GHB)**	0.11	0.114	0.046	0.024	0.032	0.016	0.066
	AL KHIDAY NEOLITHIC (AKN)	0.137	0.057	0.051	0.035	0.178	0.132	0.058
	GABATI MEROTIC (GABMER)	0.14	0.142	0.072	0.076	0.052	0.04	0.09
	GABATI POST-MEROTIC/MEDIEVAL (GABPM)	0.159	0.204	0.094	0.07	0.051	0.081	0.128
	SOBA (SBA)	0.166	0.138	0.078	0.037	0.064	0.053	0.087
LOWER NUBIA	**GEBEL RAMLAH (GRM)**	0	0.064	0.009	0.044	0.116	0.082	0.105
	C-GROUP (CGR)	0.064	0	0	0.082	0.139	0.057	0.056
	HEIRAKONPOLIS C-GROUP (HKC)	0.009	0	0	0	0.081	0.043	0.058
	PHARAONIC (PHA)	0.044	0.082	0	0	0.046	0.063	0.051
	MEROITIC (MER)	0.116	0.139	0.081	0.046	0	0.007	0.017
	X-GROUP (XGR)	0.082	0.057	0.043	0.063	0.007	0	0
	CHRISTIAN (CHR)	0.105	0.056	0.058	0.051	0.017	0	0

Red = significant at p ≤ 0.025 level

Table 6.11 Lower Nubian 36-trait MMD matrix.

value (MMD= 0.110). Gebel Ramlah is significantly different from all Upper Nubian Kerma collections, as well as the C-Group (CGR). The C-Group is significantly different from all Neolithic collections apart from Ghaba; conversely, Hierakonpolis C-Group (HKC) is akin to all. The two C-Group samples (CGR and HKC) are phenetically close, with an MMD of 0. The C-Group (CGR) is significantly different from all Kerma assemblages, whereas the Hierakonpolis C-Group (HKC) shares a close affinity to Kerma Classique (KMC) and P37 (MMD= 0).

When compared to the New Kingdom/post-New Kingdom, Hierakonpolis C-Group (HKC) is phenetically similar to Tombos (TOM) (MMD= 0), Pharaonic (PHA) (MMD= 0) and Amara West post-New Kingdom (PNK) (MMD= 0.011). On the other hand, C-group is significantly different from all the New Kingdom/post-New Kingdom, except for the Pharaonic sample. All Kerma period (including the C-group) samples share a close affinity with the Pharaonic sample, apart from H29. The Pharaonic collection is also very similar to the other New Kingdom/post-New Kingdom, sharing the closest relationship to Amara West post-New Kingdom (MMD= 0).

The Meroitic samples share a close affinity to the Pharaonic sample (PHA), with the exception of Kawa from which it differs significantly (p= 0.011). The Lower Nubian Meroitic (MER) sample only shares an affinity to the Pharaonic assemblage (PHA), and it is significantly different from all other Meroitic collections. Again, the Lower Nubian Meroitic sample (MER) only shares an affinity to the post-Meroitic assemblage from the same region, the X-Group (XGR). Whereas the X-Group is more similar to the Meroitic groups from other regions, apart from Kawa from which it differs significantly (p= 0.014).

From the Post-Meroitic samples, only the Gabati collection (GABPM) is distinct from the others producing significantly different MMD values. When compared to the medieval collections, the X-Group (XGR) and GABPM samples follow the same patterning, only showing relatedness to the samples from the same region. The 4th Cataract post-Meroitic sample (4CPM) is related to one of the 4th Cataract medieval collections (3-J-18) but not the other collection (3-J-23). Like 3-J-18, the Christian sample (CHR) shares no close affinities to the other medieval collections.

Table 6.12 shows the mean intra- and inter-region 36-trait MMD values. The 4th Cataract and Lower Nubia samples have lower mean intra-regional (i.e., samples from within the same region) than inter-regional (i.e., when compared to samples from different areas). Samples from the Dongola Reach and 6th Cataract share a lower mean MMD with other regions (6th Cataract and 4th Cataract respectively) than the intra-regional mean MMD. All three Upper Nubian regions are least similar to Lower Nubia.

Figure 6.5 is a MDS plot of the 36-trait MMD. For the MDS model, Kruskal's stress formula 1 was calculated at 0.166 and R^2 was calculated at 0.803, this means that the stress level is higher than 1.5 and the distances portrayed need to be viewed with caution. The 4th Cataract samples are more spread out across the graph than in the Upper Nubian analysis, but the samples still split into the before mentioned two distinct groups. The Dongola Reach samples are also much more widely spread than in the previous analysis. Three of the Dongola Reach samples are separated from the others (H29, Soleb (SOL), and Amara West New Kingdom (NK)). The 6th Cataract samples are quite closely grouped, except for Al Khiday which is separated

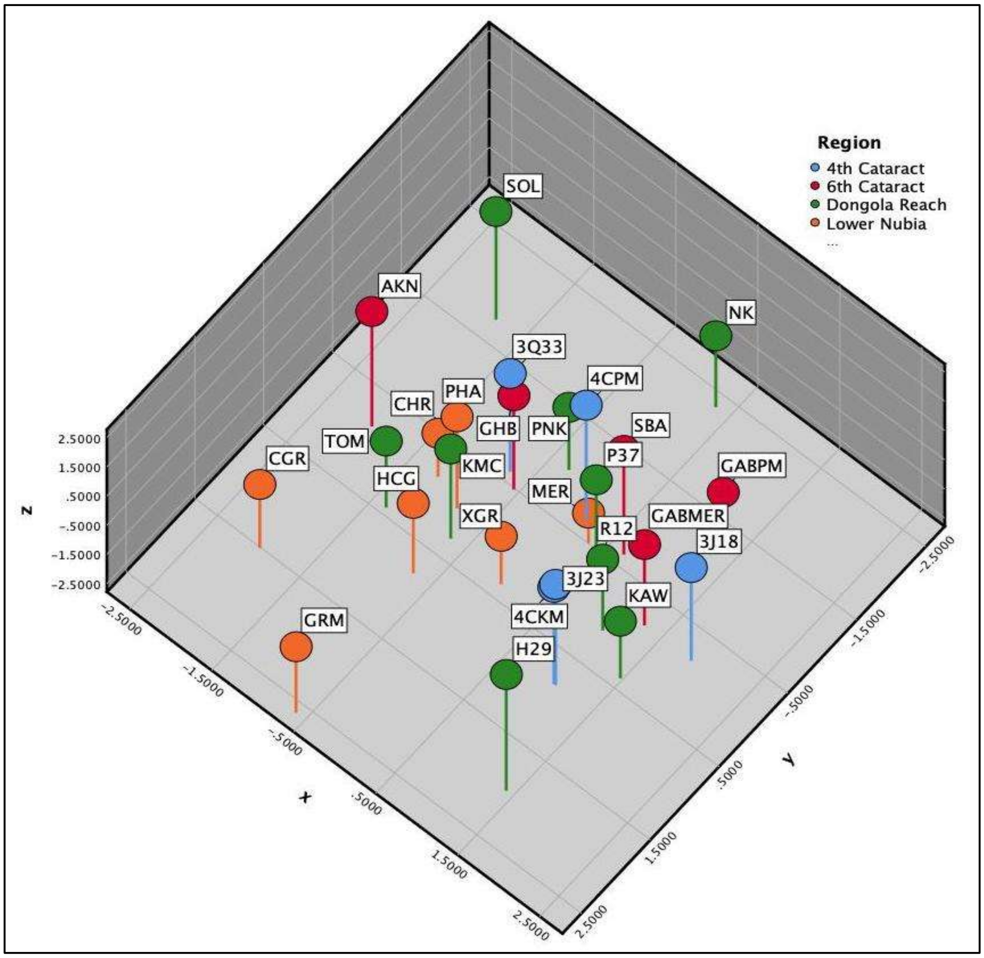
	4TH CATARACT	DONGOLA REACH	6TH CATARACT	LOWER NUBIA
4TH CATARACT	**0.037**	0.07	0.053	0.086
DONGOLA REACH	0.07	**0.075**	0.067	0.088
6TH CATARACT	0.053	0.067	**0.072**	0.088
LOWER NUBIA	0.086	0.088	0.088	**0.053**

Bold = Intra-regional mean MMD values. All other values are inter-regional mean MMD values.

Table 6.12 36-trait mean MMD values

from all other samples. The Lower Nubian samples cluster mainly to the left of the graph, but C-Group and Gebel Ramlah are isolated from each other and the rest of the samples. No temporal patterning is visible.

During the trait editing process, UP1 root number, P1/P2 odontome, mandibular torus, LC root number, and LM1 root number were removed from the analysis as these traits had less than 10% frequency across all the samples. Principal component analysis was run on the remaining 31 traits. The first six components were used in the analysis, accounting for 64% of the variation. Trait loadings for the six components are detailed Table 6.13. Figure 6.6 is a 3-D graph of the trait loadings over the 26 samples. There are two main groups visible on the graph, separated by component one. One group is made up of the all the Lower Nubian and some Upper Nubia samples (3-Q-33, 4th Cataract post-Meroitic (4CPM), Tombos (TOM), Kerma Classique (KMC), Amara West New Kingdom (NK), Amara West post-New Kingdom (PNK), Ghaba (GHB), Alkhiday (AKN)). The other group is comprised of the remaining Upper Nubia samples, minus H29 and Soleb (SOL) which are distinct from all other samples. The samples are separated by lower frequencies of UI1 shovelling, LP2 cusp number, LM1 cusp number, and LM1 deflecting wrinkle in the group containing the Lower Nubians. To finish the trait editing, correlated traits were also removed.



r^2 =0.803, Kruskal's stress formula 1 = 0.166

6.5 Multidimensional scaling Nubian 36-trait MMD data

After the full editing process was completed, 20 traits remained in the analysis (details in Table 6.4). The 20 traits were submitted to MMD analysis, results in Table 6.14. When comparing the Lower Nubian samples, the 20-trait MMD produces similar results to the 36-trait analysis. Some exceptions are the Pharaonic (PHA) sample is now significantly different from the Christian (CHR) (p= 0.034) and X-group (XGR) collections (p= 0.016), the Meroitic sample (MER) now also differs significantly from the Christian collection (p= 0.047), whereas the C-group now shares a close affinity with the Christian collection.

	PRINCIPAL COMPONENT					
	1	2	3	4	5	6
WINGING UI1	0.268	-0.065	0.358	-0.201	0.53	-0.276
LABIAL CURVATURE UI1	-0.056	0.505	0.196	0.603	0.058	0.139
PALATINE TORUS	0.464	-0.404	0.6	-0.141	0.173	-0.103
SHOVELING UI1	0.66	0.339	0.252	-0.182	0.088	0.028
DOUBLE SHOVELING UI1	-0.198	-0.053	0.683	0.361	-0.118	0.245
INTERUPTION GROOVE UI2	-0.282	-0.017	0.491	-0.322	0.057	0.245
TUBERCULUM DENTALE UI2	0.412	0.344	0.278	-0.019	-0.228	0.321
BUSHMAN CANINE UC	0.452	0.123	0.401	0.247	0.257	0.366
DISTAL ACCESSORY RIDGE UC	0.373	0.47	0.182	-0.373	-0.412	0.251
HYPOCONE UM2	0.179	0.616	-0.265	-0.253	-0.259	0.291
CUSP 5 UM1	-0.096	0.636	0.261	0.064	0.19	-0.39
CARABELLI'S CUSP UM1	0.06	0.369	0.224	0.526	-0.425	-0.254
PARASTYLE UM3	0.331	0.145	0.008	-0.504	-0.036	-0.032
ENAMEL EXTENSION UM1	0.44	-0.387	0.281	0.098	-0.406	-0.245
ROOT NUMBER UP1	-0.217	0.026	-0.139	0.387	0.196	0.065
ROOT NUMBER UM2	-0.501	0.121	0.435	0.027	0.469	0.479
PEG-REDUCED UI2	0.073	0.495	-0.142	-0.392	-0.166	0.007
CONGENITAL ABSENCE UM3	0.038	-0.031	0.659	-0.077	0.043	0.173
MID LINE DIASTEMA UI1	0.721	0.223	0.153	-0.231	0.021	-0.082
LINGUAL CUSP LP2	0.669	0.065	0.049	0.213	-0.191	0.302
ANTERIOR FOVEA LM1	0.194	0.309	0.153	0.593	0.223	-0.316
GROOVE PATTERN LM2	-0.496	0.501	0.209	-0.134	0.147	-0.182
ROCKER JAW	0.436	-0.301	0.539	0.065	-0.03	-0.356
CUSP NUMBER LM1	0.542	-0.135	-0.285	0.447	-0.096	0.135
CUSP NUMBER LM2	-0.26	0.719	0.179	0.075	-0.24	-0.266
DEFLECTING WRINKLE LM1	0.507	0.559	-0.296	-0.138	-0.007	-0.238
C1-C2 CREST LM1	0.444	-0.29	-0.509	0.391	-0.056	0.282
PROTOSTYLID LM1	-0.317	-0.054	0.231	0.401	-0.586	-0.216
CUSP 7 LM1	0.424	0.438	-0.226	0.139	0.363	-0.091
TOMES ROOT LP1	0.188	0.246	-0.32	0.178	0.646	-0.11
ROOT NUMBER LM2	0.012	0.468	-0.066	0.333	0.126	0.337
TORSOMOLAR ANGLE LM3	0.844	-0.392	-0.012	0.095	0.151	-0.057

Table 6.13 Nubia Principal component analysis loadings. Graphical representation in Appendix 5.

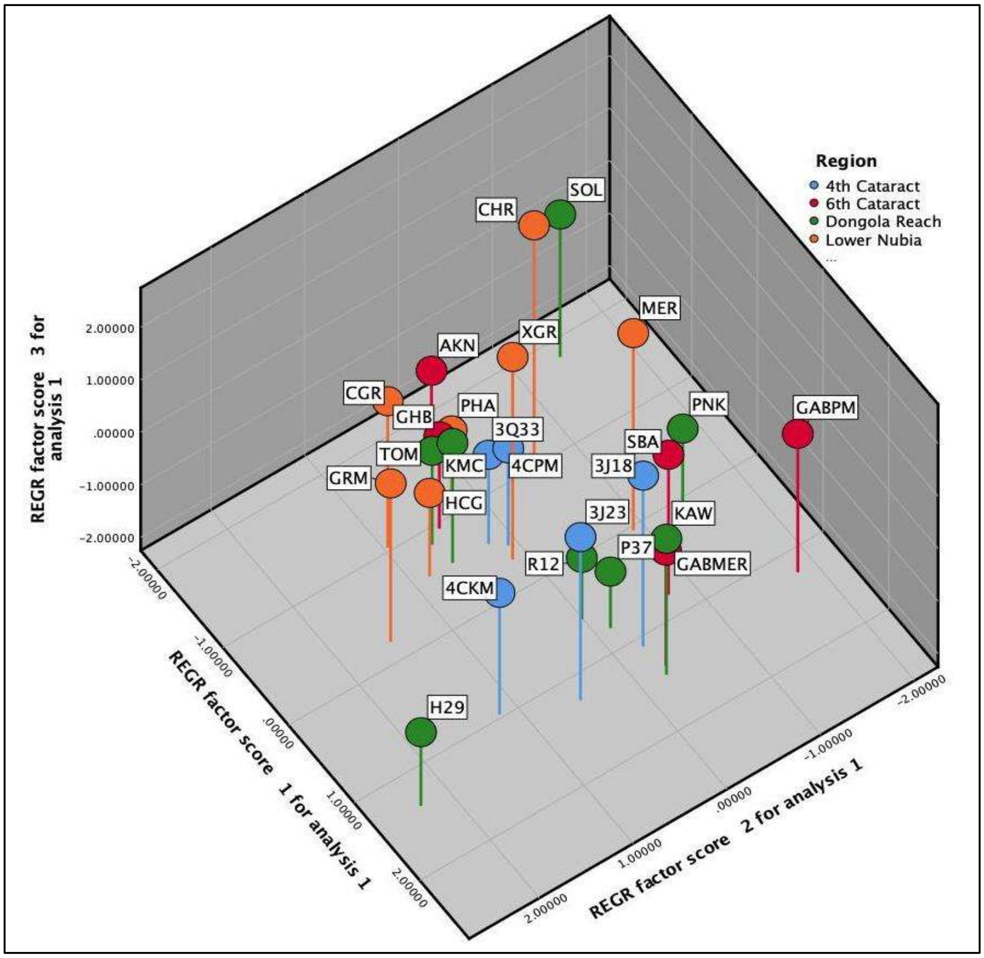


Figure 6.6 Nubia PCA loadings 3-D representation

When the Lower Nubian samples are compared to the other regional groups, the 20-trait MMD analysis again produces very similar results. Gebel Ramlah is still significantly different from all other Neolithic sites other than Ghaba. Gebel Ramlah and Ghaba produce a high MMD value (MMD= 0.115) but due to the high standard deviation this value is not significantly different. Gebel Ramlah also produces comparative results when assessed with the Kerma Period samples to those in the 36-trait analysis, only sharing a close affinity to Hierakonpolis C-Group (HKC). The C-group sample (CGR) is significantly different from all Neolithic samples, apart from Ghaba (MMD= 0.074). The Hierakonpolis C-Group sample shares a close

	GEBEL RAMLAH (GRM)	C-GROUP (CGR)	HEIRAKONPOLIS C-GROUP (HKC)	PHARAONIC (PHA)	MEROITIC (MER)	X-GROUP (XGR)	CHRISTIAN (CHR)
4TH CATARACT KERMA (4CKM)	0.098	0.154	0.030	0.104	0.057	0.057	0.154
3-Q-33 (3Q33)	0.207	0.081	0.003	0.023	0.122	0.103	0.104
4TH CATARACT POST-MEROITIC (4CPM)	0.126	0.142	0.071	0.076	0.056	0.012	0.112
3-J-23 (3J23)	0.100	0.136	0.017	0.121	0.096	0.057	0.146
3-J-18 (3J18)	0.149	0.195	0.082	0.156	0.083	0.058	0.176
R12 (R12)	0.122	0.112	0.026	0.082	0.024	0.020	0.064
H29 (H29)	0.095	0.161	0.035	0.076	0.141	0.130	0.249
P37 (P37)	0.114	0.033	0.000	0.079	0.050	0.035	0.054
KERMA CLASSIQUE (KMC)	0.147	0.053	0.000	0.071	0.081	0.015	0.007
SOLEB (SOL)	0.360	0.215	0.172	0.175	0.221	0.241	0.178
AMARA WEST NEW KINGDOM (NK)	0.360	0.252	0.122	0.176	0.075	0.124	0.182
TOMBOS (TOM)	0.138	0.041	0.006	0.114	0.105	0.046	0.054
AMARA WEST POST-NEW KINGDOM (PNK)	0.168	0.120	0.020	0.043	0.012	0.056	0.068
KAWA (KAW)	0.136	0.187	0.066	0.148	0.021	0.032	0.113
GHABA (GHB)	0.115	0.074	0.000	0.016	0.003	0.000	0.018
AL KHIDAY NEOLITHIC (AKN)	0.227	0.075	0.070	0.078	0.230	0.222	0.082
GABATI MEROTIC (GABMER)	0.173	0.152	0.071	0.141	0.031	0.043	0.142
GABATI POST-MEROTIC/MEDIEVAL (GABPM)	0.234	0.277	0.135	0.157	0.039	0.112	0.207
SOBA (SBA)	0.185	0.152	0.033	0.064	0.030	0.062	0.104
GEBEL RAMLAH (GRM)	0.000	0.084	0.008	0.059	0.146	0.125	0.158
C-GROUP (CGR)	0.084	0.000	0.000	0.065	0.155	0.081	0.011
HEIRAKONPOLIS C-GROUP (HKC)	0.008	0.000	0.000	0.000	0.070	0.034	0.046
PHARAONIC (PHA)	0.059	0.065	0.000	0.000	0.078	0.125	0.125
MEROTICI (MER)	0.146	0.155	0.070	0.078	0.000	0.006	0.053
X-GROUP (XGR)	0.125	0.081	0.034	0.125	0.006	0.000	0.001
CHRISTIAN (CHR)	0.158	0.011	0.046	0.125	0.053	0.001	0.000

Red = significant at p ≤ 0.025 level

Table 6.14 Nubia 20-trait MMD values

affinity will all Neolithic groups, particularly Ghaba (MMD= 0) and Gebel Ramlah (MMD=0.008). The C-Group sample now shows similarities to the P37 (MMD 0.033), as well as HKC and 4th Cataract Kerma (4CKM). The HKC sample is related to all others from the Kerma period.

When compared to the New Kingdom/post-New Kingdom samples, the C-Group (CGR) still differs significantly from all the collections apart from the Pharaonic (PHA). The Hierakonpolis C-Group (HKC) sample shares a close affinity with PHA (MMD= 0), Tombos (TOM) (MMD= 0.006), and Amara West post-New Kingdom (PNK) (MMD= 0.020). The Pharaonic sample shows a high level of affinity with all the Kerma Period collections except for 4th Cataract Kerma (4CKM) (MMD= 0.104), although this value is not significant. The Pharaonic sample differs significantly from Soleb, Tombos, and Amara West New Kingdom. When compared to the Meroitic samples, the Pharaonic sample is significantly different from the Gabati assemblage (GABPM), but otherwise behaves similarly to the 36-trait analysis. The Meroitic sample (MER) now shares a close affinity to the two Amara West samples (NK and PNK), as well as the Pharaonic (PHA).

Looking at all the Meroitic collections, the Lower Nubian Meroitic sample (MER) is now less divergent from the other assemblages. The MER sample is now closely related to Kawa (KAW) and Gabati Meroitic (GABMER), although it still differs significantly from 3-Q-33 (p= 0). When compared to the post-Meroitic collections, the MER sample now shares a close affinity with the 4th Cataract post-Meroitic (4CPM) as well as the X-Group (XGR). As in the 36-trait analysis, the XGR is still similar to both the MER and GABMER samples. The XGR is closely related to KAW and is significantly different from 3-Q-33 (p= 0.007).

All the post-Meroitic samples produce similar results in the 20-trait analysis to those of the 36-trait analysis. The only difference is that the MMD values are generally higher in the 20-trait analysis, indicating lower inter-group affinity. One exception to that is X-group (XGR) and 4th Cataract post-Meroitic (4CPM) where the MMD value has decreased (MMD= 0.012). When compared to the medieval samples, the XGR is now showing an affinity to Soba (SBA) as well as Lower Nubian Christian (CHR). The CHR sample is the only divergent sample in the medieval collections, being significantly different from every other sample in the group. All other medieval samples show a high level of affinity with one another.

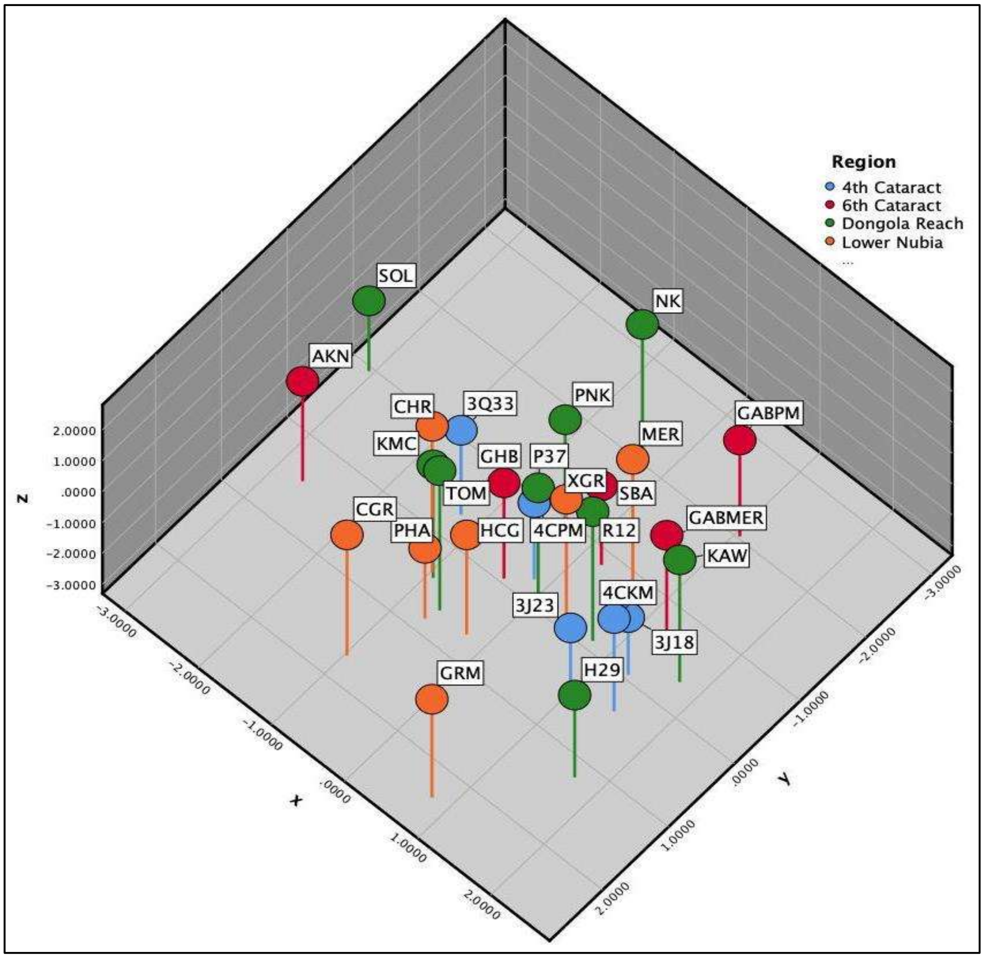
The mean values for the edited MMD data are given in Table 6.15. Again, the 4th Cataract and Lower Nubia have lower intra-regional mean MMDs than inter-regional. After trait editing, the samples from the Dongola Reach and 6th Cataract produce higher mean MMDs with samples from other regions.

	4TH CATARACT	DONGOLA REACH	6TH CATARACT	LOWER NUBIA
4TH CATARACT	**0.024**	0.085	0.09	0.099
DONGOLA REACH	0.085	**0.099**	0.107	0.105
6TH CATARACT	0.09	0.107	**0.133**	0.107
LOWER NUBIA	0.099	0.105	0.107	**0.071**

Bold = Intra-regional mean MMD values. All other values are inter-regional mean MMD values.

Table 6.15 Edited trait mean MMD values

Figure 6.7 is the MDS plot of the 20-trait MMD results. The model is a good fit for the MMD data, with Kruskal's stress formula 1 = 0.144 and r^2 = 0.859. The MDS plot shows that the Lower Nubian samples group together, except for the Meroitic (MER) and Gebel Ramlah (GRM) samples. The other three regions (4th Cataract, Dongola Reach, and 6th Cataract) show little geographical patterning. There is no temporal patterning evident. There are several samples which are outliers, these are Gabati post-Meroitic (GABPM), Amara West New Kingdom (NK), Soleb (SOL), Al Khiday (AKN), C-Group (CGR), GRM, and H29.



r^2 =0.859, Kruskal's stress formula 1 = 0.144

Figure 6.7 Multidimensional scaling Nubian 20-trait MMD data

6.2.4 East Africa and Lachish

The scope of the analysis was widened to include samples from Egypt and other countries that are geographically proximate to Nubia. The Egyptian samples are archaeological (split into Upper and Lower Egypt), and those from the neighbouring countries are mainly historical (from the 19th/20th century). The historical samples are from sub-Saharan Africa and are referred to as such below. An Iron Age sample from Lachish in Israel has also been included. Details of the samples can be found in Table 5.1.

The relevant trait frequencies for the additional samples can be found in Table 6.16. The frequencies for the Egyptian and Nubian samples are not notably dissimilar. There are a few traits where some differences can be observed, these are higher levels of UM1 Carabelli's cusp, UP1 root number, and UM3 congenital absence, in the Egyptian samples. The sub-Saharan African samples and Lachish also have quite similar frequencies to both the Nubian and Egyptian collections. The sub-Saharan African samples have a few visible differences, including higher levels of UM2 cusp pattern and UM1 cusp 7.

Table 6.17 is the 36-trait MMD results. The Egyptian samples are generally dissimilar from the Nubian collections. The Upper Egyptian samples are more similar to the Nubian collections than the Lower Egyptian samples. Out of the Upper Egyptian samples, Abydos (ABY) shows the greatest affinity with the Nubian collections, followed by Thebes (THE). The Lower Nubians have the highest affinity with the Egyptian samples out of the Nubian regional groups, with Hierakonpolis Group (HKC) and Pharaonic (PHA) showing the greatest level of similarity. The 4th Cataract group is least similar to the Egyptian samples, with only 3-Q-33 showing an affinity to ABY (MMD= 0.071) and Lisht (LIS) (MMD= 0.053). The Dongola Reach collections share a closer affinity to the Egyptian samples, with Amara West post-New Kingdom (PNK) the most similar. The 6th Cataract collections are mainly dissimilar from the Egyptian samples, except for Ghaba which shares a close affinity with all Egyptian samples apart from Saqqara (SAQ). Ghaba is also the only Neolithic sample to share similarities with the Egyptian samples, apart from Al Khiday (AKN) and Qurneh (QUR) (MMD= 0.043). Similarly, the Kerma period collections show little affinity to the Egyptian samples, apart from HKC which is similar to all bar Saqqara (SAQ). The collection from Thebes (THE) shares an affinity

	UPPER EGYPT			LOWER EGYPT			MIDDLE EAST			SUB-SAHARAN AFRICA		
	Abydos (ABY)	Thebes (THE)	Qurneh (QUR)	Saqqara (SAQ)	Lisht (LIS)	Giza (GIZ)	Lachish (LAC)	Ethiopia (ETH)	Somalia (SOM)	Chad (CHA)	Kenya (KEN)	Tanzania (TAN)
WINGING UI1	4.4[A]	5.6	5.2	2.8	2.1	4.3	3.5	0.0	6.0	0.0	4.0	5.3
(+ = ASU 1)[C]	46.0[B]	54.0	58.0	36.0	47.0	47.0	57.0	36.0	67.0	23.0	99.0	38.0
LABIAL CURVATURE UI1	11.1	47.6	28.6	9.1	45.5	17.7	37.5	36.4	27.8	63.3	37.5	57.9
(+ = ASU 2-4)	9.0	21.0	21.0	11.0	11.0	17.0	24.0	11.0	18.0	11.0	16.0	19.0
PALATINE TORUS	1.9	0.0	0.0	0.0	0.0	0.0	3.3	10.8	0.0	8.3	0.9	2.4
(+ = ASU 2-3)	52.0	51.0	61.0	39.0	51.0	47.0	61.0	37.0	70.0	24.0	108.0	41.0
SHOVELING UI1	40.0	15.8	0.0	0.0	0.0	15.4	0.0	28.6	5.6	11.1	7.1	12.5
(+ = ASU 2-6)	5.0	19.0	17.0	7.0	10.0	13.0	22.0	7.0	18.0	9.0	14.0	16.0
DOUBLE SHOVELING UI1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	0.0	6.7	0.0
(+ = ASU 2-6)	4.0	18.0	22.0	8.0	12.0	16.0	25.0	7.0	17.0	9.0	15.0	17.0
INTERUPTION GROOVE UI2	21.4	20.8	3.7	33.3	31.6	4.2	5.9	23.1	0.0	0.0	11.5	5.0
(+ = ASU +)	14.0	24.0	27.0	9.0	19.0	24.0	34.0	13.0	24.0	11.0	26.0	20.0
TUBERCULUM DENTALE UI2	36.4	30.0	52.2	66.7	36.8	25.0	26.5	41.7	39.1	30.0	36.0	47.4
(+ = ASU 2-6)	11.0	20.0	23.0	6.0	19.0	24.0	34.0	12.0	23.0	10.0	25.0	19.0
BUSHMAN CANINE UC	17.7	3.0	0.0	0.0	0.0	6.3	7.3	5.6	3.1	23.1	13.0	12.9
(+ = ASU 1-3)	17.0	33.0	31.0	10.0	27.0	32.0	41.0	18.0	32.0	13.0	46.0	31.0
DISTAL ACCESSORY RIDGE UC	30.0	10.5	8.7	0.0	0.0	7.1	7.1	27.3	34.5	55.6	36.6	48.0
(+ = ASU 2-5)	10.0	19.0	23.0	6.0	23.0	28.0	28.0	11.0	29.0	9.0	41.0	25.0
HYPOCONE UM2	85.7	85.7	87.0	95.7	88.1	84.2	82.5	66.7	71.0	64.7	78.0	87.8

(+ = ASU 3-5)	42.0	42.0	46.0	23.0	42.0	38.0	57.0	33.0	69.0	17.0	91.0	41.0
CUSP 5 UM1	19.2	14.3	5.3	0.0	15.4	5.7	21.4	7.4	19.4	7.7	14.8	5.9
(+ = ASU 2-5)	26.0	28.0	38.0	9.0	26.0	35.0	42.0	27.0	62.0	13.0	81.0	34.0
CARABELLI'S CUSP UM1	84.4	90.3	70.6	100.0	60.9	72.7	73.2	60.7	61.3	25.0	55.2	55.9
(+ = ASU 2-7)	32.0	31.0	34.0	16.0	23.0	33.0	41.0	28.0	62.0	12.0	87.0	34.0
PARASTYLE UM3	2.8	0.0	3.0	0.0	0.0	0.0	5.6	0.0	2.1	0.0	2.7	0.0
(+ = ASU 1-5)	36.0	37.0	33.0	15.0	32.0	26.0	36.0	24.0	48.0	16.0	73.0	37.0
ENAMEL EXTENSION UM1	9.3	4.8	9.8	0.0	14.9	6.4	7.8	5.6	4.4	0.0	1.1	2.5
(+ = ASU 1-3)	43.0	42.0	51.0	18.0	47.0	47.0	64.0	36.0	68.0	17.0	93.0	40.0
ROOT NUMBER UP1	71.0	85.3	70.6	89.7	61.9	62.5	69.7	53.6	75.0	50.0	68.6	62.2
(+ = ASU 2+)	31.0	34.0	34.0	29.0	42.0	32.0	33.0	28.0	44.0	24.0	102.0	37.0
ROOT NUMBER UM2	73.7	81.3	70.0	82.6	77.3	72.7	80.0	85.0	82.9	78.6	90.6	79.4
(+ = ASU 3+)	19.0	32.0	30.0	23.0	44.0	22.0	20.0	20.0	41.0	14.0	85.0	34.0
PEG-REDUCED UI2	2.0	0.0	1.6	6.1	0.0	1.8	1.5	2.6	0.0	5.3	0.0	3.8
(+ = ASU P OR R)	49.0	54.0	62.0	33.0	22.0	57.0	67.0	38.0	73.0	19.0	30.0	26.0
ODONTOME P1-P2	0.0	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0
(+ = ASU +)	36.0	39.0	50.0	12.0	42.0	42.0	70.0	27.0	68.0	17.0	85.0	43.0
CONGENITAL ABSENCE UM3	7.4	19.6	18.6	20.0	3.6	15.4	18.8	12.8	4.1	0.0	3.0	4.7
(+ = ASU -)	54.0	51.0	59.0	35.0	55.0	52.0	64.0	39.0	74.0	22.0	100.0	43.0
MID LINE DIASTEMA UI1	0.0	1.9	0.0	0.0	7.7	0.0	3.1	10.3	3.0	12.5	15.3	2.9
(+ ≥ 0.5 MM)	51.0	53.0	61.0	33.0	39.0	52.0	65.0	39.0	67.0	24.0	72.0	34.0
LINGUAL CUSP LP2	76.0	70.3	54.3	66.7	66.7	61.9	79.6	37.5	63.2	62.5	40.0	70.8
(+ = ASU 2-9)	25.0	37.0	35.0	12.0	12.0	21.0	49.0	8.0	38.0	8.0	15.0	24.0
ANTERIOR FOVEA LM1	66.7	42.9	35.3	14.3	37.5	17.4	40.0	57.1	50.0	40.0	69.2	58.8
(+ = ASU 2-4)	3.0	14.0	17.0	7.0	8.0	23.0	20.0	7.0	52.0	5.0	13.0	17.0
MANDIBULAR TORUS	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0
(+ = ASU 2-3)	41.0	52.0	52.0	37.0	37.0	51.0	73.0	12.0	64.0	20.0	21.0	29.0
GROOVE PATTERN LM2	27.0	25.0	19.6	22.7	37.5	29.6	34.3	66.7	58.3	36.4	83.3	65.4
(+ = ASU Y)	37.0	48.0	51.0	22.0	24.0	44.0	70.0	12.0	60.0	11.0	18.0	26.0

ROCKER JAW	30.6	22.6	9.6	24.3	32.4	13.7	7.7	0.0	9.4	5.9	14.3	6.9
(+ = ASU 1-2)	36.0	53.0	52.0	37.0	37.0	51.0	65.0	12.0	64.0	17.0	21.0	29.0
CUSP NUMBER LM1	0.0	2.8	6.9	0.0	5.6	2.3	3.7	8.3	14.0	0.0	5.6	8.3
(+ = ASU 6+)	20.0	36.0	29.0	10.0	18.0	43.0	54.0	12.0	57.0	17.0	18.0	24.0
CUSP NUMBER LM2	33.3	26.3	22.5	25.0	20.8	25.0	37.0	37.5	57.9	66.7	52.9	65.2
(+ = ASU 5+)	24.0	38.0	40.0	12.0	24.0	36.0	54.0	8.0	57.0	9.0	17.0	23.0
DEFLECTING WRINKLE LM1	0.0	13.3	29.2	0.0	22.2	5.7	8.1	18.2	27.1	25.0	33.3	12.5
(+ = ASU 2-3)	17.0	30.0	24.0	8.0	9.0	35.0	37.0	11.0	59.0	4.0	12.0	16.0
C1-C2 CREST LM1	0.0	0.0	4.2	0.0	11.1	2.9	3.1	0.0	0.0	0.0	0.0	0.0
(+ = ASU +)	14.0	26.0	24.0	5.0	9.0	34.0	32.0	12.0	60.0	4.0	12.0	17.0
PROTOSTYLID LM1	19.1	12.2	6.3	7.1	53.3	11.4	6.9	0.0	5.2	50.0	35.3	30.4
(+ = ASU 1-6)	21.0	41.0	32.0	14.0	15.0	35.0	58.0	12.0	58.0	6.0	17.0	23.0
CUSP 7 LM1	3.0	6.8	5.6	0.0	0.0	4.3	0.0	16.7	28.8	20.0	11.1	20.8
(+ = ASU 2-4)	33.0	44.0	36.0	20.0	23.0	47.0	67.0	12.0	59.0	10.0	18.0	24.0
TOMES ROOT LP1	3.1	11.1	12.9	6.7	8.6	0.0	6.8	0.0	18.4	31.6	25.0	25.9
(+ = ASU 3-5)	32.0	36.0	31.0	30.0	35.0	47.0	59.0	5.0	49.0	19.0	20.0	27.0
ROOT NUMBER LC	0.0	0.0	0.0	6.1	5.6	1.9	3.1	0.0	1.9	0.0	0.0	0.0
(+ = ASU 2+)	31.0	35.0	27.0	33.0	36.0	52.0	65.0	6.0	53.0	14.0	18.0	28.0
ROOT NUMBER LM1	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0
(+ = ASU 3+)	26.0	39.0	29.0	26.0	29.0	34.0	33.0	11.0	51.0	15.0	18.0	25.0
ROOT NUMBER LM2	96.3	91.7	85.7	86.7	86.2	82.4	79.6	88.9	93.8	85.7	100.0	100.0
(+ = ASU 2+)	27.0	36.0	28.0	30.0	29.0	34.0	44.0	9.0	48.0	14.0	17.0	24.0
TORSOMOLAR ANGLE LM3	9.4	22.5	2.7	0.0	30.8	2.9	14.3	0.0	10.0	7.7	12.5	18.2
(+ = ASU +)	32.0	40.0	37.0	23.0	26.0	35.0	56.0	11.0	50.0	13.0	16.0	22.0

A.Upper row for each trait is the frequency in %, B.,Lower row is the number of individuals scored,
C. ASUDAS score used as breakpoint referenced in brackets.

Table 6.16 East Africa and Lachish trait percentages and sample sizes.

with P37 (MMD= 0.042) and CGR (MMD= 0.028). The Upper Nubian New Kingdom samples (Soleb (SOL) and Amara West New Kingdom (NK)) show a closer affinity to Lower Egyptian samples, rather than Upper Egyptian. Tombos (TOM) shares no similarities with the Egyptian samples. Whereas Amara West post-New Kingdom (PNK) shares a close affinity with three Egyptian samples (Abydos (ABY), Qurneh (QUR), and Lisht (LIS)). The Lower Nubian New Kingdom sample (PHA) is highly related to all Egyptian samples.

The Meroitic samples display low levels of phenetic similarity with the Egyptian samples. Again, the most similar Egyptian sample is Abydos which shares an affinity with 3-Q-33, Kawa (KAW), and Meroitic (MER). From the post-Meroitic collections, only the X-Group (XGR) reveals similarities with the Egyptians, sharing close affinities with Abydos (ABY) (MMD= 0) and Thebes (THE) (MMD= 0.025). Both 4th Cataract medieval samples (3-J-23 and 3-J-18) are significantly different from all Egyptian samples. Soba, from the 6th Cataract, shares an affinity with ABY only (MMD= 0.058). Again, the Lower Nubian sample (CHR) is the most similar to the Egyptian collections out of the medieval Nubian samples.

The Egyptian samples are similar to the Lachish collection (LAC), only differing significantly from Thebes (THE) (p= 0.012). Additionally, Ethiopia (ETH) shows a high level of relatedness to the Egyptian collections, producing only two significantly different MMD values (Saqarra (SAQ) p=0.014, Lisht (LIS) p=0.002.). Other than the above, the only close affinity revealed between the Egyptian samples and those from sub-Saharan Africa is with Abydos (ABY) and Tanzania (TAN) (MMD= 0.53).

		UPPER EGYPT			LOWER EGYPT			MIDDLE EAST	SUB-SAHARAN AFRICA				
		ABYDOS (ABY)	THEBES (THE)	QURNEH (QUR)	SAQQARA (SAQ)	LISHT (LIS)	GIZA (GIZ)	LACHISH (LAC)	ETHIOPIA (ETH)	SOMALIA (SOM)	CHAD (CHA)	KENYA (KEN)	TANZANIA (TAN)
4TH CATARACT	**4TH CATARACT KERMA (4CKM)**	0.073	0.106	0.171	0.265	0.177	0.17	0.151	0.039	0.122	0.078	0.13	0.085
	3-Q-33 (3Q33)	0.071	0.074	0.066	0.135	0.053	0.059	0.04	0.053	0.061	0.005	0.064	0.074
	4TH CATARACT POST-MEROITIC (4CPM)	0.101	0.087	0.068	0.094	0.13	0.068	0.081	0.054	0.105	0.078	0.151	0.087
	3-J-23 (3J23)	0.086	0.124	0.162	0.269	0.149	0.159	0.124	0.05	0.105	0.068	0.104	0.083
	3-J-18 (3J18)	0.092	0.121	0.162	0.222	0.142	0.138	0.138	0.102	0.151	0.111	0.141	0.131
DONGOLA REACH	**R12 (R12)**	0.058	0.048	0.093	0.161	0.118	0.095	0.081	0.071	0.085	0.056	0.128	0.066
	H29 (H29)	0.141	0.169	0.202	0.317	0.256	0.233	0.2	0.095	0.107	0.082	0.123	0.087
	P37 (P37)	0.071	0.042	0.043	0.144	0.069	0.072	0.041	0.067	0.071	0.068	0.115	0.083
	KERMA CLASSIQUE (KMC)	0.01	0.011	0.072	0.122	0.093	0.044	0.017	0.023	0.031	0.024	0.046	0.018
	SOLEB (SOL)	0.099	0.11	0.069	0.136	0.074	0.047	0.064	0	0.106	0.112	0.1	0.142
	AMARA WEST NEW KINGDOM (NK)	0.135	0.093	0.077	0.174	0.045	0.08	0.095	0.151	0.176	0.121	0.22	0.185
	TOMBOS (TOM)	0.079	0.03	0.057	0.107	0.048	0.077	0.043	0.066	0.075	0.02	0.089	0.04
	AMARA WEST POST-NEW KINGDOM (PNK)	0.037	0.04	0.018	0.083	0.014	0.048	0.032	0.07	0.088	0.065	0.114	0.096
	KAWA (KAW)	0.039	0.064	0.112	0.177	0.136	0.124	0.098	0.09	0.124	0.107	0.172	0.099
6TH CATARACT	**GHABA (GHB)**	0.04	0.109	0.098	0.19	0.067	0.063	0.065	0.018	0.059	0.005	0.062	0.005
	AL KHIDAY NEOLITHIC (AKN)	0.098	0.066	0.043	0.11	0.089	0.064	0.039	0	0.003	0.033	0	0.035
	GABATI MEROTIC (GABMER)	0.073	0.089	0.102	0.185	0.087	0.136	0.11	0.087	0.119	0.05	0.122	0.086
	GABATI POST-MEROTIC/MEDIEVAL (GABPM)	0.064	0.093	0.114	0.188	0.102	0.074	0.099	0.115	0.147	0.1	0.19	0.152
	SOBA (SBA)	0.058	0.08	0.131	0.214	0.144	0.103	0.119	0.047	0.099	0.099	0.142	0.114
LOWER NUBIA	**GEBEL RAMLAH (GRM)**	0.049	0.079	0.137	0.148	0.134	0.124	0.128	0.024	0.079	0.062	0.051	0.035
	C-GROUP (CGR)	0.061	0.028	0.088	0.135	0.055	0.127	0.075	0.056	0.051	0.081	0.031	0.053
	HEIRAKONPOLIS C-GROUP (HKC)	0.025	0.005	0.04	0.108	0.012	0.042	0.035	0.035	0.009	0.009	0.015	0.012

	PHARAONIC (PHA)	0	0.032	0.011	0.017	0.072	0	0.053	0	0.042	0.042	0.054	0.089
	MEROITIC (MER)	0	0.073	0.135	0.135	0.069	0.078	0.105	0.086	0.158	0.068	0.137	0.096
	X-GROUP (XGR)	0	0.025	0.103	0.105	0.072	0.078	0.052	0.04	0.095	0.081	0.1	0.053
	CHRISTIAN (CHR)	0	0.01	0.1	0.08	0.053	0.056	0.023	0.054	0.082	0.052	0.06	0.052
UPPER EGYPT	**ABYDOS (ABY)**	0	0	0.068	0.029	0.078	0.004	0.038	0.023	0.074	0.098	0.081	0.053
	THEBES (THE)	0	0	0.018	0.009	0.028	0.015	0.012	0.04	0.064	0.119	0.087	0.067
	QURNEH (QUR)	0.068	0.018	0	0.01	0.046	0	0.008	0.034	0.048	0.112	0.115	0.095
LOWER EGYPT	**SAQQARA (SAQ)**	0.029	0.009	0.01	0	0.074	0.001	0.039	0.098	0.154	0.26	0.2	0.182
	LISHT (LIS)	0.078	0.028	0.046	0.074	0	0.058	0.038	0.102	0.132	0.106	0.086	0.108
	GIZA (GIZ)	0.004	0.015	0	0.001	0.058	0	0.005	0.021	0.078	0.115	0.139	0.111
MIDDLE EAST	**LACHISH (LAC)**	0.038	0.012	0.008	0.039	0.038	0.005	0	0.039	0.064	0.099	0.11	0.088
SUB-SAHARAN AFRICA	**ETHIOPIA (ETH)**	0.023	0.04	0.034	0.098	0.102	0.021	0.039	0	0	0.012	0	0.008
	SOMALIA (SOM)	0.074	0.064	0.048	0.154	0.132	0.078	0.064	0	0	0.029	0.009	0.007
	CHAD (CHA)	0.098	0.119	0.112	0.26	0.106	0.115	0.099	0.012	0.029	0	0	0
	KENYA (KEN)	0.081	0.087	0.115	0.2	0.086	0.139	0.11	0	0.009	0	0	0
	TANZANIA (TAN)	0.053	0.067	0.095	0.182	0.108	0.111	0.088	0.008	0.007	0	0	0

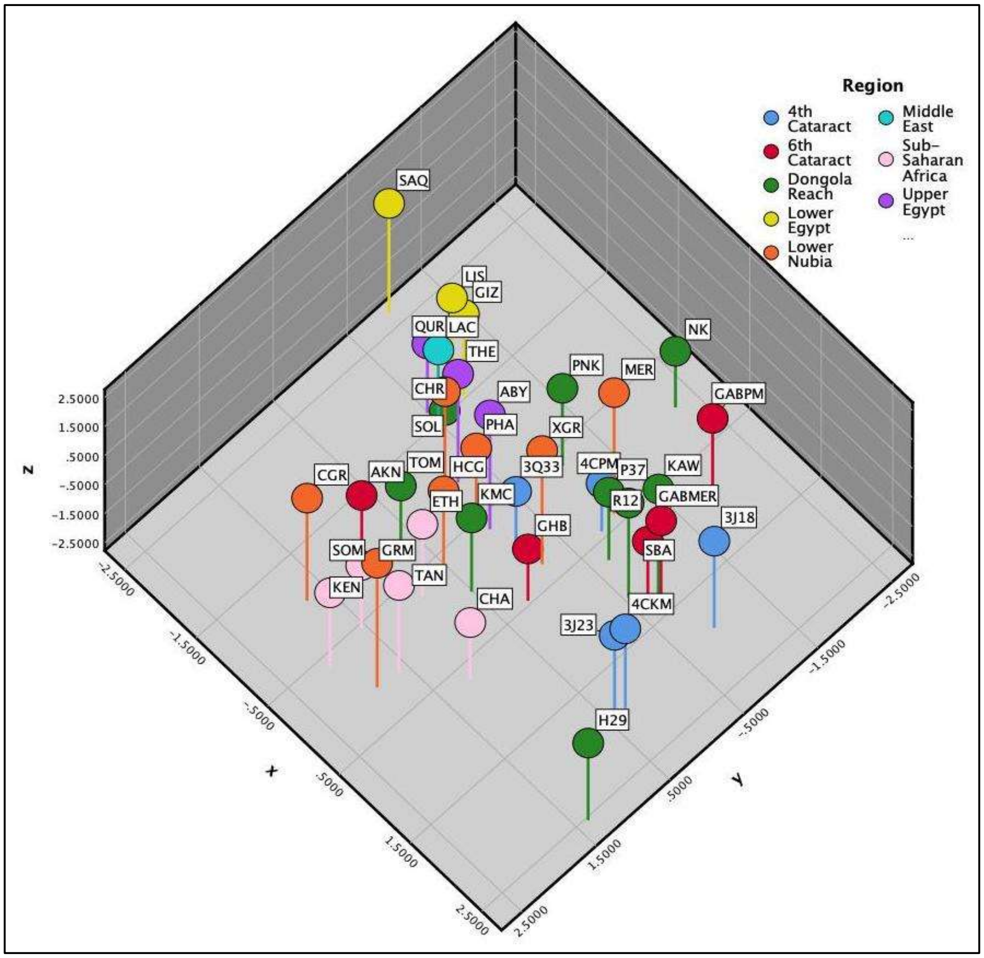
Red = significant at p ≤ 0.025 level

Table 6.17 East Africa and Lachish 36-trait MMD values

There are higher levels of affinity evident when the Nubian samples are compared to the sub-Saharan African and Lachish samples, although the majority still produce significantly different values. Ethiopia (ETH) shares the highest level of affinity with the Nubian samples, followed by Chad (CHA). The Lower Nubian collections are the most similar to the sub-Saharan African samples, followed by those from the 6th Cataract. This is also the case when compared to the Lachish sample (LAC).

From the Neolithic samples, both Ghaba (GHB) and Al Khiday (AKN) show a high level of relatedness to the sub-Saharan African collections. Conversely, Gebel Ramlah (GRM) and R12 are dissimilar from the sub-Saharan Africans. Only Al Khiday, from the Neolithic samples, shares a close affinity to Lachish (LAC) (MMD= 0.039). Both Kerma Classique (KMC) and Hierankopolis C-Group (HKC) show high levels of similarity to the sub-Saharan African collections. The other four Kerma period collections reveal that they are not similar to most of the sub-Saharan African collections. Both C-group samples (CGR and HCG) and P37 share an affinity with Lachish. Of the New Kingdom collections, only the Pharaonic (PHA) sample shares a high level of similarity to the sub-Saharan Africans. Both post-New Kingdom samples (TOM and PNK) share similarities with Chad (CHA). Lachish is similar to both Tombos and Pharaonic.

The Meroitic samples are dissimilar from those from sub-Saharan Africa, with only 3-Q-33 and Gabati Meroitic (GABMER) producing non-significant MMD values with Ethiopia (ETH) and Chad (CHA), and Chad respectively. Lachish (LAC) is only similar to 3-Q-33 (MMD= 0.40), differing significantly from all other Meroitic samples. The post-Meroitic samples show little relatedness to the sub-Saharan Africans, with only X-Group (XGR) sharing a close affinity to ETH and 4th Cataract post-Meroitic (4CPM) to ETH and CHA. Gabati post-Meroitic (GABPM) is the only sample from the group that is similar to Lachish. The medieval collections from the 4th Cataract (3-J-23 and 3-J-18) are significantly different from all from sub-Saharan African. Soba (SBA) shares a similarity to Ethiopia, and the Christian sample (CHR) shares similarities with ETH and CHA. Lachish is significantly different from all medieval collections.



r^2 =0.797, Kruskal's stress formula 1 = 0.165

Figure 6.8 Multidimensional scaling East Africa and Lachish 36-trait MMD data

Figure 6.8 shows the MDS representation of the 36-trait MMD data. Kruskal's stress formula 1 was calculated at 0.165 and R^2 was calculated at 0.797 for the MDS, indicating the model is not an optimal fit for the MMD data. As the stress level is higher than 1.5 the relationships portrayed between the samples on the graph may not be fully representative of the data. The sub-Saharan African samples are grouped together, as are the Egyptians. The majority of the Nubian samples are grouped in between the sub-Saharan African and Egyptian groups, no explicit regional patterning can be observed in the Nubian groups. Both Abydos (ABY) and Thebes (THE) are more closely associated with the Nubian group than the Egyptians. Gebel Ramlah (GRM) is placed in the sub-Saharan African cluster, additionally the C-group sample (CGR) is also closely associated with that group. Lachish (LAC) and Soleb (SOL) are located in the Egyptian group. Although regional patterning is unclear in the Nubian collections, some temporal patterning is evident. The New Kingdom/post-New Kingdom samples (Soleb (SOL), Amara West New Kingdom (NK), Tombos (TOM), Amara West post-New Kingdom (PNK)) are all placed close to (or in) the Egyptian group. The three post-Meroitic samples (4CPM, GABPM, XGR) are grouped together. All medieval samples, except for the Christian (CHR) sample, are clustered together.

Low frequency (<10%) traits were removed from the analysis, these were premolar odontome, mandibular torus, lower canine root number, and lower M1 root number. Principal component analysis was run on the remaining 32 traits. This analysis revealed that the first six principal components were responsible for 60% of the variation. Table 6.18 is the loadings for each trait across the six components. Figure 6.9 is the 3-D plot of the first three components, revealing how the trait loadings

	PRINCIPAL COMPONENT					
	1	2	3	4	5	6
WINGING UI1	0.346	-0.102	0.405	0.119	-0.366	0.263
LABIAL CURVATURE UI1	0.127	0.542	0.071	-0.327	0.29	0.098
PALATINE TORUS	0.449	-0.283	0.572	-0.077	-0.338	-0.118
SHOVELING UI1	0.689	-0.041	0.268	0.289	0.067	0.038
DOUBLE SHOVELING UI1	-0.054	0.26	0.574	-0.285	0.047	0.121
INTERUPTION GROOVE UI2	-0.123	-0.171	0.46	0.321	-0.125	0.156
TUBERCULUM DENTALE UI2	0.125	0.038	0.174	0.245	0.612	-0.002
BUSHMAN CANINE UC	0.535	0.176	0.367	-0.121	0.037	0.205
DISTAL ACCESSORY RIDGE UC	0.529	0.451	0.069	0.261	0.022	-0.343
HYPOCONE UM2	0.099	-0.173	-0.222	0.508	0.467	0.157
CUSP 5 UM1	0.258	0.376	0.244	0.197	0.041	0.105
CARABELLI'S CUSP UM1	-0.276	0	0.19	-0.055	0.728	-0.025
PARASTYLE UM3	0.422	-0.179	-0.01	0.473	-0.124	-0.002
ENAMEL EXTENSION UM1	0.254	-0.555	0.232	-0.284	0.161	-0.435
ROOT NUMBER UP1	-0.3	-0.029	-0.112	-0.08	0.38	0.595
ROOT NUMBER UM2	-0.307	0.433	0.46	0.023	-0.222	0.492
PEG-REDUCED UI2	0.144	0.16	-0.197	0.689	0.174	-0.027
CONGENITAL ABSENCE UM3	-0.363	-0.305	0.449	0.229	0.32	0.188
MID LINE DIASTEMA UI1	0.715	0.03	0.137	0.183	0.048	-0.17
LINGUAL CUSP LP2	0.611	-0.336	0.009	0.007	0.25	0.152
ANTERIOR FOVEA LM1	0.278	0.453	0.207	-0.438	0.224	0.009
GROOVE PATTERN LM2	-0.189	0.745	0.16	0.035	-0.106	-0.167
ROCKER JAW	0.175	-0.45	0.522	-0.126	0.26	-0.102
CUSP NUMBER LM1	0.536	-0.121	-0.27	-0.408	0.098	0.154
CUSP NUMBER LM2	0.061	0.809	0.041	0.064	0.162	-0.344
DEFLECTING WRINKLE LM1	0.653	0.225	-0.306	0.232	0.108	-0.023
C1-C2 CREST LM1	0.38	-0.399	-0.469	-0.403	0.113	0.167
PROTOSTYLID LM1	-0.131	0.187	0.101	-0.372	0.217	-0.444
CUSP 7 LM1	0.512	0.521	-0.192	-0.117	-0.132	0.069
TOMES ROOT LP1	0.468	0.375	-0.267	-0.098	-0.171	0.391
ROOT NUMBER LM2	0.177	0.552	0.008	-0.155	0.23	0.214
TORSOMOLAR ANGLE LM3	0.711	-0.367	-0.031	-0.338	0.065	0.091

Table 6.18 East Africa and Lachish principal component analysis loadings. Graphical representation in Appendix 5.

affect the position of the samples. As in Figure 6.8, the sub-Saharan African and Egyptian samples create separate clusters, with the Nubian samples positioned in between. There is a division in the samples associated with the first principal component, a smaller group (comprised of 3-J-18, 3-J-23, 4th Cataract Kerma (4CKM), Gabati Meroitic (GABMER), Gabati post-Meroitic (GABPM), H29, Kawa (KAW), Amara West New Kingdom (NK), P37, Amara West post-New Kingdom (PNK), R12, Soba (SBA)) is separated from the remaining Nubian samples, the Egyptian samples, and the sub-Saharan African samples. The smaller group seems to be separated due to higher levels of the following traits: UI1 shovelling, upper canine mesial marginal ridge, mid-line diastema, lower P1 cusp number, and lower M3 torso-molar angle. Finally, Kendall's tau-b was used to identify correlated traits, which were removed from the analysis.

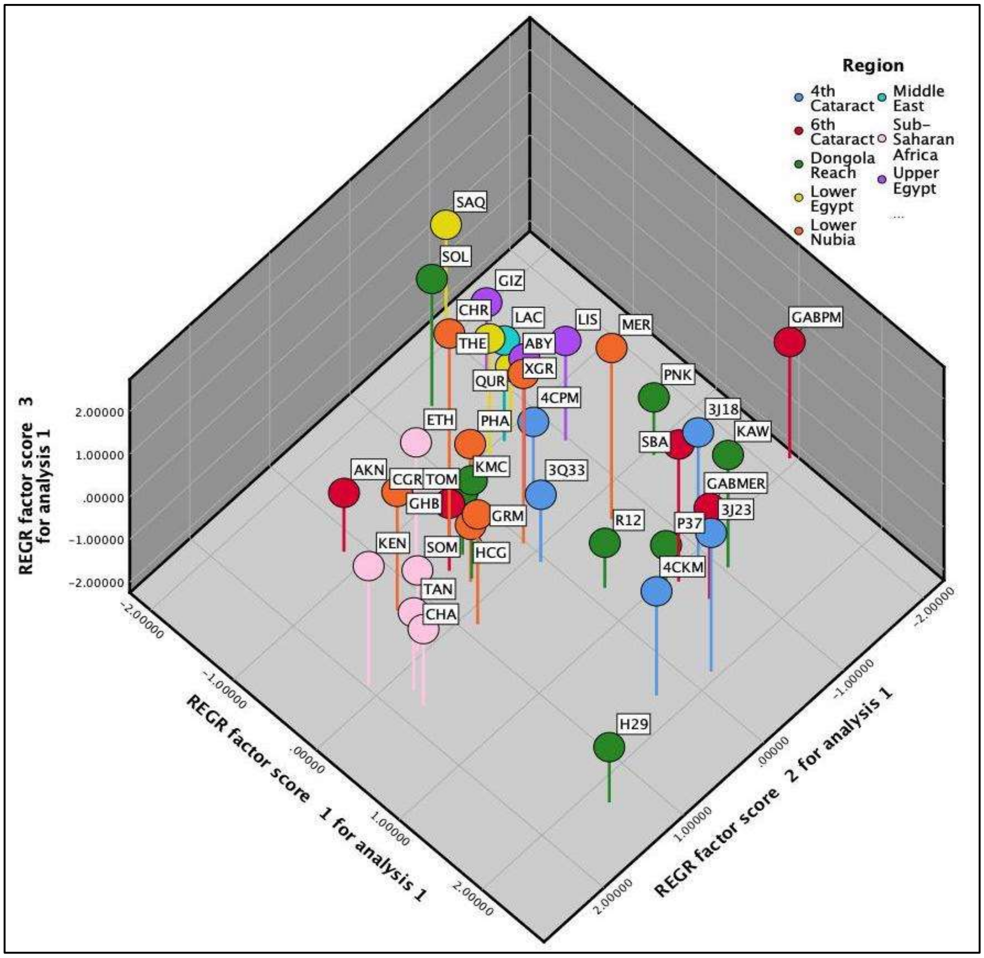


Figure 6.9 East Africa and Lachish PCA loadings 3-D representation.

After trait editing was complete, 20 traits remained (see Table 6.4 for details). Table 6.19 is the 20-trait MMD results. The Nubian samples display a slightly lower level of affinity to the Egyptian samples. Again, the Upper Egyptian collections are most like the Nubian samples, although Thebes (THE) now shares the closest affinity with the Nubians. The 4th Cataract collections are all significantly different from the Egyptian collections. Amara West New Kingdom (NK) and P37 show the highest level of affinity to the Egyptian collections out of the Dongola Reach group. All 6th Cataract samples are significantly different from the Egyptian groups, except for Ghaba which is only significantly different from Saqqara (SAQ). The Lower Nubian group is the most like the Egyptian collections out of all the Nubian groups. Abydos (ABY) and Thebes (THE) share the greatest affinity with the Lower Nubian samples. The Pharaonic (PHA) and Hierakonpolis C-Group (HKC) are most similar to the Egyptians samples.

Ghaba again shows a high level of affinity with the Egyptian samples, the other Neolithic collections show little relatedness to the Egyptians. Of the Kerma period samples, HKC is still the most similar to the Egyptian collections. Both P37 and C-Group (CGR) now share a close affinity to Querneh (QUR), Thebes (THE), and Lisht (LIS). Only the Amara West samples (NK and PNK) show a level of relatedness to the Egyptian collections, with Soleb (SOL) and Tombos (TOM) differing significantly from all Egyptian samples. The level of similarity between the Meroitic and Egyptian collections has decreased, with only the Lower Nubian Meroitic sample (MER) sharing a close affinity to Abydos (ABY) (MMD= 0.10). As with the 36-trait analysis, X-Group (XGR) is the only post-Meroitic collection that indicates any similarity to the

REGION	SAMPLE	UPPER EGYPT			LOWER EGYPT			MIDDLE EAST	SUB-SAHARAN AFRICA				
		ABYDOS (ABY)	THEBES (THE)	QURNEH (QUR)	SAQQARA (SAQ)	LISHT (LIS)	GIZA (GIZ)	LACHISH (LAC)	ETHIOPIA (ETH)	SOMALIA (SOM)	CHAD (CHA)	KENYA (KEN)	TANZANIA (TAN)
4TH CATARACT	4TH CATARACT KERMA (4CKM)	0.158	0.206	0.28	0.498	0.236	0.269	0.28	0.155	0.203	0.08	0.23	0.139
	3-Q-33 (3Q33)	0.166	0.137	0.072	0.273	0.08	0.099	0.061	0.093	0.024	0	0.076	0.09
	4TH CATARACT POST-MEROITIC (4CPM)	0.119	0.125	0.099	0.243	0.135	0.136	0.112	0.115	0.071	0.035	0.133	0.049
	3-J-23 (3J23)	0.174	0.203	0.236	0.449	0.194	0.237	0.204	0.106	0.126	0.048	0.145	0.093
	3-J-18 (3J18)	0.156	0.198	0.272	0.381	0.193	0.25	0.235	0.16	0.171	0.137	0.176	0.158
DONGOLA REACH	R12 (R12)	0.087	0.033	0.122	0.241	0.124	0.129	0.102	0.14	0.074	0.054	0.177	0.064
	H29 (H29)	0.205	0.184	0.234	0.409	0.26	0.278	0.292	0.138	0.126	0.073	0.148	0.094
	P37 (P37)	0.102	0.028	0.05	0.194	0.024	0.087	0.039	0.113	0.063	0.022	0.127	0.065
	KERMA CLASSIQUE (KMC)	0.08	0.041	0.117	0.223	0.111	0.086	0.064	0.079	0.037	0.049	0.09	0.033
	SOLEB (SOL)	0.241	0.268	0.169	0.337	0.146	0.12	0.166	0.086	0.182	0.139	0.173	0.23
	AMARA WEST NEW KINGDOM (NK)	0.161	0.094	0.106	0.279	0.091	0.093	0.074	0.217	0.169	0.13	0.309	0.231
	TOMBOS (TOM)	0.139	0.042	0.053	0.196	0.078	0.106	0.045	0.102	0.062	0.041	0.137	0.049
	AMARA WEST POST-NEW KINGDOM (PNK)	0.053	0.063	0.025	0.156	0.064	0.069	0.032	0.129	0.075	0.077	0.179	0.127
	KAWA (KAW)	0.089	0.108	0.195	0.294	0.173	0.195	0.179	0.208	0.178	0.131	0.277	0.147
6TH CATARACT	GHABA (GHB)	0.09	0.19	0.158	0.346	0.143	0.098	0.104	0.041	0.078	0.019	0.118	0.011
	AL KHIDAY NEOLITHIC (AKN)	0.206	0.115	0.065	0.207	0.087	0.102	0.078	0.031	0.008	0.036	0	0.06
	GABATI MEROTIC (GABMER)	0.151	0.138	0.17	0.336	0.12	0.235	0.2	0.196	0.133	0.062	0.183	0.118
	GABATI POST-MEROTIC/MEDIEVAL (GABPM)	0.12	0.184	0.219	0.366	0.13	0.157	0.169	0.232	0.233	0.171	0.322	0.272
	SOBA (SBA)	0.116	0.152	0.225	0.402	0.181	0.173	0.218	0.129	0.135	0.068	0.197	0.146
LOWER NUBIA	GEBEL RAMLAH (GRM)	0.084	0.088	0.142	0.21	0.165	0.133	0.175	0.039	0.088	0.125	0.097	0.074
	C-GROUP (CGR)	0.105	0.003	0.036	0.124	0.049	0.079	0.064	0.066	0.012	0.072	0.052	0.05
	HEIRAKONPOLIS C-GROUP (HKC)	0.038	0	0.02	0.127	0.014	0.033	0.045	0.024	0	0.056	0.034	0.019
	PHARAONIC (PHA)	0.035	0.089	0.044	0.136	0.17	0.038	0.12	0.024	0.037	0.082	0.073	0.135
	MEROITIC (MER)	0.01	0.084	0.145	0.208	0.126	0.072	0.109	0.105	0.154	0.107	0.238	0.142
	X-GROUP (XGR)	0.036	0.052	0.128	0.184	0.11	0.082	0.061	0.095	0.087	0.097	0.187	0.072

	CHRISTIAN (CHR)	0.038	0.005	0.107	0.114	0.065	0.063	0.011	0.093	0.085	0.086	0.126	0.072
UPPER EGYPT	**ABYDOS (ABY)**	0	0.022	0.105	0.057	0.134	0	0.087	0.1	0.112	0.205	0.202	0.123
	THEBES (THE)	0.022	0	0.043	0.048	0.022	0.03	0.03	0.113	0.068	0.152	0.136	0.088
	QURNEH (QUR)	0.105	0.043	0	0.044	0.031	0.024	0.025	0.089	0.054	0.127	0.146	0.129
LOWER EGYPT	**SAQQARA (SAQ)**	0.057	0.048	0.044	0	0.129	0.043	0.074	0.23	0.191	0.4	0.293	0.272
	LISHT (LIS)	0.134	0.022	0.031	0.129	0	0.056	0.007	0.144	0.111	0.157	0.131	0.137
	GIZA (GIZ)	0	0.03	0.024	0.043	0.056	0	0.02	0.047	0.092	0.179	0.189	0.159
MIDDLE EAST	**LACHISH (LAC)**	0.087	0.03	0.025	0.074	0.007	0.02	0	0.11	0.097	0.147	0.168	0.135
SUB-SAHARAN AFRICA	**ETHIOPIA (ETH)**	0.1	0.113	0.089	0.23	0.144	0.047	0.11	0	0.002	0	0.01	0.024
	SOMALIA (SOM)	0.112	0.068	0.054	0.191	0.111	0.092	0.097	0.002	0	0.014	0	0
	CHAD (CHA)	0.205	0.152	0.127	0.4	0.157	0.179	0.147	0	0.014	0	0.026	0
	KENYA (KEN)	0.202	0.136	0.146	0.293	0.131	0.189	0.168	0.01	0	0.026	0	0.003
	TANZANIA (TAN)	0.123	0.088	0.129	0.272	0.137	0.159	0.135	0.024	0	0	0.003	0

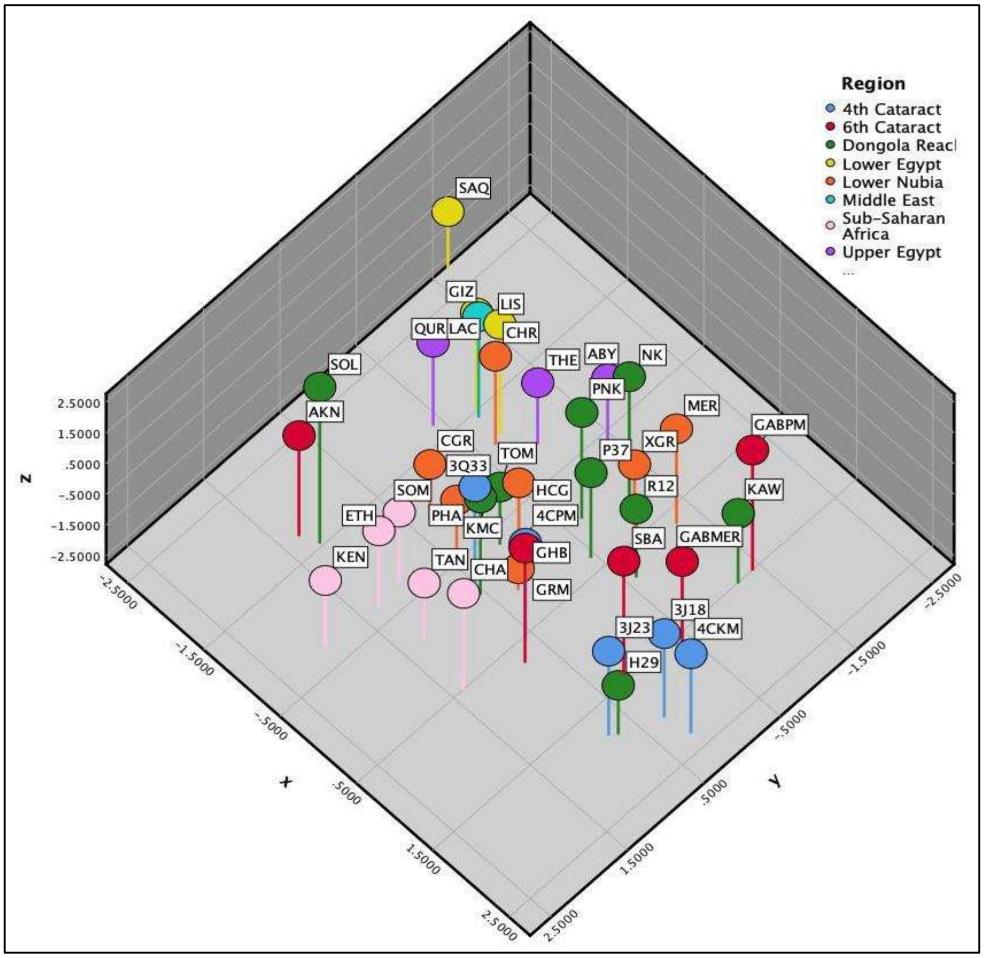
Red = significant at $p \leq 0.025$ level

Table 6.19 East Africa and Lachish 20-trait MMD values

Egyptian group, sharing a close affinity with ABY (MMD= 0.036). The Christian sample (CHR), from Lower Nubia, is again showing a similarity with ABY, THE, and LIS. No other medieval sample shares a close affinity with the Egyptians.

After trait editing the sub-Sharan African samples exhibit more similarity to the Nubian collections overall, with only Kenya (KEN) decreasing in relatedness. Chad (CHA) is now most similar to the Nubian samples, followed by Ethiopia (ETH). Lachish (LAC) generates similar results to those in the 36-trait analysis. The Neolithic samples produce very similar results to the 36-trait analysis, with Ghaba (GHB) and Al Khiday (AKN) both sharing a high level of relatedness to all sub-Saharan African samples. Gebel Ramlah is still similar to ETH and R12 to CHA. Only Ghaba shares an affinity with Lachish. Of the Kerma groups, Hierakonpolis C-Group (HKC) and Kerma Classique (KMC) share the closest affinity with the sub-Saharan African collections, with KMC only differing significantly from Kenya (KEN) (p= 0.001). Chad is shares close affinities with all the Kerma collections. Lachish is significantly different from most Kerma samples, except P37 and HKC. The New Kingdom/Post New Kingdom samples (Soleb (SOL), Amara West New Kingdom (NK), Tombos (TOM), Amara West post-New Kingdom (PNK)) all share a close affinity with Chad, except for Soleb which is only similar to the Ethiopian sample (MMD= 0.086). Lachish is akin to both Amara West samples (NK MMD= 0.074, PNK MMD= 0.032).

Sample 3-Q-33 is the most similar of the Meroitic collections to the sub-Saharan African samples (sharing an affinity with Ethiopia (ETH), Somalia (SOM), and Chad (CHA)), it is also the only sample that is similar to Lachish (LAC). The other Meroitic samples (Kawa (KAW), Gabati Meroitic (GABMER), Meroitic (MER) differ significantly from all sub-Saharan African samples, although one exception is GABMER which shares a close affinity to Chad (CHA). As with the 36-trait analysis, all the post-Meroitic samples differ significantly from all sub-Saharan Africans, bar the 4th Cataract post-Meroitic sample (4CPM) which shares a close affinity with Chad (CHA) and Tanzania (TAN). All post-Meroitic samples are significantly different from Lachish. All medieval samples are similar to Chad, apart from 3-J-18. The medieval samples all differ significantly from the other sub-Saharan African



r^2 =0.828, Kruskal's stress formula 1 = 0.158

Figure 6.10 Multidimensional scaling East Africa and Lachish 20-trait MMD data samples. Lachish now shares a close affinity with the Lower Nubian Christian sample (CHR).

Figure 6.10 is the MDS plot of the 20-trait MMD data. As the stress level calculated for the MDS model is slightly above the recommended level (Kruskal's stress formula 1 = 0.158), the relationships illustrated may not be fully optimal. R^2 was calculated at 0.828. Like Figures 6.8 and 6.9, Figure 6.10 the sub-Saharan African and the Egyptian samples (plus Lachish) form two distinct clusters. The Nubian samples are positioned between the two groups. Saqqara (SAQ) is an outlier, positioned away from the rest of the Egyptians. Regional patterning is also visible in the Nubian samples. The Lower Nubian samples are clustered together, close to the Egyptian group. The Christian sample (CHR) is removed from the Lower Nubian samples and is positioned in the midst of the Egyptian group. The Dongola Reach assemblages are also grouped together, below the Egyptian samples and closely associated with the Lower Nubian group. Soleb (SOL) is not part of the Dongola Reach cluster, positioned close to the sub-Saharan African samples with Al Khiday (AKN). Additionally, H29 is situated away from the group, closely associated with 3-J-23. The 6th Cataract collections are grouped below the Dongola Reach and Lower Nubian clusters, except for Al Khiday as mentioned above.

The 4th Cataract samples are once again separated into two groups. The Meroitic (3-Q-33) and post-Meroitic (4CPM) samples are positioned between the Dongola Reach/Lower Nubian cluster and the 6th Cataract group, close to the sub-Saharan African cluster. The other 4th Cataract samples (4th Catarct Kerma (4CKM), 3-J-23, and 3-J-18) are clustered below 6th Cataract group, relatively close to the sub-

TRAIT	REGIONAL COLLECTIONS					
	sub-Saharan Africa Central (SSC)	sub-Saharan Africa East (SSE)	sub-Saharan Africa South (SSS)	sub-Saharan Africa West (SSW)	North West Africa (NWA)	Southeastern Mediterranean (SEM)
WINGING UI1	2.7[A]	3.0	5.0	4.1	7.2	2.6
(+ = ASU 1)[C]	188.0[B]	460.0	1014.0	293.0	264.0	545.0
LABIAL CURVATURE UI1	50.5	46.3	61.8	46.9	31.5	30.9
(+ = ASU 2-4)	107.0	175.0	709.0	143.0	89.0	286.0
PALATINE TORUS	2.8	1.6	4.4	2.4	12.8	5.4
(+ = ASU 2-3)	217.0	489.0	1141.0	383.0	298.0	672.0
SHOVELING UI1	8.9	12.3	18.2	23.7	12.0	11.1
(+ = ASU 2-6)	101.0	163.0	620.0	135.0	75.0	264.0
DOUBLE SHOVELING UI1	0.0	1.2	0.8	1.4	9.8	0.0
(+ = ASU 2-6)	100.0	168.0	718.0	140.0	82.0	272.0
INTERUPTION GROOVE UI2	6.3	8.5	8.6	9.5	36.9	15.5
(+ = ASU +)	111.0	199.0	700.0	168.0	122.0	304.0
TUBERCULUM DENTALE UI2	39.6	33.2	34.1	33.3	34.9	24.0
(+ = ASU 2-6)	106.0	196.0	674.0	168.0	106.0	299.0
BUSHMAN CANINE UC	15.1	11.2	27.7	16.7	2.8	4.9
(+ = ASU 1-3)	159.0	286.0	733.0	252.0	142.0	442.0
DISTAL ACCESSORY RIDGE UC	43.2	33.3	37.7	42.0	17.9	11.0
(+ = ASU 2-5)	139.0	246.0	636.0	193.0	95.0	355.0
HYPOCONE UM2	83.7	78.6	86.7	83.4	77.7	63.5
(+ = ASU 3-5)	239.0	495.0	1015.0	356.0	255.0	651.0
CUSP 5 UM1	11.6	17.7	23.7	19.5	14.2	13.4

(+ = ASU 2-5)	173.0	413.0	844.0	262.0	190.0	476.0
CARABELLI'S CUSP UM1	54.6	56.9	43.5	57.3	54.2	32.0
(+ = ASU 2-7)	196.0	432.0	862.0	309.0	179.0	544.0
PARASTYLE UM3	2.8	1.5	1.6	1.9	1.5	1.6
(+ = ASU 1-5)	179.0	405.0	690.0	311.0	203.0	531.0
ENAMEL EXTENSION UM1	2.0	2.1	1.6	8.7	2.1	4.3
(+ = ASU 1-3)	200.0	434.0	799.0	370.0	281.0	626.0
ROOT NUMBER UP1	62.6	69.0	50.7	58.7	52.2	63.6
(+ = ASU 2+)	179.0	381.0	609.0	298.0	272.0	537.0
ROOT NUMBER UM2	79.0	82.7	76.5	82.3	77.7	68.5
(+ = ASU 3+)	143.0	295.0	439.0	243.0	202.0	430.0
PEG-REDUCED UI2	5.6	2.2	5.7	4.2	1.7	4.3
(+ = ASU P OR R)	198.0	417.0	1116.0	288.0	177.0	555.0
ODONTOME P1-P2	0.4	0.6	0.6	1.1	0.9	0.9
(+ = ASU +)	264.0	498.0	1059.0	361.0	217.0	679.0
CONGENITAL ABSENCE UM3	2.9	5.0	6.3	3.9	15.1	20.4
(+ = ASU -)	246.0	558.0	1009.0	410.0	317.0	728.0
MID LINE DIASTEMA UI1	15.0	8.3	10.2	9.6	6.3	3.2
(+ ≥ 0.5 MM)	187.0	432.0	1050.0	322.0	256.0	563.0
LINGUAL CUSP LP2	68.2	66.4	69.2	68.5	71.3	49.6
(+ = ASU 2-9)	151.0	265.0	863.0	222.0	160.0	407.0
ANTERIOR FOVEA LM1	60.0	59.4	67.1	73.0	27.9	44.7
(+ = ASU 2-4)	110.0	261.0	704.0	196.0	129.0	335.0
MANDIBULAR TORUS	0.0	2.5	0.9	0.0	1.5	0.5
(+ = ASU 2-3)	163.0	403.0	1131.0	319.0	259.0	565.0
GROOVE PATTERN LM2	72.6	67.0	64.2	54.8	46.6	29.8
(+ = ASU Y)	175.0	379.0	976.0	292.0	232.0	529.0

ROCKER JAW	6.1	10.2	5.2	4.8	18.0	14.1
(+ = ASU 1-2)	148.0	381.0	884.0	314.0	250.0	548.0
CUSP NUMBER LM1	8.4	8.3	7.9	18.6	10.9	2.1
(+ = ASU 6+)	143.0	336.0	904.0	258.0	193.0	453.0
CUSP NUMBER LM2	75.6	68.5	83.7	75.3	42.1	38.7
(+ = ASU 5+)	156.0	346.0	915.0	267.0	209.0	475.0
DEFLECTING WRINKLE LM1	19.5	20.4	22.3	22.7	7.0	11.1
(+ = ASU 2-3)	113.0	299.0	764.0	207.0	157.0	360.0
C1-C2 CREST LM1	0.0	0.7	1.8	1.4	1.4	4.6
(+ = ASU +)	120.0	305.0	765.0	222.0	145.0	383.0
PROTOSTYLID LM1	16.8	12.5	7.6	19.9	27.6	2.8
(+ = ASU 1-6)	137.0	337.0	868.0	261.0	192.0	456.0
CUSP 7 LM1	23.4	25.6	29.8	24.4	7.7	2.5
(+ = ASU 2-4)	154.0	352.0	961.0	295.0	233.0	521.0
TOMES ROOT LP1	20.5	18.1	10.3	24.0	7.3	7.1
(+ = ASU 3-5)	127.0	265.0	604.0	233.0	218.0	426.0
ROOT NUMBER LC	0.0	0.9	0.2	0.5	2.2	2.8
(+ = ASU 2+)	135.0	322.0	616.0	223.0	181.0	434.0
ROOT NUMBER LM1	0.9	0.4	0.2	0.0	1.5	1.7
(+ = ASU 3+)	114.0	252.0	482.0	259.0	201.0	425.0
ROOT NUMBER LM2	91.8	94.5	90.5	96.3	89.9	90.9
(+ = ASU 2+)	97.0	238.0	485.0	217.0	179.0	365.0
TORSOMOLAR ANGLE LM3	7.1	9.6	9.2	9.3	17.3	16.7
(+ = ASU +)	140.0	345.0	781.0	281.0	202.0	479.0

A.Upper row for each trait is the frequency in %, B.,Lower row is the number of individuals scored, C. ASUDAS score used as breakpoint referenced in brackets.

Table 6.20 Regional collections trait percentages and sample sizes.

Saharan African group. H29 also forms part of this cluster. Some temporal patterning is also evident. The New Kingdom/Post New Kingdom collections (Amara West New Kingdom (NK), Tombos (TOM), Amara West post-New Kingdom (PNK) are positioned close together, below the Egyptian group, except for Soleb (SOL) (see above). The medieval samples, apart from the Christian (CHR), are also grouped together.

6.2.5 Continental view

Regional samples that consist of an amalgamation of assemblages from different areas of Africa (sub-Saharan South Central, sub-Saharan Southeast, sub-Saharan Southwest, Northwest) and a sample from Southeastern Mediterranean were added to the Nubian and Egyptian samples for analysis. The East African and Lachish samples from the previous chapter were removed, but they form part of the regional samples in this analysis. Details of the composition of the samples can be found in Table 5.1. Trait frequencies for the regional samples are presented in Table 6.20.

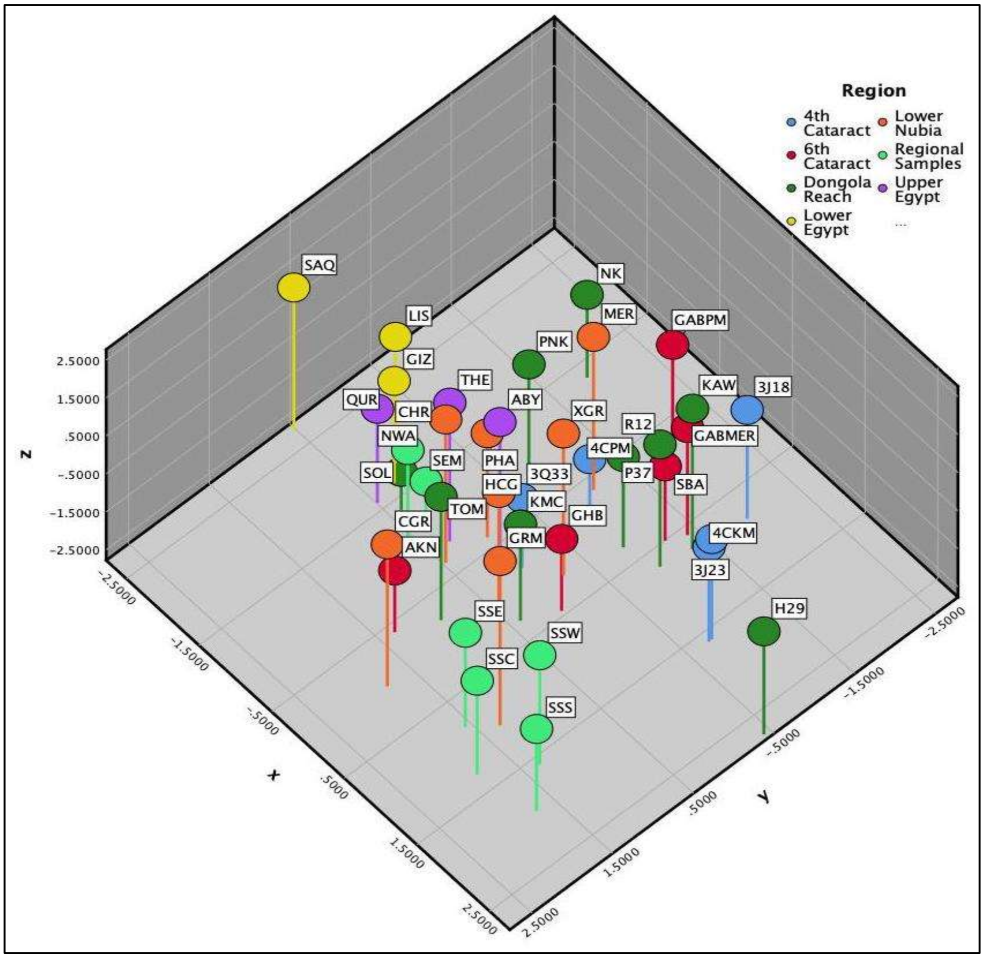
The results of the 36-trait MMD analysis can be found in Table 6.20. The Regional samples show a high level of dissimilarity with the Nubian and Egyptian samples. There are also low levels of inter-sample affinity evident among the regional samples. Only sub-Saharan East (SSE) and sub-Saharan Central (SSC) produce a non-significant MMD value (MMD= 0.004). Both the Neolithic collections from the 6th Cataract (Ghaba (GHB), Al Khiday (AKN)) share close affinities with the regional samples. Ghaba is similar to all other samples, whereas Al Khiday is similar to sub-Saharan East (SSE) and Southeastern Mediterranean (SEM). From the Kerma period, only Hierakonpolis C-Group (HKC) and SSE create a non-significant MMD value (MMD= 0.025). Soleb (SOL) and Pharaonic (PHA), from the New Kingdom period, both share an affinity with Northwest Africa (NWA) and Southeastern Mediterranean. Both post-New Kingdom samples differ significantly from the regional samples. All Meroitic samples, apart from 3-Q-33, are significantly different from the regional samples (3-Q-33 shares a close affinity with NWA). Apart from the Christian sample is similar to NWA, all other medieval samples are not related to the regional samples. Abydos is the only Egyptian sample to produce a non-significant MMD value with a regional sample (NWA, MMD= 0.037). Figure 6.11 is an MDS representation of the 36-trait MMD data. As the stress level of the MDS model is slightly higher than 0.15 (Kruskal's stress formula 1 = 0.151) the distances depicted may not be fully optimal, R^2 was calculated to be 0.833. The graph shows that the Egyptian samples and sub-Saharan regional collections are separated along the x-axis, with the Nubian samples in between. The Nubian samples show the most variation along the y-axis. Gebel Ramlah (GRM) and C- Group (CGR) are positioned near the sub-Saharan group. The rest of the samples are split into two larger clusters. The first contains all Egyptian samples, Northwest Africa (NWA), Southeast Mediterranean (SEM), and several Nubian samples (Ghaba (GHB), Al Khiday (AKN), Hierankopolis (HCG), Kerma Classique (KMC), Pharaonic (PHA), Soleb (SOL), Tombos (TOM), 3-Q-33, X-Group (XGR), and Christian (CHR)). The second cluster contains all other Nubian samples, except for H29 and Amara West New Kingdom (NK) which are placed away from the cluster. The second cluster consists of Upper Nubian samples, except for the Meroitic sample (MER) from Lower Nubia. Within the Nubian samples, some vague regional patterning can be observed, with the majority of the Upper Nubian collections grouping together. No temporal patterning is evident on the graph.

REGION	SAMPLE	SUB-SAHARAN AFRICA CENTRAL (SSC)	SUB-SAHARAN AFRICA EAST (SSE)	SUB-SAHARAN AFRICA SOUTH (SSS)	SUB-SAHARAN AFRICA WEST (SSW)	NORTH WEST AFRICA (NWA)	SOUTH EASTERN MEDITERRANEAN (SEM)
4TH CATARACT	4th Cataract Kerma (4CKM)	0.121	0.105	0.104	0.079	0.100	0.137
	3-Q-33 (3Q33)	0.079	0.065	0.106	0.097	0.030	0.050
	4th Cataract post-Meroitic (4CPM)	0.128	0.112	0.148	0.149	0.068	0.093
	3-J-23 (3J23)	0.110	0.099	0.102	0.086	0.099	0.140
	3-J-18 (3J18)	0.175	0.155	0.198	0.166	0.125	0.150
DONGOLA REACH	R12 (R12)	0.113	0.091	0.127	0.093	0.117	0.125
	H29 (H29)	0.111	0.104	0.095	0.078	0.213	0.204
	P37 (P37)	0.118	0.094	0.125	0.101	0.094	0.084
	Kerma Classique (KMC)	0.054	0.026	0.064	0.045	0.048	0.056
	Soleb (SOL)	0.163	0.120	0.171	0.169	0.046	0.000
	Amara West New Kingdom (NK)	0.249	0.204	0.276	0.209	0.117	0.100
	Tombos (TOM)	0.076	0.063	0.107	0.078	0.067	0.095
	Amara West post-New Kingdom (PNK)	0.151	0.124	0.208	0.134	0.049	0.064
	Kawa (KAW)	0.157	0.135	0.164	0.115	0.124	0.135
6TH CATARACT	Ghaba (GHB)	0.054	0.047	0.064	0.050	0.005	0.076
	Al Khiday Neolithic (AKN)	0.039	0.014	0.078	0.065	0.069	0.028
	Gabati Merotic (GABMER)	0.147	0.124	0.157	0.123	0.105	0.102
	Gabati post-Merotic/Medieval (GABPM)	0.186	0.169	0.206	0.178	0.088	0.100
	Soba (SBA)	0.165	0.120	0.158	0.128	0.078	0.082
LOWER NUBIA	Gebel Ramlah (GRM)	0.060	0.061	0.084	0.052	0.099	0.174
	C-Group (CGR)	0.086	0.049	0.114	0.070	0.089	0.121
	Heirakonpolis C-Group (HKC)	0.051	0.025	0.091	0.037	0.056	0.085
	Pharaonic (PHA)	0.112	0.082	0.162	0.111	0.033	0.057
	Meroitic (MER)	0.169	0.146	0.184	0.131	0.047	0.125
	X-Group (XGR)	0.107	0.081	0.113	0.083	0.023	0.104

	Christian (CHR)	0.112	0.078	0.132	0.094	0.017	0.096
UPPER EGYPT	Abydos (ABY)	0.110	0.076	0.129	0.082	0.037	0.068
	Thebes (THE)	0.122	0.077	0.154	0.111	0.047	0.062
	Qurneh (QUR)	0.131	0.102	0.176	0.139	0.081	0.050
LOWER EGYPT	Saqqara (SAQ)	0.224	0.185	0.294	0.249	0.085	0.123
	Lisht (LIS)	0.169	0.133	0.215	0.165	0.042	0.086
	Giza (GIZ)	0.145	0.109	0.171	0.153	0.047	0.037
REGIONAL COLLECTIONS	sub-Saharan Africa Central (SSC)	0.000	0.004	0.017	0.013	0.107	0.133
	sub-Saharan Africa East (SSE)	0.004	0.000	0.025	0.015	0.081	0.099
	sub-Saharan Africa South (SSS)	0.017	0.025	0.000	0.024	0.133	0.141
	sub-Saharan Africa West (SSW)	0.013	0.015	0.024	0.000	0.111	0.139
	North West Africa (NWA)	0.107	0.081	0.133	0.111	0.000	0.064
	South Eastern Mediterranean (SEM)	0.133	0.099	0.141	0.139	0.064	0.000

Red = significant at p ≤ 0.025 level

Table 6.21 Regional Collections 36-trait MMD values



r^2 =0.833, Kruskal's stress formula 1 = 0.151

Figure 6.11 Multidimensional scaling Regional Collections 36-trait MMD data

Before running a principal component analysis, low frequency traits across all samples were removed (premolar odontome, mandibular torus, lower canine root number, and LM1 root number). For the remaining 32 traits that were analysed, the first six components were responsible for 62% of the variation. Table 6.22 shows the trait loadings for the 32 traits across the components. The trait loadings for the first three components were plotted on a graph, Figure 6.12, to show how this affected sample distribution. As in Figure 6.11, the Egyptian (also including

Northwest Africa (NWA) and Southeast Mediterranean (SEM)) and sub-Saharan regional samples form clusters and are separated along the x-axis, which relates to the first component. The separation of these two groups is due to differences in the

	PRINCIPAL COMPONENT					
	1	2	3	4	5	6
WINGING UI1	0.218	0.269	0.462	-0.209	-0.419	0.083
LABIAL CURVATURE UI1	0.394	-0.444	0.177	0.445	0.153	0.14
PALATINE TORUS	0.189	0.568	0.59	-0.048	-0.232	-0.028
SHOVELING UI1	0.617	0.336	0.229	-0.257	0.106	0.099
DOUBLE SHOVELING UI1	-0.088	-0.064	0.71	0.219	0.056	0.046
INTERUPTION GROOVE UI2	-0.257	0.079	0.527	-0.297	-0.065	0.021
TUBERCULUM DENTALE UI2	0.148	0.054	0.087	-0.233	0.688	0.253
BUSHMAN CANINE UC	0.588	0.046	0.342	0.11	0.033	0.308
DISTAL ACCESSORY RIDGE UC	0.696	-0.103	0.117	-0.292	0.185	-0.237
HYPOCONE UM2	0.255	-0.097	-0.309	-0.376	0.475	0.046
CUSP 5 UM1	0.465	-0.332	0.332	-0.047	-0.065	-0.104
CARABELLI'S CUSP UM1	-0.149	-0.167	0.124	0.185	0.719	0.037
PARASTYLE UM3	0.392	0.275	-0.049	-0.49	-0.093	-0.148
ENAMEL EXTENSION UM1	0.029	0.607	0.119	0.271	0.249	-0.36
ROOT NUMBER UP1	-0.278	-0.119	-0.221	0.105	0.235	0.671
ROOT NUMBER UM2	-0.096	-0.413	0.451	-0.079	-0.202	0.534
PEG-REDUCED UI2	0.28	-0.259	-0.183	-0.569	0.227	-0.013
CONGENITAL ABSENCE UM3	-0.435	0.065	0.357	-0.214	0.298	0.303
MID LINE DIASTEMA UI1	0.692	0.3	0.076	-0.197	0.129	-0.038
LINGUAL CUSP LP2	0.501	0.483	0.054	0.088	0.234	0.074
ANTERIOR FOVEA LM1	0.502	-0.276	0.185	0.506	0.054	0.007
GROOVE PATTERN LM2	0.221	-0.735	0.209	-0.027	-0.121	-0.194
ROCKER JAW	-0.151	0.551	0.431	0.051	0.31	0.033
CUSP NUMBER LM1	0.505	0.269	-0.185	0.467	-0.03	0
CUSP NUMBER LM2	0.457	-0.704	0.149	0.066	0.116	-0.3
DEFLECTING WRINKLE LM1	0.671	0.12	-0.333	-0.196	0.097	0.021
C1-C2 CREST LM1	0.164	0.495	-0.484	0.437	-0.001	0.15
PROTOSTYLID LM1	-0.214	-0.045	0.227	0.429	0.332	-0.421
CUSP 7 LM1	0.746	-0.305	-0.079	0.15	-0.173	0.01
TOMES ROOT LP1	0.53	-0.035	-0.245	0.061	-0.322	0.45
ROOT NUMBER LM2	0.367	-0.383	0.076	0.258	0.1	0.198
TORSOMOLAR ANGLE LM3	0.308	0.796	0.036	0.227	-0.075	0.112

Table 6.22 Regional Collections PCA loadings. Graphical representation in Appendix 5.

following traits: UC mesial marginal ridge, UC distal accessory ridge, midline diastema, LM1 anterior fovea, LM1 deflecting wrinkle, and LM1 cusp 7. The sub-Saharan group show much higher frequencies of the aforementioned traits compared to the Egyptians. The Nubian samples are showing levels of variation along both the x-axis and y-axis (which relates to the second principal component). Similar to Figure 6.11, the Nubian Samples have grouped into two clusters, although unlike Figure 6.12, the groups are split along the x-axis. The larger group cluster just below the Egyptian samples, the smaller group of Upper Nubian samples form a cluster away from them in line with the sub-Saharan group. The differences between the groups are caused by higher frequencies of the following traits in the Upper Nubian group: UI1 shovelling, UC mesial marginal ridge, midline diastema, LM1 deflecting wrinkle, and LM1 cusp 7. Although the smaller Nubian group is aligned with the sub-Saharan group on the x-axis, the groups are separated on the y-axis. This separation is due to higher levels of maxillary torus, enamel extension, rocker jaw, and torso-molar angle, and lower levels of LM2 cusp pattern and LM2 cusp number, present in the Upper Nubian group.

Twenty traits remained after editing was complete, (details in Table 6.4). The results of the 20-trait MMD analysis can be found in Table 6.23. The regional samples still reveal a high level of dissimilarity when compared to the Nubian groups. Ghaba (GHB) produced non-significant MMD values with all regional samples, although the actual MMD values are relatively high (MMD= 0.098-0.121), apart from Northwest Africa (NWA) (MMD= 0.011). Of the rest of the Neolithic samples, only Al Khiday (AKN) shows any similarities to the regional samples, producing non-significant MMD results with sub-Saharan Africa Central (SSC), sub-Saharan Africa East

(SSE), and South-eastern Mediterranean (SEM). The 4th Cataract Kerma sample (4CKM) is the most similar to the regional samples from this period, sharing an affinity with sub-Saharan Africa Southwest (SSW), SSC, SSE, and NWA. The 4CKM sample is also the only sample from the 4th Cataract that has similarities with the regional samples. The Hierakonpolis C-group (HCG) sample (which shares an affinity with SSE and NWA) and H29 (which is similar to SSC) are the only other Kerma period samples to produce non-significant MMD results. The New Kingdom/Post New Kingdom samples share affinities with the more northern regional samples, with Pharaonic (PHA) and Amara West New Kingdom (NK) both

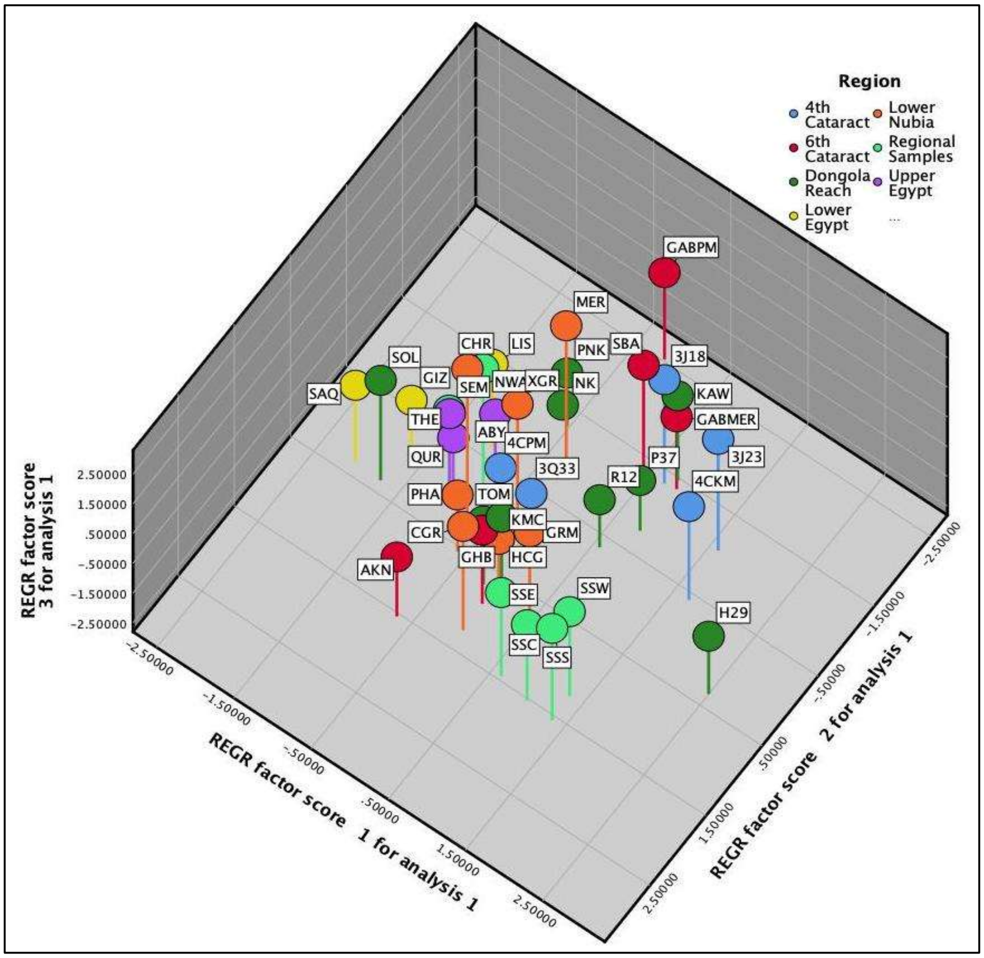


Figure 6.12 Regional Samples PCA loadings 3-D representation

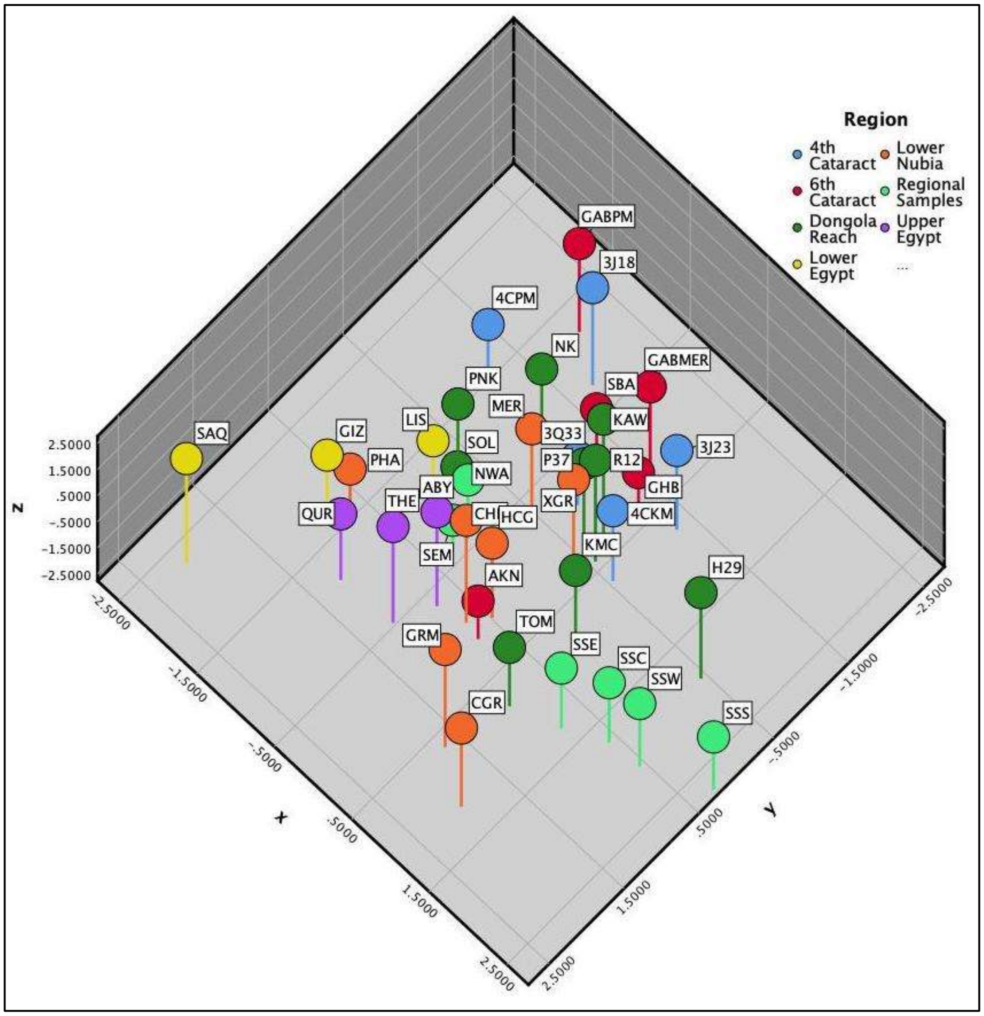
REGION	Samples	sub-Saharan Africa Central (SSC)	sub-Saharan Africa East (SSE)	sub-Saharan Africa South (SSS)	sub-Saharan Africa West (SSW)	North West Africa (NWA)	South Eastern Mediterranean (SEM)
4TH CATARACT	4th Cataract Kerma (4CKM)	0.030	0.032	0.066	0.040	0.018	0.092
	3-Q-33 (3Q33)	0.111	0.093	0.164	0.137	0.052	0.073
	4th Cataract post-Meroitic (4CPM)	0.194	0.195	0.271	0.264	0.099	0.173
	3-J-23 (3J23)	0.113	0.111	0.138	0.112	0.070	0.137
	3-J-18 (3J18)	0.224	0.210	0.302	0.252	0.108	0.176
DONGOLA REACH	R12 (R12)	0.097	0.090	0.167	0.115	0.108	0.181
	H29 (H29)	0.024	0.038	0.060	0.030	0.143	0.207
	P37 (P37)	0.091	0.083	0.156	0.110	0.062	0.124
	Kerma Classique (KMC)	0.073	0.043	0.108	0.065	0.075	0.103
	Soleb (SOL)	0.229	0.197	0.279	0.248	0.105	0.021
	Amara West New Kingdom (NK)	0.171	0.148	0.273	0.197	0.073	0.075
	Tombos (TOM)	0.062	0.057	0.127	0.084	0.087	0.146
	Amara West post-New Kingdom (PNK)	0.164	0.136	0.274	0.175	0.038	0.061
	Kawa (KAW)	0.162	0.150	0.225	0.153	0.106	0.187
6TH CATARACT	Ghaba (GHB)	0.100	0.098	0.121	0.098	0.011	0.104
	Al Khiday Neolithic (AKN)	0.044	0.024	0.120	0.060	0.080	0.042
	Gabati Merotic (GABMER)	0.143	0.134	0.210	0.164	0.091	0.143
	Gabati post-Merotic/Medieval (GABPM)	0.243	0.239	0.312	0.280	0.088	0.148
	Soba (SBA)	0.145	0.111	0.201	0.146	0.032	0.075
LOWER NUBIA	Gebel Ramlah (GRM)	0.055	0.062	0.105	0.079	0.102	0.167
	C-Group (CGR)	0.094	0.050	0.143	0.081	0.137	0.152
	Heirakonpolis C-Group (HKC)	0.048	0.014	0.116	0.047	0.030	0.070

	Pharaonic (PHA)	0.173	0.133	0.289	0.213	0.032	0.066
	Meroitic (MER)	0.109	0.100	0.167	0.124	0.026	0.083
	X-Group (XGR)	0.110	0.086	0.141	0.112	0.054	0.133
	Christian (CHR)	0.138	0.102	0.183	0.141	0.075	0.126
UPPER EGYPT	Abydos (ABY)	0.125	0.085	0.185	0.113	0.060	0.092
	Thebes (THE)	0.143	0.095	0.226	0.153	0.067	0.109
	Qurneh (QUR)	0.149	0.122	0.249	0.173	0.059	0.075
LOWER EGYPT	Saqqara (SAQ)	0.294	0.260	0.443	0.348	0.159	0.250
	Lisht (LIS)	0.150	0.121	0.233	0.167	0.036	0.065
	Giza (GIZ)	0.191	0.157	0.264	0.224	0.047	0.074
REGIONAL COLLECTIONS	sub-Saharan Africa Central (SSC)	0.000	0.003	0.022	0.007	0.106	0.144
	sub-Saharan Africa East (SSE)	0.003	0.000	0.040	0.011	0.086	0.112
	sub-Saharan Africa South (SSS)	0.022	0.040	0.000	0.030	0.160	0.189
	sub-Saharan Africa West (SSW)	0.007	0.011	0.030	0.000	0.137	0.160
	North West Africa (NWA)	0.106	0.086	0.160	0.137	0.000	0.042
	South Eastern Mediterranean (SEM)	0.144	0.112	0.189	0.160	0.042	0.000

Red = significant at p ≤ 0.025 level

Table 6.23 Regional Collections 20-trait MMD values related to NWA and SEM, Soleb (SOL) is only similar to SEM and Amara West post-New Kingdom (PNK) shares an affinity with NWA. Soba (SBA) shares an affinity with NWA, no other medieval collections produce non-significant results. All Egyptian samples are significantly different from all regional samples. Figure 6.13 is the MDS of the 20-trait MMD results. The data are a good fit for the MDS; Kruskal's stress formula 1 = 0.148, and R^2 = 0.844. All the samples are more tightly grouped together than in Figure 6.12. As in Figures 6.11 and 6.12, the Egyptian samples cluster together, although Saqqara (SAQ) is an outlier. The Northwest Africa (NWA) and South-eastern Mediterranean (SEM) samples are located just below the Egyptians. The Nubian samples are grouped together and positioned below the Egyptians. The sub-Saharan regional collections form a cluster, located underneath the Nubians. The sub-Saharan East sample (SSE) shows the greatest affinity to the Nubian group, the sub-Saharan South sample (SSS) is farthest away from the Nubians. Additionally, the Gebel Ramlah (GRM) and C-Group (CGR) samples are positioned slightly away from the main group, closer to the sub-Saharan African cluster. The H29 sample is more closely associated with sub-Saharan groups than the Nubians. Some regional patterning among the Nubians is evident. The Lower Nubian samples mainly group together below the Egyptians, whereas the Pharaonic sample (PHA) is more closely associated with them.

The Dongola Reach samples are also grouped together, see figure 6.13. These samples are split into two sub-groups, with those more geographically southern (Kawa (KAW), P37, R12, Kerma Classique (KMC), and Tombos (TOM)) closer to the sub-Saharan African group. The 6th Cataract collections for a cluster, except for Al Khiday (AKN) which sits with the Lower Nubian samples. The 4th Cataract collections are once again split into two groups. However, in this graph 3-Q-33, 4th Cataract Kerma (4CKM), and 3-J-23 form a group, and 4th Cataract post-Meroitic (4CPM) and 3-J-18 comprise the other. Temporal patterning can be observed for some periods. The Upper Nubian Kerma samples are close together. Additionally, the Meroitic samples form a cluster.



R^2 =0.844, Kruskal's stress formula 1 = 0.148

Figure 6.13 Multidimensional scaling regional collections 20-Trait MMD data

6.3 Mantel tests

Matrices based on temporal, straight-line, and river distances (Tables 6.24 and 6.25) were compared with the MMD matrices (Tables 6.7, 6.9, 6.11, and 6.14) using

Mantel tests. Simple Mantel tests were used to compare each new distance matrix with the MMD matrices. Partial Mantel tests were also used to compare temporal distance controlling for geographical distance (both straight-line and river), and vice versa. Only the samples from Nubia (Upper Nubia and Nubia as a whole) were used in the analysis.

6.3.1 Upper Nubia - Simple Mantel tests

Firstly, the MMD data (36- and 21-trait) were compared with the temporal distance matrix (Table 6.24). The Mantel test revealed that the correlation between temporal distance and the 36-trait MMD data was not significant, showing a weak negative correlation (r= -0.065, p= 0.718). When compared to the 21-trait MMD data (r= -0.129, p= 0.846) the negative correlation is slightly stronger but still not significant. Next, the straight-line geographical distances (Table 6.25) were compared to the MMD data. The Mantel tests showed that both the 36-trait (r= -0.191, p= 0.993) and the 21-trait (r= -0.136, p=0.971) MMD matrices are negatively correlated to the straight-line geographical distance matrix. The correlations are weak and not significant. Lastly, the river distance matrix (Table 6.25) was compared to the MMD matrices. Weak positive correlations were calculated with both the 36-trait (r= 0.299, p= 0.003) and 21-trait (r= 0.288, p= 0.014) MMD matrices. The correlations are significant at the 0.05 alpha level. Results are summarised in Table 6.26.

6.3.2 Upper Nubia – Partial Mantel tests

Firstly, the 36- and 21-trait MMD matrices were compared to the temporal distance matrix (Table 6.24), controlling for geographic distance (straight-line and river). The

		UPPER NUBIA																		LOWER NUBIA							
		4th Cataract Kerma (4CKM)	3-Q-33 (3Q33)	4th Cataract post-Meroitic (4CPM)	3-J-23 (3J23)	3-J-18 (3J18)	R12 (R12)	H29 (H29)	P37 (P37)	Kerma Classique (KMC)	Soleb (SOL)	Amara West New Kingdom (NK)	Tombos (TOM)	Amara West post-New Kingdom (PNK)	Kawa (KAW)	Ghaba (GHB)	Al Khiday Neolithic (AKN)	Gabati Merotic (GABMER)	Gabati post-Merotic/Medieval (GABPM)	Soba (SBA)	Gebel Ramlah (GRM)	C-Group (CGR)	Heirakonpolis C-Group (HKC)	Pharaonic (PHA)	Merotici (MER)	X-Group (XGR)	Christian (CHR)
UPPER NUBIA	4th Cataract Kerma (4CKM)	0	1650	2075	2340	2900	2975	600	450	0	315	444	485	775	1650	3325	3025	1625	2500	2675	2890	175	225	125	1750	2075	2575
	3-Q-33 (3Q33)	1650	0	425	690	1250	4625	2250	2100	1650	1335	1207	1166	875	0	4975	4675	25	850	1025	4540	1825	1875	1525	100	425	600
	4th Cataract post-Meroitic (4CPM)	2075	425	0	265	825	5050	2675	2525	2075	1760	1632	1591	1300	425	5400	5100	450	425	600	4965	2250	2300	1950	325	0	500
	3-J-23 (3J23)	2340	690	265	0	560	5315	2940	2790	2340	2025	1897	1856	1565	690	5665	5365	715	160	335	5230	2515	2565	2215	590	265	235
	3-J-18 (3J18)	2900	1250	825	560	0	5875	3500	2100	2900	2585	2457	2416	2125	1250	6225	5925	1275	400	225	5790	3075	3125	2775	1150	825	325
	R12 (R12)	2975	4625	5050	5315	5875	0	2375	2525	2975	3290	3419	3460	3750	4625	350	50	4600	5475	5650	85	2800	2750	3100	4725	5050	5550
	H29 (H29)	600	2250	2675	2940	3500	2375	0	150	600	915	1044	1085	1375	2250	2725	2425	2225	3100	3275	2290	425	375	725	2350	2675	3175
	P37 (P37)	450	2100	2525	2790	2100	2525	150	0	450	765	894	935	1225	2100	2875	2575	2075	2950	3125	2440	275	225	575	2200	2525	3025
	Kerma Classique (KMC)	0	1650	2075	2340	2900	2975	600	450	0	315	444	485	775	1650	3325	3025	1625	2500	2675	2890	175	225	125	1750	2075	2575
	Soleb (SOL)	315	1335	1760	2025	2585	3290	915	765	315	0	129	170	460	1335	3640	3340	1310	2185	2360	3205	490	540	190	1435	1760	2260
	Amara West New Kingdom (NK)	444	1207	1632	1897	2457	3419	1044	894	444	129	0	41	332	1207	3769	3469	1182	2057	2232	3334	619	669	319	1307	1632	2132
	Tombos (TOM)	485	1166	1591	1856	2416	3460	1085	935	485	170	41	0	291	1166	3810	3510	1141	2016	2191	3375	660	710	360	1266	1591	2091
	Amara West post-New Kingdom (PNK)	775	875	1300	1565	2125	3750	1375	1225	775	460	332	291	0	875	4100	3800	850	850	1900	3665	950	1000	650	975	1300	1800
	Kawa (KAW)	1650	0	425	690	1250	4625	2250	2100	1650	1335	1207	1166	875	0	4975	4675	25	850	1025	4540	1825	1875	1525	100	425	925
	Ghaba (GHB)	3325	4975	5400	5665	6225	350	2725	2875	3325	3640	3769	3810	4100	4975	0	300	4950	5825	6000	435	3150	3100	3450	5075	5400	5900
	Al Khiday Neolithic (AKN)	3025	4675	5100	5365	5925	50	2425	2575	3025	3340	3469	3510	3800	4675	300	0	4650	5525	5700	135	2850	2800	3150	4775	5100	5600
	Gabati Merotic (GABMER)	1625	25	450	715	1275	4600	2225	2075	1625	1310	1182	1141	850	25	4950	4650	0	875	1050	4515	1800	1850	1500	125	125	950
	Gabati post-Merotic/Medieval (GABPM)	2500	850	425	160	400	5475	3100	2950	2500	2185	2057	2016	850	850	5825	5525	875	0	175	5390	2675	2725	2375	750	425	75
	Soba (SBA)	2675	1025	600	335	225	5650	3275	3125	2675	2360	2232	2191	1900	1025	6000	5700	1050	175	0	5565	2850	2900	2550	925	600	100

LOWER NUBIA	Gebel Ramlah (GRM)	2890	4540	4965	5230	5790	85	2290	2440	2890	3205	3334	3375	3665	4540	435	135	4515	5390	5565	0	2715	2665	3015	4640	4965	5465
	C-Group (CGR)	175	1825	2250	2515	3075	2800	425	275	175	490	619	660	950	1825	3150	2850	1800	2675	2850	2715	0	50	300	1925	2250	2750
	Heirakonpolis C-Group (HKC)	225	1875	2300	2565	3125	2750	375	225	225	540	669	710	1000	1875	3100	2800	1850	2725	2900	2665	50	0	350	1975	2300	2800
	Pharaonic (PHA)	125	1525	1950	2215	2775	3100	725	575	125	190	319	360	650	1525	3450	3150	1500	2375	2550	3015	300	350	0	1625	1950	2450
	Merotici (MER)	1750	100	325	590	1150	4725	2350	2200	1750	1435	1307	1266	975	100	5075	4775	125	750	925	4640	1925	1975	1625	0	325	825
	X-Group (XGR)	2075	425	0	265	825	5050	2675	2525	2075	1760	1632	1591	1300	425	5400	5100	125	425	600	4965	2250	2300	1950	325	0	500
	Christian (CHR)	2575	600	500	235	325	5550	3175	3025	2575	2260	2132	2091	1800	925	5900	5600	950	75	100	5465	2750	2800	2450	825	500	0

Table 6.24 – Temporal distance matrix (years)

		UPPER NUBIA																			LOWER NUBIA						
		4th Cataract Kerma (4CKM)	3-Q-33 (3Q33)	4th Cataract post-Meroitic (4CPM)	3-J-23 (3J23)	3-J-18 (3J18)	R12 (R12)	H29 (H29)	P37 (P37)	Kerma Classique (KMC)	Soleb (SOL)	Amara West New Kingdom (NK)	Tombos (TOM)	Amara West post-New Kingdom (PNK)	Kawa (KAW)	Ghaba (GHB)	Al Khiday Neolithic (AKN)	Gabati Merotic (GABMER)	Gabati post-Merotic/Medieval (GARPM)	Soba (SBA)	Gebel Ramlah (GRM)	C-Group (CGR)	Heirakonpolis C-Group (HKC)	Pharaonic (PHA)	Merotici (MER)	X-Group (XGR)	Christian (CHR)
UPPER NUBIA	4th Cataract Kerma (4CKM)	0	28.45	11.05	11.61	14.36	192.38	188.10	184.67	220.26	273.62	290.73	225.66	290.73	196.31	268.87	309.16	239.10	239.10	376.27	468.38	355.88	693.75	357.80	326.48	326.48	340.05
	3-Q-33 (3Q33)	31.65	0	18.78	18.74	16.67	165.47	160.00	157.14	196.61	255.55	276.16	202.48	276.16	169.32	281.18	307.09	254.79	254.79	375.88	461.64	353.13	700.22	355.37	318.76	318.76	335.30
	4th Cataract post-Meroitic (4CPM)	11.2	20.45	0	0.84	3.35	181.38	177.42	173.77	209.34	263.67	281.61	214.80	281.61	185.32	276.91	312.42	248.09	248.09	380.19	461.61	350.35	691.74	352.38	319.32	319.32	333.84
	3-J-23 (3J23)	12.02	19.63	0.82	0	2.75	180.91	177.07	173.35	208.71	262.90	280.80	214.15	280.80	184.85	277.75	313.20	248.90	248.90	380.99	460.77	349.53	691.01	351.56	318.48	318.48	333.01
	3-J-18 (3J18)	14.75	16.9	3.55	2.73	0	178.17	174.42	170.65	206.00	260.45	278.57	211.45	278.57	182.12	279.76	314.04	251.14	251.14	381.99	459.13	348.22	690.56	350.27	316.75	316.75	331.52
	R12 (R12)	347.88	316.23	336.68	335.86	333.13	0	30.70	15.30	57.80	146.17	186.83	66.13	186.83	4.20	420.02	393.31	403.40	403.40	463.66	398.00	324.02	701.80	327.87	265.20	265.20	296.98
	H29 (H29)	319.78	288.13	308.58	307.76	305.03	28.1	0	17.09	88.26	176.80	217.51	96.55	217.51	30.38	400.23	366.18	386.22	386.22	436.19	428.65	353.09	730.19	356.86	295.19	295.19	326.41
	P37 (P37)	338.18	306.53	326.98	326.16	323.43	9.7	18.4	0	72.89	160.99	201.09	81.23	201.09	16.64	406.65	378.13	390.88	390.88	448.45	412.10	336.00	713.15	339.77	278.20	278.20	309.33
	Kerma Classique (KMC)	409.47	377.82	398.27	397.45	394.72	66.13	94.23	75.83	0	88.66	130.68	8.34	130.68	57.91	466.19	448.67	446.04	446.04	519.30	341.80	274.66	653.38	278.75	212.68	212.68	246.51
	Soleb (SOL)	552.15	520.5	540.95	540.13	537.4	208.81	236.91	218.51	145.92	0	45.33	80.49	45.33	146.52	535.18	531.40	510.33	510.33	602.29	254.08	199.73	575.83	204.16	133.20	133.20	170.24
	Amara West New Kingdom (NK)	614	582.35	602.8	601.98	599.25	270.66	298.76	280.36	207.77	63.09	0	122.89	0.00	187.67	557.35	563.68	529.70	529.70	634.58	211.23	155.59	530.62	160.08	88.35	88.35	125.95

	Tombos (TOM)	415.94	384.29	404.74	403.92	401.19	72.6	100.7	82.3	9.71	137.03	198.88	0	122.89	66.19	473.36	456.84	452.81	452.81	527.49	333.89	268.15	646.85	272.28	205.63	205.63	239.83
	Amara West post-New Kingdom (PNK)	614	582.35	602.8	601.98	599.25	270.66	305.16	286.76	207.77	63.09	0	198.88	0	187.67	557.35	563.68	529.70	529.70	634.58	211.23	155.59	530.62	160.08	88.35	88.35	125.95
	Kawa (KAW)	348.45	316.8	337.25	336.43	333.7	5.11	33.21	14.81	62.82	205.5	267.35	69.29	267.35	0	422.72	394.66	406.42	406.42	464.93	398.89	326.01	703.98	329.89	266.76	266.76	298.83
	Ghaba (GHB)	495.2	526.85	506.4	507.22	509.95	843.08	814.98	833.38	904.67	1047.35	1109.2	911.14	1109.2	843.65	0	153.30	45.31	45.31	178.35	735.78	619.44	926.98	620.86	594.83	594.83	606.17
	Al Khiday Neolithic (AKN)	763.77	793.86	773.41	774.23	776.96	1110.09	1081.99	1100.39	1171.68	1314.36	1376.21	1178.15	1376.21	1110.66	300.11	0	188.10	188.10	70.92	763.60	659.65	1002.03	662.03	620.63	620.63	640.53
	Gabati Merotic (GABMER)	446.56	478.21	457.76	458.58	461.31	794.44	766.34	784.74	856.03	998.71	1060.56	862.5	1060.56	795.01	50.2	321.21	0	0.00	221.06	701.87	583.67	884.47	584.88	562.28	562.28	571.69
	Gabati post-Merotic/Medieval (GABPM)	446.56	526.85	457.76	507.22	509.95	794.44	766.34	833.38	856.03	998.71	1060.56	862.5	1060.56	795.01	50.2	321.21	0	0	221.06	701.87	583.67	884.47	584.88	562.28	562.28	571.69
	Soba (SBA)	728.86	758.95	738.5	739.32	742.05	1075.18	1047.08	1065.48	1136.77	1279.45	1341.3	1143.24	1341.3	1075.75	236.1	93.11	286.3	286.3	0	833.97	728.91	1066.96	731.21	690.92	690.92	710.26
LOWER NUBIA	Gebel Ramlah (GRM)	1034.03	1002.38	1022.83	1022.01	1019.28	690.69	718.79	700.39	620.12	483.12	422.57	618.91	422.57	687.38	1529.23	1796.24	1480.59	1480.59	1761.33	0	124.71	351.51	125.22	143.14	143.14	130.54
	C-Group (CGR)	795.2	763.55	784	783.18	780.45	486.76	514.86	496.46	388.97	244.29	183.74	380.08	183.74	448.55	1290.4	1557.41	1240.2	1241.76	1522.5	240.7	0	378.71	4.60	67.92	67.92	29.67
	Heirakonpolis C-Group (HKC)	1261.93	1230.28	1250.73	1249.91	1247.18	918.59	946.69	928.29	855.7	711.02	650.47	846.81	650.47	915.28	1757.13	2024.14	1708.49	1708.49	1989.23	519.9	470.47	0	374.64	442.82	442.82	407.14
	Pharaonic (PHA)	795.2	763.55	784	783.18	780.45	486.76	521.26	502.86	388.97	244.29	183.74	380.08	183.74	448.55	1290.4	1557.41	1240.2	1241.76	1522.5	240.7	0	470.47	0	72.49	72.49	34.21
	Merotici (MER)	725.83	694.18	714.63	713.81	711.08	382.49	410.59	392.19	319.6	174.92	114.37	310.71	114.37	379.18	1221.03	1488.04	1172.39	1172.39	1453.13	312.4	73.57	540.3	73.57	0	0	38.35
	X-Group (XGR)	725.83	694.18	714.63	713.81	711.08	382.49	416.99	398.59	319.6	174.92	114.37	310.71	114.37	379.18	1221.03	1488.04	1172.39	1172.39	1453.13	312.4	73.57	540.3	73.57	0	0	38.35
	Christian (CHR)	766.12	734.47	754.92	754.1	751.37	422.78	450.88	432.48	359.89	215.21	154.66	351	154.66	419.47	1261.32	1528.33	1212.68	1212.68	1493.42	269.49	30.66	497.39	30.66	44.49	44.49	0

Below the diagonal Nile distances, above the diagonal straight-line distances.

Table 6.25 – Geographical distance matrix (km)

	SIMPLE MANTEL TESTS (R)			PARTIAL MANTEL TESTS (R)		
	Time	Straight-line	River	Time	Straight-line	River
36-TRAIT MMD	-0.065	-0.191	0.299	0.006*/ 0.050**	0.187	0.293
21-TRAIT MMD	-0.129	-0.136	0.288	0.075* / 0.118**	0.126	0.27

Red = significant p=0.05. *controlling for river distance, **controlling for straight-line distance

Table 6.26 Upper Nubian mantel test results

partial Mantel tests, controlling for river distance, for the 36-trait (r= 0.006, p= 0.463) 21-trait (r= 0.07507, p= 0.2564) MMD results reveal a very weak positive correlation with the temporal matrix; results are not statistically significant. When the temporal and MMD matrices were compared, controlling for straight-line distances, a weak positive correlation was found for both the 36-trait (r= 0.05004, p= 0.3275) and 21-trait (r= 0.1181, p= 0.1716) MMD data. The correlations are not significant.

Next, the straight-line distance matrix (Table 6.25) was compared to the MMD matrices, controlling for temporal distance. The partial Mantel test results show that the 36-trait (r=0.187, p= 0.007) and 21-trait (r= 0.126, p= 0.045) MMD matrices are weakly positively correlated to the straight-line distance matrix. Both correlations are significant (p ≤ 0.05). Finally, the river distance matrix (Table 6.25) was compared to the MMD matrices, controlling for temporal distance. The 36-trait (r= 0.2925, p= 0.0043) and 21-trait (r= 0.2702, p= 0.0164) MMD results again showed a weak positive correlation. Both correlations are significant (p ≤ 0.05).

6.3.3 Nubia – Simple Mantel tests

The MMD data were firstly compared to a temporal distance matrix (Table 6.24). Only a weak positive nonsignificant correlation was found when compared to the 36-trait MMD matrix (r= 0.144, p= 0.075). Again, the 20-trait MMD and temporal matrix only produced a weak positive correlation (r= 0.083, p= 0.204). The correlation is not significant. The MMD data were next compared to a geographical straight-line distance matrix (Table 6.25). The 36-trait MMD data were weakly correlated to the geographical distance matrix (r= 0.099, p= 0.054). Similarly, the 20-trait MMD matrix was also weakly positively correlated with the geographical distance matrix (r= 0.040, p= 0.247). Both correlations are not significant. Finally, the MMD data were compared to the river distance matrix (Table 6.25). The 36-trait MMD data produced a weak but significant positive correlation (r = 0.211, p= 0.011). The 20-trait MMD data also produced a weak positive nonsignificant correlation (r= 0.137, p= 0.082).

	SIMPLE MANTEL TESTS (R)			PARTIAL MANTEL TESTS (R)		
	Time	Straight-line	River	Time	Straight-line	River
36-TRAIT MMD	0.144	0.099	0.211	0.098*/ 0.138**	0.090	0.183
21-TRAIT MMD	0.0843	0.040	0.137	0.051* /	0.034	0.121

Red = significant p=0.05. *controlling for river distance, **controlling for straight-line distance.

Table 6.27 Nubian Mantel test results

6.3.4 Nubia – Partial Mantel tests

The MMD data were compared with temporal distances (Table 6.24), controlling for geographic distance (straight-line and river). Firstly, the analysis was performed, controlling for river distance. This analysis revealed that the 36-trait (r= 0.098, p= 0.152) and 20-trait (r= 0.051, p= 0.296) MMD data are weakly correlated with temporal distance. The correlations are not significant. Additionally, the partial Mantel test was performed, controlling for straight-line geographic distance. When the 36-trait MMD data were used in the analysis, a weak negative correlation with temporal distance was found (r= -0.138, p= 0.922). When the temporal distance data were compared to the 20-trait data a weak positive correlation was produced (r= 0.080, p= 0.211). Neither correlation is significant.

The relationship between geographical distance (Table 6.25) and the MMD data were also tested, controlling for time. When the river distance matrix and the 36-trait MMD matrix were compared a weak positive correlation was found (r= 0.183, p= 0.021), the correlation was significant. The 20-trait MMD data (r= 0.121, p= 0.097) also produced a weak positive correlation when tested against the river distance matrix, the correlation was not significant. The straight-line distance matrix and MMD matrices were revealed to be very weakly positively correlated (36-trait r= 0.090, p= 0.078, and 20-trait r= 0.034, p= 0.269). Both correlations are not significant. Results are summarised in Table 6.27

6.4 Summary

The intra-group MMD values ranged from 0.00 to 0.082 for the 4th Cataract, 0.00 to 0.376 for the Dongola Reach, 0.00 to 0.297 for the 6th Cataract, and 0.00 to 0.158 for Lower Nubia. Multidimensional scaling revealed that the Nubian samples grouped together, between the Egyptian and sub-Saharan African clusters. Mantel test and partial mantel tests on both Upper Nubian and Nubian (Upper and Lower) data produced weak correlations, although some were significant at the 0.05 alpha level. Results in this chapter are used as the basis for the discussion in Chapter 7.

Chapter 7 – Discussion

The archaeology (Chapter 2) and previous research (Chapter 3) will be used to contextualise the results from the prior chapter. The discussion will be based on the hypotheses laid out in Chapter 4. All tables referenced are from Chapter 6.

7.1 Was there population continuity in the Fourth Cataract region between the Kerma – Medieval periods?

The 4th Cataract collection is unique as it comprises skeletal remains covering circa 4000 years, from a 30km wide locale. As such, the remains offer an excellent opportunity to explore biological continuity without geographical distance influencing results. Calculating the biodistance between samples dated from distinct time periods (Kerma – Medieval) in the region allows for a comprehensive review of how changes in cultural practice correspond to biological relationships.

In section 4.1 the following hypothesis was used to test whether biological continuity in the 4th Cataract was evident. Ho: there is no difference, Ha: there are significant differences between samples from consecutive periods in the 4th Cataract group. The biodistance results (tables 6.2 and 6.5) reveal that the samples are closely related. In both the 36- and 20-trait analysis, samples from consecutive periods produced low mean measure of divergence (MMD) values. Additionally, all samples, except the medieval samples (3-J-18 and 3-J-23), share a close affinity with the other samples from the group. As such, the null hypothesis cannot be rejected, supporting biological continuity.

Archaeological excavations in the 4th cataract region have revealed that there are distinct shifts in culture between periods. The defined cultural landscape for each often shares similarities with other areas of Upper Nubia (e.g., the Dongola Reach) (Emberling, 2012). These changes, coupled with the MMD data, suggest that there was cultural diffusion, but it was not associated with major movements of people into the area. Biological continuity has been noted in other regions of Nubia, which show similar cultural shifts between periods (Armelagos et al., 1972; Calcagno, 1986; Carlson, 1976; Carlson and Van Gerven, 1977; Carlson and Van Gerven, 1979; Galland et al., 2016; Greene, 1972; Greene, 1982; Greene et al., 1967; Irish, 2005; Irish and Usai, 2021; Schrader et al., 2014; Stynder et al., 2009; Van Gerven, 1982; Van Gerven et al., 1977). Biological continuity infers that the cultural changes observed in the 4th Cataract region are not stimulated by mass movement of people or replacement, even when large swathes of Nubia were controlled by one governing force (i.e., Kerma or Meroitic empires). The region is difficult to reach, as the Nile is difficult to transverse at this point. As such, it was not on the main trade route, with the Korosko road being the preferred course (Emberling, 2012). Additionally, the 4th Cataract region was not heavily populated until the Medieval period (Welsby, 2002), with other areas of the Nile valley more favourable for settlement and agriculture. These factors mean that the region may not have been subject to the movement of people associated with large settlements and trade.

Additionally, cultural links to groups from the Eastern Desert have also been found in 4th Cataract region up until the post-Meroitic (Emberling et al., 2014; Kołosowska, 2010; Paner and Borcowski, 2007). Pottery from these Eastern Desert groups is unique to the region and not often found in burials in other areas of Upper Nubia

(Paner and Borcowski, 2007). Cultural interactions between the two groups may also have been accompanied with genetic exchange. Consistent biological interactions with Eastern Desert groups could have potentially had a homogenising effect on 4th Cataract populations over time, similar to the effect described in the isolation by time theory described in Section 5.6.5 (Konigsberg, 1990). If there is genetic influence from the Eastern Desert in the groups studied then these data would suggest this was ongoing from the Kerma-Medieval periods.

Although there is evidence for biological continuity in the 4th Cataract region, some differences between samples have been noted. These differences are associated with the medieval samples, 3-J-23 and 3-J-18. They are significantly different from each other in both the 36- and 20-trait analysis, despite the MMD values being relatively small (0.028 and 0.030 respectively). Sample 3-J-18 is the most divergent of the collections, only sharing a close affinity with the post-Meroitic samples (4CPM) in the 36-trait analysis. Conversely, 3-J-23 only differs significantly from 4CPM in the 36-trait analysis. Both medieval samples increase in similarity to the other samples in the 20-trait analysis. This suggests that although there was a level of biological continuity, the new groups may have moved into the region in these later periods.

The Medieval period in the 4th Cataract also saw an increase in population densification (Welsby, 2002). As described above, sample 3-J-18 is divergent from the other 4th Cataract collections, whereas 3-J-23 is more similar to the other samples. The cemetery at 3-J-18 has been assigned a later date than 3-J-23 (Vandenbeusch and Antoine, 2015), which could suggest that temporal distance influenced biological affinities between 3-J-18 and other samples from the region. Previous research has also indicated that 3-J-18 is distinct from other medieval samples (3-J-10 and 3-J-11) from the 4th Cataract region (Streetman, 2018). Both 3-J-10 and 3-J-11 originate from the same island in the Nile (Mis Island) and may have been in use at the same time as 3-J-18 (Streetman, 2018). As there may be no temporal distance between the Mis Island samples, the distinctiveness of 3-J-18 could be indicative of different group inhabiting the region. Lower levels of disease (Davies-Barrett, 2018; Soler, 2012) and significantly more heterogeneity (Streetman, 2018) have been found at 3-J-18 compared to other medieval Nubian sites. Some have suggested that these differences can be attributed to the cemetery being used by refugees (Soler, 2012). The late Medieval period saw an increase in hostilities between Egypt and Nubia (Welsby, 2006). As the area of Nubia controlled by Egypt increased, people were forced to relocate to the ever-decreasing regions where Christian rule was still upheld (Welsby, 2002). Due to the late dating of the cemetery at 3-J-18 combined with its island location (providing a level of safety), the migration of people from other areas of Nubia may explain the differences observed in the sample.

Additionally, differences in social status associated with individuals from the medieval cemeteries in the 4th Cataract region may have influenced biological affinities. The medieval burials from the 4th Cataract are Christian in style (with only a few non-Christian medieval burials present), and as such social status is hard to establish due to the homogenous nature of the internments (Ginns, 2010b; Welsby, 2016). The association with a church distinguishes 3-J-18 from the other medieval 4th Cataract cemeteries referred to above. Proximity to the church may have been reserved for those of higher status (Zurawski, 2006). The skeletal collection from 3-J-18 also includes an individual who was buried under the church walls in finely made clothing, inferring a high-status (Ginns, 2010a). As such, high-status individuals from distinct 4th Cataract groups (and potentially beyond) may have chosen to be buried at 3-J-18. The mix of people from different groups could have produced a biologically distinctive sample.

Archaeological research has posited that the post-Meroitic and Medieval periods were associated with an influx of people from the south (Edwards, 2019; Kirwan, 1960; Leclant, 1981; Williams, 1991). The post-Meroitic sample (4CPM) shares a closer affinity to 3-J-18 than 3-J-23, patterning that is reversed when the Kerma (4CKM) and Meroitic (3-Q-33) samples are considered. This finding could indicate that during the post-Meroitic period, people migrated to the 4th Cataract region. These new groups may have integrated with the existing population or created new settlements and living alongside one another. The medieval collections (3-J-18 and 3-J-23) could represent two distinct groups living in the 4th Cataract, one more similar to the existing population from Kerma-Meroitic periods (3-J-23) and the other more akin to those appearing in the post-Meroitic period (3-J-18). Burials in both medieval 4th Cataract cemeteries are Christian in style and therefore standardised, offering little evidence of potential cultural differences between groups. The fact that there are multiple cemeteries in use at the same time in the region and more specifically on Mis Island is suggestive of distinctions between groups.

Biodistance data from the 4th Cataract region support the theory of biological continuity from the Kerma to Medieval period. During the post-Meroitic and Medieval periods there is some evidence (i.e., significant differences between 4CPM and 3-J-23) for different groups moving into the region, but there is no data to suggest full replacement. As such, these data indicate that there was a stable population for around 2000 years. The sample from the cemetery at 3-J-18 is most distinct from all the other 4th cataract collections included in this study, with its association to the church potentially being a key difference. Whether 3-J-18 was a place of refuge, place of burial for high status individuals, or both is unclear. The following sections will use data from across Nubia and the surrounding areas to contextualise and help to better understand the patterning observed in the 4th Cataract data.

7.2 Is there evidence of geographical patterning in the biological affinities between Nubian groups (Neolithic – Medieval)? Are intra-regional affinities closer than inter-regional affinities?

Previous research has shown that Nubian samples from the same region, Upper or Lower Nubia, share close affinities. Model-free analysis was performed using the MMD to measure biodistance between samples. To further investigate this regional patterning on a smaller scale, the Upper Nubia samples from this study were divided by location into smaller regions (4th Cataract, Dongola Reach, and 6th Cataract). To help quantify if the close regional affinities observed are specific to that group and how they relate to the other regions, the hypotheses described in section 4.2 were used (i.e., Ho: there is no difference between regional groups, Ha: inter-regional differences are greater than intra-regional differences). Additionally, mean MMD values within and between regions were calculated (see Tables 6.12 and 6.15) to provide an overview of the biological distance within and between regions. As such, if the mean values between regions (inter-regional) are the same as the within (intra-regional), then the null hypothesis cannot be rejected. If intra-regional mean MMD values are lower (i.e. biological affinities are stronger) when compared to other regions, then the null can be rejected.

The 4th Cataract region samples share a close affinity to each other. Both the Dongola Reach and 6th Cataract samples also show high levels of intra-regional similarities in the 36-trait MMD analysis (see Tables 6.7 and 6.9). Similarly, in each region there are samples that are distinct from the group (H29, Soleb, and Tombos in Dongola Reach; Al Khiday in the 6th Cataract). Contra to the 4th Cataract results, after trait editing, the intra-regional affinities in both the Dongola Reach and 6th Cataract decrease. Lower Nubia follows the same pattern (see Tables 6.11 and 6.14), exhibiting close intra-regional affinities in both the 36- and 20-trait MMD analysis. Gebel Ramlah and the C-Group samples produce the highest MMD values compared to the other Lower Nubians.

When intra- and inter-regional MMD values are considered, the data from Upper Nubia show mixed results. The 4th Cataract group has a lower mean intra-regional MMD than when compared to the other regions in both the 36-trait (mean intra-regional MMD= 0.37) and edited MMD analysis (mean intra-regional MMD= 0.28), which supports the alternative hypothesis. The Dongola Reach and 6th Cataract samples do not follow this pattern. In both sets of analyses the intra-regional mean MMD is higher than at least one the inter-regional mean MMD values. Figure 6.2 is the 3-D illustration of the Multidimensional scaling (MDS) of the 36-trait MMD data for the Upper Nubian samples. The figure shows that both the 6th Cataract and Dongola Reach samples are widely spread across the graph. The 4th Cataract samples are more closely grouped, mirroring the mean MMD data. Figure 6.4, the 21-trait MMD MDS, shows similar patterning to Figure 6.2 but all samples are more closely grouped. The Dongola Reach and 4th Cataract samples form clusters, whereas the 6th Cataract group is still dispersed, mirroring the high mean MMD value (0.139). Outliers are evident from both the Dongola Reach (Soleb and H29) and 6th Cataract (Gabati post-Meroitic and Al Khiday) groups. These outliers may have skewed the mean MMD results, decreasing the intra-regional affinities in these regions.

So why is the 4th Cataract region the only one in Upper Nubia that supports the alternative hypothesis? It was relatively inaccessible and not heavily populated until the Medieval period (Emberling, 2012; Welsby, 2002). Therefore, it may not have been subject to migration associated with trade and large settlements. Additionally, the 4th Cataract samples originate from the most geographically focused area of the Upper Nubian regions (Emberling, 2012), so the inter-sample spatial distance will not influence biodistance results. Moreover, the 4th Cataract has consistent cultural associations with Eastern Desert groups from Kerma – post-Meroitic periods (Emberling et al., 2014; Kołosowska, 2010; Paner and Borcowski, 2007). If these cultural associations were accompanied with biological interactions, then this may have homogenised the biological make-up of the 4th Cataract inhabitants over time, creating closer intra-regional affinities.

These factors are the opposite of those in the other two Upper Nubian regions. Skeletal assemblages from large urban centres (e.g. Kerma, Kawa, Amara West, and Soba) are included in the Dongola Reach and 6th Cataract collections.

Industries and trade associated with urban settlements (Binder, 2014; Bonnet, 2019; Welsby et al., 1998), may have also been coupled with the movement of people. Non-locals have been identified in samples ranging from Kerma – Napatan periods, in both urban and rural sites in the Dongola Reach region (Buzon, 2011; Buzon and Simonetti, 2013; Buzon et al., 2007; Schrader et al., 2019). If migrants into Nubian towns were from outside the local area, this may have affected intra-regional biological affinities. The 6th Cataract and Dongola reach regions are both spread over around 300km, a much larger area than the 4th Cataract. Therefore, geographical distance between samples could have affected inter-regional affinities (Konigsberg, 1990). Additionally, sites from different regions may be geographically closer than two from the same defined region, and therefore potentially share more biological similarities (e.g., Gabati Meroitic is geographically and biologically closer to 3-J-18 than Soba). All three Upper Nubian regions are missing collections from certain periods and the number of samples represented for each period differs. In the 6th Cataract group, there are two Neolithic samples but then a large gap (c. 4100 years) until the next sample Gabati Meroitic (GABMER). The isolation by time model predicts that as time progresses, biological affinities should increase (Konigsberg, 1990), therefore the gap in samples from the 6th Cataract region should not adversely affect intra-regional affinities. In the Dongola Reach there are multiple samples from the New Kingdom/post-New Kingdom period—which is not represented in the other Upper Nubian groups. The New Kingdom is associated with the movement of people from Egypt into Nubia (Buzon et al., 2007). If, as suggested, there was an influx of non-locals, then it could have increased intra-regional affinities in this group.

When Lower Nubians are also considered, the mean MMD data reveal that this region also has closer intra-regional affinities than inter-regional, like the 4th Cataract. In the 36-trait analysis all Upper Nubian regions share the least similarities with Lower Nubians (Table 6.12). This is not the case in the edited MMD data, where differences with the Lower Nubian sample are evident but not always the most distinct (Table 6.15). Additionally, if the Lower Nubians are compared to all Upper Nubian samples, the intra-regional affinities are again higher than the inter-regional. Figures 6.5 and 6.7 (3-D MDS of the edited and unedited MMD data) mirror this relationship, with Lower Nubian samples grouped together, whereas the Upper Nubians are more interspersed. The PCA analysis (Table 6.13 and Figure 6.6) also revealed differences between Lower and some Upper Nubian groups. Lower frequencies of certain traits (UI1 shovelling, LP2 cusp number, LM1 cusp number, and LM1 deflecting wrinkle) were identified in the Lower Nubians when compared to Upper Nubians, although they are not part of the Afridonty complex (Irish, 1997) (see 5.6.2 for details). These data suggest that while there may have been movement of people between regions within Upper Nubia, there was little movement between Upper and Lower Nubia. Cultural distinctions have been noted between the latter regions at different periods (i.e., Kerma, post-Meroitic, Medieval) (Edwards, 2007), perhaps associated with biological differences. Biological differences between Upper and Lower Nubians have been identified in previous research (Irish, 2005). Lower Nubia has been subjected to higher levels of aridity than Upper Nubia and has seen periods of sparse populations (Edwards, 2004). As such, like the 4th Cataract region, Lower Nubia may not have been conducive to migration from other areas. Additionally, Lower Nubia has a closer relationship with Egypt both geographically and historically (Spencer, 2019), with the latter having invaded and ruled Lower Nubia during both the Middle and New Kingdoms (Knoblauch, 2019; Spencer, 2019). Although Egypt occupied parts of Upper Nubia during the New Kingdom, the relationship between cultures is still unclear (Buzon et al., 2016). This is particularly true of Upper Nubians south of the 3rd Cataract, where it is thought Egyptian influence was limited (Morkot, 2001). This sustained Egyptian genetic input could be the cause of differences between Lower and Upper Nubians. Previous research suggested Lower Nubians have a strong Egyptian affinity (Irish and Friedman, 2010).

Intra- and inter-regional mean MMDs were found to be different, so the null hypothesis can be rejected. The alternative hypothesis (intra-regional affinities are higher than inter-regional) can only be supported in Lower Nubia and 4th Cataract samples. Much of the existing Nubian research is based on Lower Nubian groups and these data support strong biological affinities between groups there. Data from Upper Nubia is more complex and regional patterning may have been disrupted by within-region movement of people. Biological distinctions between Upper and Lower Nubia in the data suggest inter-regional differences in the cultural record may also have been a barrier to migration (Edwards, 2004).

The isolation by distance model predicts that as geographical distance increases so does biological distance (Wright, 1943). The model does not have any predefined notions of regions or cultural affinities, and is an objective test of the relationship between space and biodistance (Konigsberg, 1990). The simple Mantel tests revealed that Upper Nubian MMD matrices were weakly positively correlated to river distance; these correlations are statistically significant. The straight-line distances are weakly negatively correlated and are not significant. Partial Mantel tests produced significant weak positive correlations for both river and straight-line distances accounting for time. When the data from Lower Nubia are also considered, river distances have a stronger relationship to biological distance in both the simple and partial Mantel tests. Only the 36-trait MMD data produced significant results. As such, the null hypothesis detailed in section 4.2 (Ho: There is no significant correlation) cannot be rejected and there is no support for the alternative hypothesis (Ha: there is a strong positive correlation between biological and geographical distances). Like previous research, river distances have a stronger relationship to biodistance than straight-line distances in Nubia (Godde, 2013). All Mantel tests (simple and partial) involving river distance are significant, although weak. This suggests that geographical distance has a small impact on biological distance but that other factors are also involved. As the correlations are weak, the statistical significance is probably due to a large data set used in the analysis (Schober et al., 2018.)

Godde (2013) proffered that Konigsberg's model did not work on the Lower Nubian samples she studied as neither straight-line nor river distances were a true representation of the geographical distance between collections. Although the Nile was the main mode of transport there were areas where the river is unnavigable (Auenmüller, 2019). At certain points in Nubian history, desert roads were used to bypass these areas of the Nile and were employed as shorter routes between important settlements (Auenmüller, 2019; Edwards and Judd, 2012). Therefore, the geographical distance between the samples in this study may not be fully accurate, at least for some periods.

Both isolation by distance models outlined in section 5.6.5 (Konigsberg, 1990; Vecchyo and Slatkin, 2019) account for temporal distance, and, in theory, should not obscure the relationship between geographical and biological distance. Even with temporal distance accounted for, changes between different periods could still be affecting biodistances between Nubian samples. Both models presume a steady flow of migration (Konigsberg, 1990; Vecchyo and Slatkin, 2019). If major migration events took place between different periods, biodistances between samples may have been affected, decreasing the relationship between geography and phenetic similarities. As such temporal patterning will be discussed further in the following section.

Both the model-free and model-bound approaches show that while geography does influence Nubian biological affinities, it does not fully explain the relationship between the groups studied here. These data reveal that the relationship between geography and biodistance is specific to different Nubian regions. Distinctions between Upper and Lower Nubians were revealed. Data suggests Upper Nubian groups potentially mixed with each other but not with Lower Nubians. Biological affinities are affected by multiple factors, with geography being just one. Additional factors highlighted in this section have included outside genetic influence, temporal distance, and migration. These themes will be further investigated in the subsequent sections.

7.3 Is there evidence of temporal patterning in Nubia (Neolithic – Medieval)? Are biological changes in the population correlated with diachronic shifts in social and cultural practices?

Konigsberg's (1990) isolation model also investigates the relationship between temporal and biological distance. Contra the isolation by distance model, biological distance should decrease as temporal distance increases. The theory predicts that over time samples will become more similar to each other due to groups genetically interacting (Konigsberg, 1990). As such, the two variables should be negatively correlated. The hypotheses detailed in section 4.3 (Ho: there is no strong correlation and Ha: there is a strong negative correlation between these distances) were used to test the relationship. Only simple Mantel tests using the Upper Nubian data revealed very weak negative correlations. All other Mantel tests (simple and partial) produced very weak positive correlations when either the Upper Nubian or Nubian data were considered. Therefore, the null hypothesis cannot be rejected.

Vecchyo and Slatkin (2019) found that the isolation by time model works over short geographical distances, but isolation by distance is dominant over longer geographical distances. Although the null hypothesis relating to isolation by distance could not be rejected in the previous section, biological distance was more highly correlated to geographical over temporal distance. Therefore, the geographic scale of the data may have obscured the temporal patterning. If the samples are divided into regional groups and viewed separately there is some evidence of the predicted patterning. In the 4th Cataract group, the Kerma sample (4CKM) is more similar to the Medieval sample (3-J-23) than the Meroitic (3-Q-33) and post-Meroitic (4CPM). However, it should be noted that the other Medieval collection (3-J-18) does not follow that patterning. If 3-J-18 did contain non-local individuals (as previously discussed), then this may have disrupted the homogenising effect of time. Similarly, in the 6th Cataract group, Ghaba (GHB) is more similar to Soba (SBA) than the other collections which are temporally closer. Al Khiday (AKN) does not follow this patterning, differing significantly from all other samples in the 6th Cataract group bar Ghaba. This may indicate that Al Khiday is not the progenitor of the groups from this region. Kawa (KAW) and R12, from the Dongola Reach, also follow the temporal patterning. Although the latter periods of Nubian history (post-Meroitic and Medieval) are associated with more southerly groups moving into the area (Phillipson, 2012), these data suggest that the origin of these groups may have been within Nubia. It is unknown if the Noba (who came to prominence in the post-Meroitic period) were from outside Nubia or if they were one of the many groups under the control of the Meroitic Empire (Welsby, 2002). As samples from the post-Meroitic and Medieval share similarities with earlier Nubian samples, the latter may be a more likely theory.

Conversely, in Lower Nubia the patterning is not evident with regards to Gebel Ramlah (GRM) or the two C-Group samples (CGR, HKC) and the Medieval sample (CHR). Both isolation models (Konigsberg, 1990; Vecchyo and Slatkin, 2019) presume a steady level of migration into the area studied. Lower Nubia is known to have been occupied by Egyptian and Upper Nubian forces at several times in the past (Knoblauch, 2019). Previous research has revealed that C-Group samples have close biological affinities with Egyptian and Upper Nubian collections (Irish and Friedman, 2010). Studies of New Kingdom cemeteries in Upper Nubia have reported the presence of Egyptians (Buzon, 2007), suggesting that the occupation of Nubia was also accompanied with human migration. These higher periods of migration may have influenced the temporal patterning in Lower Nubia. Although close intra-regional affinities were noted in Lower Nubia in the previous section, some temporal differences can be observed. The MMD results (Tables 6.11 and 6.14) reveal that the Lower Nubians fall into two groups. Neolithic – C-Group samples (GRM, CGR, and HKC) share close affinities, as do the Meroitic – Medieval samples (MER, XGR, and CHR), while the Pharaonic sample is similar to both. The two groups differ significantly from each other in most instances. They can be observed on Figures 6.5, 6.6, and 6.7 with the Pharaonic (PHA) sample positioned between groups. In these Figures the later samples (MER, XGR, and CHR) are closer to the Upper Nubians. This proximity could indicate that from the Meroitic period onwards there was a greater genetic influence from Upper into Lower Nubia. From the Napatan period onwards, political (and potentially genetic) influence has been associated with groups from Upper Nubia (Morkot, 2000; Török, 2008; Welsby, 2002). Movement of people from there may have caused the change in biological affinities visible in the Lower Nubian data.

Although some of predictions of the isolation by time model can be observed in the Nubian regions, the model did not explain the relationship between groups in Upper Nubia or Nubia as a whole. Migration can influence the genetic makeup of populations within regions, as such it has been previously suggested as a reason that model-based theories do not work when studying Nubian groups (Godde, 2013). Godde (2012) using discrete cranial traits found evidence of extra regional gene flow in Nubian populations from the Palaeolithic to C-Group. Additionally, distinct periods have been identified in Nubian history/prehistory (Edwards, 2004) but it is unclear whether these shifts in cultural practice also came with genetic changes due to migration. To investigate this further, samples were split by period, and the following null and alternative hypotheses used to test for patterning (Ho: there are no differences, as opposed to Ha: there are significant differences between samples from different periods). As such, if samples differ significantly from those of the preceding period, then migration is assumed.

The Upper Nubian Neolithic samples (R12, Ghaba (GHB), and Al Khiday (AKN)) reveal a complex picture compared to the Kerma collections. Ghaba and R12 share close MMD affinities with most Kerma samples. The opposite is true for Al Khiday which differs significantly from all, except Kerma Classique (KMC), in both the 36- and 21-trait analyses. Although some inter-sample differences are evident, these data indicate biological continuity from the Neolithic to Kerma in Upper Nubia. Biological continuity between these periods has been observed in other studies of Upper Nubian groups (Irish, 2005; Irish, 2008; Irish and Friedman, 2010; Irish and Usai, 2021). Al Khiday and Ghaba (both from the 6th Cataract region) share the closest similarities to Kerma Classique (KMC) from the Dongola Reach. Although several important Neolithic sites have been found in southern Upper Nubia (5th-6th Cataract of the Nile) no evidence of human occupation between the late Neolithic and Meroitic periods has been identified (Usai, 2016). The interruption in occupation in the 6th Cataract region could be due to a lack of excavation, or perhaps the inhabitants emigrated or were replaced (Salvatori and Usai, 2016). These data suggest similarities between southern Neolithic and later Kerma populations in northern Upper Nubia, potentially indicating immigration from the south. As no 6th Cataract Kerma samples are available for comparison, the extent of this potential movement is unclear. Additionally, this study does not contain 4th Cataract Neolithic material, as burials from this period are rare in the region (Emberling, 2012). It was suggested that a different burial rite was practiced, like that of the El Mutaga region, potentially indicating a different culture than in other parts of Upper Nubia (Osypiński, 2014). The 4th Cataract Kerma (4CKM) sample shares similarities with both Ghaba and R12 indicating either biological continuity or replacement if there was a different Neolithic culture in the region.

Gebel Ramlah (GRM) is distinct from all Kerma/C-Group samples bar Hierakonpolis C-Group (HKC). Gebel Ramlah also does not share a close affinity with the other Neolithic samples. Figures 6.5 and 6.6 also show Gebel Ramlah as an outlier. The C-Group (CGR) is significantly different from Gebel Ramlah in both sets of analysis but does share some similarities with Ghaba (GHB) in MMD and PCA analyses. Hierakonpolis C-Group shares close affinities with Gebel Ramlah, Ghaba, and Al Khiday (AKN). Similar to the patterning in Upper Nubia, C-Group sample affinities could suggest movement of people to Lower Nubia from the southern regions of Upper Nubia after the Neolithic. Although distinct from the C-Group (CGR) sample, Gebel Ramlah does share an affinity with Hierakonpolis C-Group (HKC), indicating some level of biological continuity. Other bioarchaeological research on Lower Nubians has suggested continuity between Neolithic and A-Group (the culture proceeding the C-Group) (Irish, 2005), as well as A-Group and C-Group (Galland et al., 2016). These combined data from Upper and Lower Nubia imply that, although biological continuity between the Neolithic and Kerma/C-Group is clear, this may have also been coupled with inter-regional movement of Nubian people.

Upper Nubian Kerma collections reveal close inter-sample affinities (see Tables 6.7 and 6.9). This is mirrored with the homogeneity observed in material cultural from these groups (Bonnet, 2019; Honegger et al., 2009). These data suggest a high degree of interactions between groups in Upper Nubia during this period. In Lower Nubia, the two C-Group samples (CGR and HKC) also share a close affinity. C-Group (CGR) differs significantly from the Kerma samples in the 36-trait MMD analysis but shares a close affinity with P37 and Kerma Classique (KMC) in the 20-trait analysis. Hierakonpolis C-Group is similar to some Kerma collections in the 36-trait analysis (P37 and KMC) and has a close relationship with all Kerma samples after the trait editing. The C-Group and Kerma are culturally distinct, especially in later periods (Edwards, 2004). The close affinities between these samples could indicate a level of admixture between groups or that both have similar origins (Hafsaas, 2021). When these data were submitted to Multidimensional scaling (Figures 6.5-6.7), the C-Group and Kerma samples do not group together inferring that they have different relationships to the other samples. Differences between the two cultures has been noted in other biodistance studies (Godde and Jantz, 2017; Irish, 2005), but a close affinity with an earlier Kerma sample was also evident (Irish, 2005). Cultural similarities between pre-Kerma and Lower Nubian A-Group cultures have been observed (Honegger, 2019), potentially indicating some common ancestry. Additionally, dental data revealed a close biological affinity between A-Group and Kerma samples (Irish, 2005), which is also suggestive that the origins of the two could be related. Similarities in material culture and behaviour between Kerma and C-Groups have been noted in the earlier phases of these cultures (Edwards, 2004). Close affinities between the two groups in this study add support to a shared Kerma and C-Group origin.

The Kerma Ancien sample H29 is the most distinct of the Kerma samples and is an outlier in Figures 6.2-6.6. This distinction could indicate that during the earliest phase of the Kerma period there was a higher level of inter-group phenetic variation in Upper Nubia and that these differences decreased as groups interacted. More variation in funerary practices has been observed in the Kerma Ancien period, with practices becoming more standardised in later phases (Paner, 2003). Kerma Classique (KMC) and H29 also differ significantly from each other. As the former sample originates from the city of Kerma, it may represent a more varied sample. The city was vast during the latter phases of the empire (Bonnet, 2021) and was potentially inhabited by people from other parts of Nubia. The Kerma Classique (KMC) sample shares similarities with those from throughout Nubia (Upper and Lower), perhaps providing evidence for variation or admixture. As time progressed, the Kerma culture broadened their area of control from the Dongola Reach to around 700km of the Nile valley (Honegger, 2019). This expansion would have brought different groups into the Kerma sphere and potentially influenced the genetic make-up of the kingdom and at large settlements like Kerma.

Nonmetric dental data reveal that the relationship between Kerma/C-Group samples and those from the New Kingdom/post New Kingdom is complex. The 4th Cataract Kerma (4CKM), H29 and C-Group (CGR) samples are dissimilar from those from the New Kingdom/post-New Kingdom. Egyptians occupied Nubia for over 500 years during the New Kingdom (Spencer, 2014). They built numerous towns along the Nile, mainly between the 2nd and 3rd Cataracts (Spencer, 2019). The New

Kingdom/post-New Kingdom samples originate from these towns, so it is likely they contain some Egyptian individuals. Additionally, apart from Soleb (SOL), there is a high level of inter-sample affinity between New Kingdom/post-New Kingdom groups. Previous research on New Kingdom samples also revealed high levels of inter-sample relatedness (Phillips et al., 2022; Schrader et al., 2014). These results are suggestive of Egyptian immigration. The addition of Egyptians in the New Kingdom samples may have caused the dissimilarities with the Kerma/C-Group. Additionally, if Egyptians were present, this may have increased inter-sample affinities as the make-up of the samples would have been more similar.

Conversely, P37, Kerma Classique (KMC), and Hierakonpolis C-Group (HKC) share similarities with the New Kingdom/post-New Kingdom groups. Hierakonpolis C-Group has been shown in previous research to be similar to Egyptian and Nubian samples, suggesting admixture (Irish and Friedman, 2010; Schrader et al., 2014). There is no evidence of substantial Egyptian migration at Kerma or settlements associated with P37 (Welsby, 2001), although non-locals have been identified in Nubia during the Kerma period (Schrader et al., 2014). Intercultural marriages were only thought to have occurred between Nubian and Egyptian elites; it unclear to what extent members of the lower classes interacted (Morkot, 2001). Regardless, lower status Nubians are supposed to have lived, worked, and been buried in Egyptian temple towns during the New Kingdom (Spencer, 2019). Isotopic and bioarchaeological evidence from Tombos has also sugested the presence of Egyptians, Nubians, and those of mixed heritage (Buzon, 2007). As such, if the Nubian inhabitants of these towns originated in the Dongola Reach or surrounding areas, this may have created the close biological affinities observed with the New Kingdom/post-New Kingdom groups.

There is no evidence of Egyptian occupation in Nubia past the 3rd Cataract (Morkot, 2001). As such, Egyptian influence in the more southern reaches of Upper Nubia has been debated (Buzon et al., 2007; Morkot, 2001; Welsby, 2004). Scholars have suggested that these areas were still controlled by local Nubian elites (Morkot, 2001). As the 4th Cataract region was potentially not under Egyptian control, there may have been little interaction between the inhabitants and those from Egyptian temple towns. Consequently, life and populations in the 4th Cataract region may not have substantially changed. Although H29 is also located in the Dongola Reach, it is the oldest Kerma collection dating to the Kerma Ancien period (c. 2500-2050 BCE) (Welsby, 2001). Greater temporal distance from the New Kingdom/post-New Kingdom groups could have caused the significant difference in MMD data.

In Upper Nubia, 3-Q-33 shares close affinities with all New Kingdom/post-New Kingdom samples. Two additional Meroitic samples, Kawa (KAW) and Gabati Meroitic (GABMER), produced significant differences with these samples in both the 36- and 21-trait MMD analysis, although some similarities were noted. This separation is visible in Figures 6.2, 6.3, and 6.4 where Kawa and Gabati Meroitic are placed close together, whereas 3-Q-33 is placed on the opposite side of the graph close to the New Kingdom/post-New Kingdom samples. Kawa (KAW) and Gabati Meroitic (GABMER) are positioned on the graphs close to older samples (Kerma and Neolithic) or more southernly located samples (e.g., Soba (SBA)). The relationship between 3-Q-33 and the samples from the previous period suggest biological continuity in some cases but this was not wholesale throughout Upper Nubia. Kawa and Gabati Meroitic share close affinities to Kerma and C- Group samples suggesting that continuity with groups present before the Egyptian occupation. When Nubia as a whole is considered, the Lower Nubian Meroitic sample (MER) produces similar results to Kawa and Gabati Meroitic. Sample 3-Q-33 continues to differ significantly from the other Meroitic samples when the other Nubian samples are considered. Figures 6.5, 6.6 and 6.7 again show 3-Q-33 separated from the other Meroitic samples, more closely associated with Lower Nubian samples and those from the New Kingdom/post-New Kingdom period.

When the capital of the Nubian empire moved to Meroe, the focus of the culture moved south (Welsby, 2005). The expansion of the land controlled by the Meroitic empire increased and as such encompassed many new groups (Edwards, 1998). The close affinities between the three Meroitic samples (KAW, GABMER, and MER) and older Upper Nubian samples and those from the south (i.e., 6th Cataract region) suggest that genetic influence came from within Nubia during this period. This mirrors the cultural changes that occurred in the Meroitic period (Welsby, 2005). Whereas the Napatan was seen as a mix of both Nubian and Egyptian customs (Török, 2015), the Meroitic saw more traditionally Nubian practices reappear (Helmbold-Doyé, 2019). Meroitic kings were not mummified, as their Napatan forebearers had been, and were instead buried in coffins on beds (Helmbold-Doyé, 2019). The flexed body position was also reintroduced into burial practices (Helmbold-Doyé, 2019). Additionally, the biological similarities between Meroitic and Kerma/C-Group samples add support to the theory that some groups were not affected by the Egyptian invasion, especially those outside the heavily controlled region (i.e. 1st-3rd Cataract) (Morkot, 2001). The close affinities between Meroitic samples indicate a certain level of biological homogeny throughout Nubia in both rural and urban settings. Inter-sample similarities could suggest the movement of people throughout Nubia during the Meroitic, potentially encouraged by the imperial infrastructure.

The distinction of 3-Q-33 indicates that there could be something different happening in the 4th Cataract region. As discussed above the 4th Cataract Kerma sample (4CKM) is significantly different from all New Kingdom/post-New Kingdom collections, whereas 3-Q-33 is similar to these collections. The city of Napata was based near the 4th Cataract (Adams, 1984) and the shift of focus to this area during this period may have been coupled with the movement of people into the area. If migration into the 4th Cataract did occur, the change in genetic influence does not seem substantial as the 4th Cataract Kerma and 3-Q-33 samples share a close affinity (indicating a level of biological continuity). Data from 3-Q-33 suggest that although the Meroitic empire may have provided a level of cultural and biological homogeny, regional variation was still apparent. Previous archaeological and biological research has also highlighted differences between regions in the Meroitic, confirming that homogeny of the empire was not wholesale (Irish, 2005; Phillips et al., 2022).

The Upper Nubian post-Meroitic samples produced very different results compared to the Meroitic. Gabati post-Meroitic (GABPM) is distinct from all Meroitic samples, including Gabati Meroitic (GABMER) in the 21-trait MMD analysis. Gabati post-Meroitic is an outlier in Figures 6.2-6.4, also differing significantly from 4th Cataract post-Meroitic sample. A previous biodistance study, based on craniometrics, also found significant differences between the Gabati samples (Vollner, 2016). Another study by Streetman (2018) using cranial non-metric traits found the Gabati post-Meroitic assemblage to be homogenous, potentially representing a familial group. If this was the case, then the smaller gene pool represented by a family may be causing the phenetic distinction observed in this research. The 4th Cataract post-Meroitic (4CPM) sample is similar to 3-Q-33 and Gabati Meroitic but differs significantly from Kawa (KAW). The results are suggestive of a stable population in the region, as attested by continuity from the Meroitic period. The results could also point to some admixture with southern Nubian groups. In Figures 6.2 and 6.4, the 4th Cataract post-Meroitic is positioned closely to both 3-Q-33 and the Kerma period and 6th Cataract region samples. During the post-Meroitic the Noba emerge as a prominent group in Nubia (Phillipson, 2012). Although their origins are unknown, some believe they were already present in the south of Nubia during the Meroitic period (Welsby, 2002). Admixture with groups from the south, like the Noba, may have resulted in the close affinities observed in PM4C.

The Lower Nubian post-Meroitic sample shows similar patterning. The X-Group (XGR) sample is similar to the Lower Nubian Meroitic collection (MER), as well as the Upper Nubian Meroitic groups (KAW, 3Q33, and GABMER). These data suggest that there was also biological continuity in both Upper and Lower Nubia between the Meroitic to the post-Meroitic. Previous research has also reported biological continuity between Meroitic and X-Group samples from Lower Nubia (Carlson and Van Gerven, 1977; Carlson and Van Gerven, 1979; Godde and Jantz, 2017; Smith and Shegev, 1988). Cultural continuity is also evident between the two time periods in Lower Nubia (Trigger, 1969), whereas in Upper Nubia no cultural connections to the old Meroitic empire are evident (Edwards, 2019). Cemeteries containing both Meroitic, post-Meroitic, and transitional graves have been found, suggesting continuity between the two eras (El-Tayeb and Kolosowska, 2007). This relationship is mirrored in Figures 4, 5, and 6 where the X-Group (XGR) and 4th Cataract post-Meroitic (4CPM) are proximate. These similarities are reflected in cultural practice where general homogeny is evident throughout Nubia (Edwards, 2019). Similar burial customs, farming practices, and material culture have been observed in both Upper and Lower Nubia (Edwards, 1998; Edwards, 2019; Shinnie, 1996). Fuller (2014) suggests that the introduction of the saqia (waterwheel) during the post-Meroitic period increased the need for labour due to farming. As such this may have caused a mixing of groups as labourers moved throughout the region based on which crops needed to be harvested. An increase in movement of people could have caused groups to mix both biologically and culturally producing high levels of homogeneity.

Soba shares close affinities with the post-Meroitic samples and other medieval samples from Upper Nubia. The MMD results (Tables 6.7 and 6.9) reveal that Soba is similar to most Upper Nubian samples. This is reflected in Figures 6.2, 6.3 and 6.4, where Soba is positioned in the middle of the graph surrounded by the other Upper Nubian samples. Soba was a large urban settlement with potentially a multicultural population (Welsby, 1998). Variations observed in burial custom between the three different cemeteries comprising the Soba sample suggest the presence of diverse peoples (see section 5.3.9) (Welsby, 1998). Such a population could have created the similarities observed in these dental data. The 4th Cataract medieval samples (3-J-18 and 3-J-23) share a close affinity with the post-Meroitic sample from the same area, as well as Soba. Both 3-J-18 and 3-J-23 are distinct from the Dongola Reach samples but share affinities with collections from the 4th and 6th Cataract regions. These results suggest a genetic link between southern Nubia and the 4th Cataract region. Similarities between Soba, located in Alodia, and the 4th Cataract medieval cemeteries in Makuria, may indicate the movement of people between kingdoms. Commonalities in material culture also indicate strong trade links between regions (Welsby, 2002).

The results from Lower Nubia (Tables 6.11 and 6.14) reveal that the X-Group (XGR) and Christian (CHR) are significantly different from the Upper Nubian Medieval samples. The Christian sample is also significantly different from post-Meroitic 4th Cataract (4CPM). The two Lower Nubian samples (CHR and XGR) share a close affinity to each other. The results suggest that Lower Nubia is biologically distinct from Upper Nubia during the Medieval period. Although there were cultural similarities between the medieval kingdoms of Nubia (i.e., language, religion), Nobadia (in Lower Nubia) is often viewed as distinct from the other kingdoms. Different ceramics and religious architecture have been identified compared to the two more southerly kingdoms (Welsby, 2002). Historical records also reveal that the relationship between Nobadia and Makuria was hostile (Adams, 1964), which could have limited the movement of people between states.

Significant differences were found between samples from consecutive periods, but this was not always the case; therefore, the null hypothesis cannot be rejected. The significant differences between samples from different periods suggest gene flow from migration through time changed the biological make-up of groups. Although these changes were observed they were not consistent throughout Nubia, with temporal continuity also apparent. These data suggest that biological affinities are not always mirrored in observed cultural behaviour. As such, the movement of people and transfer of cultural ideas in Nubia is complex and not uniform throughout time or region. In the following sections, data from outside Nubia will be used to further elucidate the geographical and temporal patterning described above.

7.4 What influence did sub-Saharan gene flow have in Nubia? Is there evidence of human migration from sub-Saharan Africa to Nubia?

Data from sub-Saharan collections adjacent to Nubia were compared to identify what genetic influence these groups may have had. This will be further contextualised by adding data pooled by region from throughout the subcontinent. The influence that geography has on similarities between sub-Saharan African and Nubian groups will be discussed. As mentioned, geographical proximity of groups should confer biological affinities. As such, Upper Nubians should be phenetically closer to sub-Saharan Africans than Lower Nubians. The following null and alternative hypotheses will be used Ho: there is no difference and Ha: sub-Saharan groups are different from Upper Nubians and/or Ha: sub-Saharan groups are different from Lower Nubian samples.

In Upper Nubia similar levels of biological affinity to sub-Saharan Africans are evident in the 4th Cataract, Dongola Reach, and 6th Cataract regions (see Tables 6.17, 6.19, 6.21, and 6.23). A cline from south to north is discernible, with the 6th

Cataract samples showing the closest affinity to the sub-Saharan groups, with the Dongola Reach least similar. Figure 6.10 illustrates this relationship. A similar cline has been observed in genetic data where more southern Nile valley groups had a higher frequency of sub-Saharan genes than those in the north (Krings et al., 1999). Chad and Ethiopia share the closest affinity to Upper Nubian samples and are geographically closer. Trade and political interactions between Ethiopia and Nubia have been detailed (Hatke, 2013). Previous research using dental nonmetric traits confirmed affinities between Ethiopia and Nubian groups with temporal patterning evident (Phillips et al., 2021). Cultural and genetic links from the west have not been fully investigated, but some research reported affinities between Late Palaeolithic Nubians and West Africans (Irish and Turner, 1990).

The MMD data (Tables 6.17, 6.19, 6.21, and 6.23) reveal that Lower Nubians share a closer affinity to sub-Saharan groups on average than do Upper Nubians. The earlier Lower Nubian samples, especially C-Group, are mainly responsible. These data reveal that both C-Group samples share close affinities to all sub-Saharan groups (i.e., Ethiopia, Somalia, Tanzania, Chad, and Kenya). Figures 6.8-6.13 reveal that the C-Group samples may have a stronger relationship with the samples from the east (Somali, Ethiopia, and sub-Saharan East), over other areas of the subcontinent. Gebel Ramlah shares some similarities with sub-Saharan African groups but is still significantly different from the C-Group. These affinities suggest that both cultures have something of a relationship with sub-Saharan Africans, though with potentially different origins.

Some geographic patterning is visible in Upper Nubia, where the more southern regions have a slightly closer affinity to sub-Saharan groups. When Nubia is considered as a whole, the relationship between geographical and biological distance is disrupted as Lower Nubian samples are more akin to sub-Saharan Africans but located further away. The geographic patterning for Lower Nubia was likely influenced by the strong affinities observed in earlier samples (Neolithic and C-Group). As such, the null hypothesis can be rejected. These results support both the alternative hypotheses that there are differences between Lower and Upper Nubians and sub-Saharan African groups. The MMD data reveal that gene flow from sub-Saharan Africa has considerably influenced groups from throughout Nubia. This genetic influence has been observed in DNA studies where sub-Saharan African haplotypes have been identified in individuals from both Upper and Lower Nubia (Breidenstein, 2019). The dental data suggest that this influence is clinal rather than via the mass movement of people into Nubia from the south.

To investigate if biological affinities to sub-Saharan African groups change over time, the Nubian samples will be considered by cultural period. The null and alternative hypotheses detailed in section 4.4 (Ho: there is no difference and Ha: there are significant differences between sub-Saharan African and Nubian samples, when separated by period, will be used to quantify the findings.

The Neolithic samples generally share a close affinity to the sub-Saharan samples, although some of the MMD values are significantly different. Similarities between the Neolithic samples and the sub-Saharan groups are varied. R12 is only closely related to Chad (see Tables 6.17 and 6.19) and is unrelated to the regional sub-

Saharan samples. In comparison the two samples from the 6th Cataract region (Al Khiday (AKN) and Ghaba (GHB)) share similarities with most sub-Saharan groups, although their relationship with the other Nubian samples still distinguishes them from each other. In Figures 6.8-6.13, both Al Khiday and Ghaba are positioned close to the sub-Saharan African samples but away from each other. Al Khiday has the closest affinities to all the sub-Saharan East African groups (see Tables 6.17, 6.19, 6.21, and 6.23) and is no longer positioned as an outlier in the MDS/PCA representations (Figures 6.8-6.13). Gebel Ramlah share similarities with several of the sub-Saharan groups, and with Ethiopia in particular. These data reveal that there was not one area of sub-Saharan Africa from which the Neolithic groups in Nubia originated. A variety of genetic influences from sub-Saharan Africa has also been noted in Nubian Palaeolithic groups (Irish and Usai, 2021). If there was biological continuity in the region, the variation observed in the Neolithic may have been passed on from Palaeolithic groups. Up until 5300 B.C.E. Nubia and the surrounding areas supported savannah-like environments (Kuper and Kröpelin, 2006). As such, there were no geographical barriers (i.e., deserts) impeding the movement of humans from other regions of Africa into Nubia. Hence, it is possible that the biological variation observed in the Neolithic may have been relatively recent. The Neolithic cultural package is believed to have been dispersed into Nubia from the Near East via Egypt (Bar-Yosef, 1998). Some researchers believe that the diffusion of this cultural package was accomplished through trade and inter-group marriage rather than replacement (Bar-Yosef, 1998). As the Neolithic samples share strong affinities to sub-Saharan groups, replacement from the Near East seems unlikely.

The Kerma/C-Group samples also show a high level of relatedness with the sub-Saharan Africans, with patterning similar to the Neolithic. When compared to the East Africans, most Upper Nubian Kerma samples (H29, P37, and 4CKM) share close affinities with Ethiopia and Chad. Kerma Classique (KMC) has more wide-ranging affinities to sub-Saharan Africans, similar to the Lower Nubian C-Group samples (HKC and CGR). When compared regionally (Tables 15 and 17) several of Kerma period samples (4th Cataract Kerma, H29, and Hierakonpolis C-Group) reveal similarities with the sub-Saharan West and sub-Saharan Central samples. These data reveal that, like the Neolithic, there seems to be influence from various regions of sub-Saharan Africa during this period. Cultural links have been made between sub-Saharan Africa and Kerma culture, with similarities in ceramics noted (Edwards, 2004). As discussed above, there is a level of biological continuity between the Neolithic and Kerma periods in Upper Nubia, with the former groups likely progenitors of the latter. As such, the relationship of Kerma with sub-Saharan samples could be due to the genetic make-up of preceding Neolithic peoples rather than new groups moving into the area. As with the Upper Nubians, the C-Group may be related to Neolithic cultures within Nubia, just not Gebel Ramlah. Strong links with sub-Saharan Africa and biological continuity observed in both the Kerma and C-Group samples indicate that the Nubian Bronze Age cultures derive from within Nubia, rather than outside sources as previously suggested (e.g., Reisner, 1910).

The Upper Nubian New Kingdom/post-New Kingdom samples are mostly distinct from the sub-Saharan groups (see Tables 6.17 and 6.19). Post-New Kingdom samples (Tombos (TOM) and Amara West (PNK)) display a close affinity with Chad

(CHA) and Soleb (SOL) shares some similarities with Ethiopia. Close affinities with Chad and Ethiopia are a continuation of patterning observed in the Kerma period, although in Figures 6.8-6.10, the New Kingdom/post-New Kingdom samples are positioned further away from the sub-Saharan African cluster. The Lower Nubian Pharaonic (PHA) sample also shares similar affinities to the preceding C-Group samples, having an affinity with most of the sub-Saharan East Africans, though to a lesser extent (Figs. 6.8-6.10). When compared to the regional sub-Saharan samples none of the New Kingdom/post-New Kingdom groups show similarities. These data suggest that the sub-Saharan genetic influence was localised in East Africa, but it is also generally less influential in the New Kingdom/post-New Kingdom than previously. The presence of Egyptians in Nubia has been noted in the New Kingdom (Buzon et al., 2007) and this new genetic influence may have changed the relationship with sub-Saharan Africans.

The Meroitic samples, bar 3-Q-33 from the 4th Cataract, reveal low levels of affinity with sub-Saharan groups, continuing a pattern established in the New Kingdom/post-New Kingdom samples. In the MMD analysis, three Meroitic samples (Kawa (KAW), Gabati Meroitic (GABMER), and Meroitic (MER)) are significantly different from the sub-Saharan groups and are also positioned away from the latter cluster in Figures 7-12. The three Meroitic samples are also placed closely together in Figures 7, 9 and 12, providing further indications of biological homogeneity in this period. The 4th Cataract Meroitic sample (3-Q-33) behaves differently with the East African groups, sharing close affinities with most samples (see Table 6.14). As discussed above (Section 7.3) there is a level of biological homogeneity observed in the Meroitic, potentially created by the movement of people between different areas of Nubia. As the 4th Cataract is not located on the main trading route, the region may not have been subjected to the same movement of people as the other regions. Conversely, 3-Q-33 has strong affinities with both sub-Saharan Africa and New Kingdom/post New Kingdom groups (see section 7.3), these affinities are similar to those held by the older Lower Nubian samples (C-Group, Hierakonpolis C-Group, and Pharaonic). The 3-Q-33 sample is also located close to the Lower Nubian samples in the MDS analysis. As such, the change in affinities could indicate Lower Nubian groups had moved into the area, although no cultural associations to suggest this have been observed. Similar to the New Kingdom/post-New Kingdom, none of the Meroitic samples bear a likeness to the regional sub-Saharan Africans (Tables 6.21 and 6.23). These data suggest influence from sub-Saharan groups was becoming more localised from eastern Africans in post-Kerma periods.

The post-Meroitic continues the patterning observed in the Meroitic period, with only 4th Cataract sample 4CPM revealing close affinities to the East African samples. No post-Meroitic samples share similarities with the wider regional sub-Saharan samples. Some scholars have proposed that the changes visible in the burial and cultural record between the Meroitic and post-Meroitic resulted from the arrival of new groups (i.e., Noba or Axumites) originating from the south (Edwards, 2019; Leclant, 1981). Figures 6.8, 6.9, and 6.10 reveal a close relationship between Meroitic and post-Meroitic samples from the different regions, indicating biological continuity at a regional level. These data suggest that the observed cultural shifts were not accompanied by substantial movement of people into Nubia from sub-Saharan Africa. Other researchers have suggested that the Noba were one of the many groups living under the Meroitic empire (Welsby, 2002). As such any migration would have been from within Nubia. Whether or not the new elite in post-Meroitic Nubia came from sub-Saharan Africa or Nubia, the underlying population appears to have remained stable after the fall of the Meroitic Empire. Ceramics associated with Eastern Desert cultures have been found in post-Meroitic burials around the 4th Cataract (Kołosowska, 2010). Cultural connections to these groups have been observed from the Kerma period onwards (Emberling et al., 2014). It is possible that associations with groups from the east could be responsible for the closer biological affinities between 4th Cataract region and East African assemblages.

Data from the Medieval samples suggests that sub-Saharan genetic influence from East Africa slightly increases during this period in both the 6th Cataract (Soba) and Lower Nubia (Christian) regions. In the 4th Cataract the pattern is reversed, and the two medieval samples (3-J-18 and 3-J-23) share less similarities with sub-Saharan groups than in the post-Meroitic. Nubia was heavily populated during the Medieval period (Adams, 1993) and this increase in population may have been driven by the movement of people into Nubia from the south. As previously discussed, agricultural innovations like the Saqia in the post-Meroitic period meant that more areas of the middle Nile valley were viable for crop production throughout the year (Fuller, 2014). This would have meant that some areas of Nubia were able to support larger populations than in previous periods. Increased population in Lower Nubia may have been coupled with the movement of people, potentially from the south. Soba was a multicultural metropolis, and this is reflected in the burial record (Welsby et al., 1998). The Soba collection used in this study contains individuals from multiple burial complexes, each with different funerary goods and some differences in burial style (Welsby et al., 1998). It is thought that these different complexes were for distinct groups living at Soba, some of whom may have been associated with groups from sub-Saharan Africa (Welsby et al., 1998). Genetic research has confirmed the presence of haplotypes linked to sub-Saharan groups in medieval Nubians (Breidenstein, 2019). The genetic influence from sub-Saharan Africa was also coupled with haplotypes linked to the Near East (Breidenstein, 2019). These dental data mirror the genetic research, where Medieval are related to sub-Saharan Africa groups, but this was not the only influence.

Although there are strong similarities between sub-Saharan African and Nubian groups, these do not apply for all samples and all time periods, and the null hypothesis cannot be rejected. Irish (2005) found that dental samples from both Upper and Lower Nubia fell into two distinct groups when analysed, one contained Neolithic-New Kingdom samples, the other Meroitic-Christian. Different patterning is evident with the samples from this study. Here, the older samples (Neolithic and Kerma) share a closer affinity with the sub-Saharan groups. Neolithic and Kerma groups reveal similarities with samples throughout sub-Saharan Africa. As time progresses the phenetic affinities become localised in East African groups. Additionally, temporal similarities between Nubian and sub-Saharan groups decreased. These data suggest that the sub-Saharan genetic influence is associated with Neolithic groups and remained in Nubian peoples via biological continuity, as there is no evidence of later migration. The decline in biological affinities could be due to the homogenising effects of interactions among Nubians throughout history. Genetic research has revealed that Nubians have haplotypes that are related to both sub-Saharan populations and those from Eurasia (Breidenstein, 2019; Cherifi and Amrani, 2020). If there was no movement of people from the south post-Neolithic in Nubia, the Eurasian admixture may have diminished the phenetic relationship with sub-Saharan groups. These data suggest that there is evidence of the movement of people, but that potentially was from within Nubia.

7.5 What was the genetic relationship between Nubia and Egypt and Eurasia? Is admixture due to invasion or long-term biological diffusion?

The relationship between Nubia and Egypt has been well documented (mainly from Egyptian sources) and much studied (Edwards, 2004). The focus of research has often been on major events (invasions (Buzon, 2008), religious conversions (Adams, 1993)), but as neighbours, the two cultures interacted throughout their history (Spencer, 2014). Additionally, evidence of cultural and genetic influence from Eurasia has been noted in Nubia (Abdu and Gordon, 2004; Breidenstein, 2019; Cherifi and Amrani, 2020; Sirak et al., 2021). To investigate the relationship between Nubia and Egypt/Eurasia further geographical and temporal patterning will be explored. Firstly, the effect of geographical proximity to Egypt and Eurasia was tested. As geographical distance between Egypt and Upper Nubia is greater, it is assumed that biological distance will also be greater when compared to Lower Nubians. The null and alternative hypotheses are detailed in section 4.5 (i.e., Ho: there is no difference, and Ha: Egyptian (and Eurasian) groups are different from Lower Nubians and/or Ha: Egyptian (and Eurasian) groups are different than Upper Nubians).

The data from Tables 6.17 and 6.19 reveal that the Lower Nubian samples have a closer affinity to the Egyptian and Lachish assemblages than the Upper Nubians.

This is true when all Upper Nubian samples are considered and when Upper Nubia is divided into regions (4th Cataract, Dongola Reach, and 6th Cataract). This relationship is illustrated in Figures 6.8, 6.9 and 6.10 where the Lower Nubian samples are located just below the Egyptian cluster, which contains Lachish, with most the Upper Nubian samples positioned below. Lower Nubia is geographically closer to Egypt, as such the dental data follow the isolation by distance model (details in Chapter 4.2). Additionally, Upper Egypt shares a higher level of affinity with Nubian samples than does Lower Egypt. These data suggest there is a cline from north to south of biological affinity in the Nile valley. This relationship mirrors DNA results which revealed that northern haplotypes were more prevalent in the north and decreased going south along the Nile valley (Krings et al., 1999).

The historical links between Egypt and Lower Nubia are strong, with Egypt controlling the latter region during the Middle and New Kingdoms (Morkot, 2001). Additionally, Lower Nubian groups (C-Group and Pan Grave) were thought to have been part of the Egyptian army and lived in Egypt (Friedman, 2007). The C-Group cemetery at Hierakonpolis showed evidence of admixture between Nubians and Egyptians both culturally and biologically (Irish and Friedman, 2010). In this study the Hierakonpolis C-Group sample is the most similar to Egyptians, agreeing with previous admixture results (Irish and Friedman, 2010). Therefore, the occupation of Lower Nubia may also have resulted in the two cultures mixing, creating strong biological affinities. Egyptian associations are also apparent in the Lower Nubian archaeological record, with Egyptian influence in the burial record and material culture (Johnson and Lovell, 1995). The MMD results for the Pharaonic sample (PHA) reveal a very close affinity to Egyptians which could also suggest admixture.

Conversely, the high level of relatedness in the Pharaonic sample may have arisen from Egyptians being buried in Lower Nubia and forming part of the skeletal collection. It is thought that Egyptians not only lived in colonial Nubian towns but were also buried in the associated cemeteries (Spencer et al., 2017). At Tombos, another New Kingdom site, bioarchaeological methods identified the presence of non-locals, locals, and potentially those of mixed heritage (Buzon, 2006).

The Upper Nubian samples are generally distinct from the Egyptians and Lachish. When divided into regions, the Dongola Reach samples share the closest affinity to the Egyptians and Lachish. Geographically the Dongola Reach is most proximate to Egypt and would have bordered Egyptian controlled Lower Nubia in the Middle Kingdom (Spencer, 2019). Evidence for non-locals, originating in the north, has been found in collections from the Dongola Reach (Buzon and Simonetti, 2013; Buzon et al., 2007; Schrader et al., 2019). These collections date from the Kerma to Napatan periods and suggest ongoing movement between Upper Nubia and Egypt. Trade along the Nile between these regions is well documented (Bonnet, 2021), and this long-standing relationship could have been facilitated by migration between regions. Additionally, the Dongola Reach is the only Upper Nubian region to contain samples dating to the New Kingdom, which is associated with higher levels of Egyptian migration (Buzon, 2006).

The 6th and 4th Cataract samples are less similar to the Egyptians, with the 4th Cataract most dissimilar. These regions are geographically farther from Egypt and may not have been subject to the mixing of people that may have occurred in the Dongola Reach. There is no evidence of Egyptian New Kingdom settlements past the 3rd Cataract (Morkot, 2000). Thus, the more southern areas may not have been influenced by Egyptian migration during the New Kingdom. As discussed, the 4th Cataract was potentially not on the main trade routes, being bypassed by desert roads (Auenmüller, 2019). As such interactions from traders would not have influenced the groups in this region. The majority of the 6th Cataract collections are dated to the Meroitic period or after (see Table 5.1). It is thought that by this time trade links with Egypt had become less important for Nubia, with access to Indian Ocean via the Red Sea the more important route (Haaland, 2014). The movement of people along the Nile from Egypt may not have been as regular as in earlier periods.

The MMD data from Tables 6.21 and 6.23 reveal a slightly different relationship between the Nubian samples and the south-eastern Mediterranean (SEM). Lower Nubia is most similar to the SEM sample when compared to Upper Nubia as a whole. When Upper Nubia is divided into regions the 6th Cataract group shares the closest affinity to SEM. The Near East has strong links to the Nile valley cultures (Bar-Yosef, 1998). The land bridge between Eurasia and Africa has been the entry point for the cultural revolution in the Neolithic (Bar-Yosef, 1998), as well as the route which Christianity was spread through the region (Crowfoot, 1927). Additionally, the area was part of the trade system which linked Africa to the Mediterranean (Haaland, 2014). The close affinity between the Egyptian samples and Eurasian samples (Lachish and the southeast Mediterranean) is clear in both the MMD distances (Tables 6.17, 6.19, 6.21, and 6.23) and MDS/PCA graphs (Figures 6.8-6.13). Haplotypes associated with Near East populations have been found in individuals from both Lower and Upper Nubia (Breidenstein, 2019; Cherifi and Amrani, 2020; Sirak et al., 2021). Sirak and colleagues (2021) found that the nuclear DNA linked to the Near East was probably introduced via Egypt. The close affinities between Egypt and some Nubian groups in this study may account for this. As the 6th Cataract samples do not have strong links to Egypt, the affinities with the southeastern Mediterranean may suggest another link to this region, perhaps via the Red Sea trading route (Haaland, 2014).

Differences between Nubian and Egyptian/Eurasian samples are evident from the MMD values that indicate the null hypothesis can be rejected. Upper Nubians are dissimilar to Egypt/Eurasia samples, providing support for the one of the alternative hypotheses. Geographic proximity of Egypt is mirrored with increased biological affinities in both Lower and Upper Nubian groups. Closer affinities were noted in the Lower Nubians, which is suggestive of historical interactions between the two cultures (Johnson and Lovell, 1995; Spencer, 2019). The Egyptian occupation of Nubia during the Middle and New Kingdoms (Spencer, 2019) seems to have affected the genetic relationship between cultures. Groups from Upper Nubia outside of the area controlled by Egypt (1st-3rd Cataracts (Morkot, 2001) are the most distinct from the Egyptian/Eurasians. This suggests that although there is clinal patterning in affinities with Northern groups from north to south, the movement of people during the Middle/New Kingdoms may also have affected Nubian populations.

The relationship between Nubia and Egypt/Eurasia has often changed throughout their long shared history. To further explore if biological affinities between groups varied between time periods, the null and alternative hypotheses in section 4.5 will be used (Ho: there is no difference and Ha: there are significant differences between Egyptian (and Eurasian) and Nubian samples (pooled by period)).

The Neolithic Nubian samples are generally distinct from Egyptian samples and Lachish (Table 6.19), although some similarities are evident in the 36-trait analysis (Table 6.17). On Figures 6.8-6.10, the Neolithic samples are located away from the Egyptian cluster, nearer to the sub-Saharan African samples. A similar pattern is evident when compared to southeast Mediterranean (SEM). One exception is Al Khiday which shares a close affinity to the latter sample. The Neolithic 'package' was disseminated throughout Nubia from the Near East via Egypt (Sadig, 2013). It is thought that the cultural diffusion was facilitated by trade and intergroup marriage (Bar-Yosef, 1998). Some researchers believe that due to the speed in which the new culture spread through the Nile valley, there was an element of population replacement (Salvatori and Usai, 2016). Dental data suggest that Egypt and Eurasian genetic influence was low during the Neolithic in Nubia, indicating that cultural exchange was not coupled with substantial biological exchange. If there was population replacement, these data suggest it was probably from groups originating within Africa, as they have closer affiliations to sub-Saharan Africans. The close affinity of Al Khiday and the southeast Mediterranean group could suggest some movement of people into Nubia from outside Africa in the Neolithic. Archaeological evidence from Al Khiday shows no links to Eurasia (Salvatori and Usai, 2019) and the sample shares closer affinities with sub-Sharan Africans, migration of northern groups seems unlikely.

The Kerma samples reveal a complex relationship with those from Egypt and Eurasia. The 4th Cataract Kerma (4CKM) and H29 are distinct from Egyptian/Eurasian samples, whereas P37 and Kerma Classique (KMC) share similarities to some. The 4th Cataract collections are generally distinct from the Egyptian/Eurasians, potentially due to the relative inaccessibility of the region. The dissimilarities between H29 and the Egyptians may suggest that during the Kerma Ancien period there was little interaction between cultures. Similarities in iconography have been observed between Kerma Ancien and predynastic Egypt (Honegger, 2019), but they are not mirrored in the biodistance data. As the Kerma kingdom expanded and grew in power during the Moyen and Classique periods, interactions between the two may have increased. This is suggested by the closer dental affinities between P37 and Kerma Classique and the Egyptians. Trade between regions has been documented (Raue, 2019). The movement of goods may have facilitated the movement of people from the north. Isotopic data has also identified non-locals from the north (Schrader et al., 2019). During the Kerma Classique period, Lower Nubia was under the control of the Kerma culture (Johnson and Lovell, 1995). Kerma Classique (KMC) and P37 revealed similarities with the C-Group (see sections 7.3 and Table 6.11). Potentially the affinity of Kerma samples to Egyptian groups may be due to interactions with Lower Nubians, which have been shown to share close affinities with Egyptian samples (Irish and Friedman, 2010). Although there may have been some biological influence from Egypt/Eurasia, the Kerma samples share closer affinities to the sub-Saharan Africans.

Both C-Group samples are closely related to the Egyptian/Eurasians. In Figures 6.8-6.12 the C-Group samples are positioned between Egyptian and sub-Saharan clusters, indicating an association to both. The Hierakonpolis C-Group sample from Upper Nubia consists of individuals buried in C-Group style graves (Irish and Friedman, 2010). Previous research using these data revealed close affinities with both Egyptian and Nubian samples (Irish and Friedman, 2010), mirroring the results from this study. Similar to Kerma samples, the C-Group (CGR) is more closely related to sub-Saharan Africans than Egyptian/Eurasians.

The New Kingdom is closely linked with the movement of people from Egypt into Nubia, when an area from the 1st-3rd Cataracts was controlled directly by Egyptians (Spencer, 2019). Egypt's claim to have ruled up to the 5th Cataract (Welsby, 2004). Morkot (2001) suggests that, past the 3rd Cataract, their control was achieved using local Nubian elites who paid homage to their occupiers. There is no evidence of Egyptian settlement farther south (Morkot, 2001). The New Kingdom samples (Soleb, Amara West New Kingdom, and Pharaonic) share a close affinity to Egyptian/Eurasian samples, bar Soleb (SOL). Although, when viewing the PCA results (Figures 6.9 and 6.12), Soleb is located with the Egyptian samples. Archaeological, biodistance and isotopic research revealed evidence of Egyptian individuals in Nubia during this period (Buzon, 2006; Buzon and Simonetti, 2013; Buzon et al., 2007; Schrader et al., 2019). This evidence is sourced from Egyptian established settlements. Egyptian material culture and burial rites dominated temple towns, with many scholars believing they were highly influenced by Egyptian goods and beliefs, sometimes referred to as Egyptianisation (e.g., Trigger, 1976; Smith, 1998; Morris, 2005). This has led to difficulties in identifying Nubians in associated cemeteries (Buzon, 2006). The New Kingdom samples from this study show strong affinities to both Egyptians and Nubians, suggesting that individuals of both heritage groups were present in these cemeteries. The results could also be suggestive of admixture. The level of biological interactions between cultures has also been debated (Morkot, 2001; Van Pelt, 2013). While it is documented that the Nubian elite would have assimilated into Egyptian culture via marriage, the link with lower status groups is unclear (Van Pelt, 2013). Research from New Kingdom Tombos revealed evidence of Egyptians, Nubians, and mixed heritage (Buzon, 2006), which could be indicative of other temple towns.

Post-New Kingdom Nubian groups were comprised of remnants of the New Kingdom populations (Egyptians, Nubians, and mixed heritage) (Buzon et al., 2016). During the post-New Kingdom, migration from Egypt may have stopped (Buzon, 2014; Buzon et al., 2016). Additionally, customs associated with indigenous Nubians are found in the burial rite (e.g. use of funerary beds, flexed body position, and tumuli) (Binder, 2011). Researchers have suggested this was due to the return of Nubian people from the unoccupied regions (Smith, 1995). Tombos (TOM) is related to both Egyptians and Nubians, but more closely to the latter. The opposite is true for Amara West post-New Kingdom, which again shares an affinity to both cultures but is more similar to Egyptians. Similarities to both cultural groups suggest that post-New Kingdom populations contained Nubian, Egyptian, and potentially those of mixed heritage. It has been questioned whether all Egyptians left Nubia after their official withdrawal (Buzon et al., 2016). As genetic influence from Egypt is still strong in the post-New Kingdom, this suggests populations were not fully replaced by Nubians and that those of Egyptian heritage remained after the occupation ended.

The Meroitic samples (3-Q-33, Kawa, Gabati Meroitic, and Meroitic) are mainly distinct from the Egyptian/Eurasians groups, although some affinities are apparent (see Tables 6.17, 6.19, 6.21, 6.23). This is mirrored in the MDS figures (Figures 6.8-6.13) where the Meroitic samples are located away from the Egyptian cluster. As mentioned, during the Meroitic period the focus of the empire moved from Napata (close to 4th Cataract region) down to Meroe (between 5th and 6th Cataracts) (Török, 1997). The move was coupled with a shift in trading focus from Egypt and the Mediterranean to the Indian Ocean via the Red Sea (Haaland, 2014). If trade between Egypt and Nubia was less important, then potentially the two cultures interacted less. As discussed in section 7.4, the Meroitic samples (bar 3-Q-33) are also not closely related to the sub-Saharan Africans. The former mainly cluster with the Upper Nubians in the MDS graphs (Figures 6.8-6.13). This suggests that the main genetic influence for this period came from within Nubia, but potentially from the more southern reaches. During the Meroitic the empire expanded to include more of the Nile valley as well as its hinterlands (Wolf et al., 2019). Thus, more groups from Upper Nubia would have come under Meroitic control (Edwards, 1998). An increase in the Upper Nubian population may have influenced the change in biological make-up of the Meroitic study samples.

The Upper Nubian post-Meroitic (4th Cataract post-Meroitic (4CPM) and Gabati post-Meroitic (GABPM)) samples are distinct from the Egyptians/Eurasians, whereas the Lower Nubian X-Group shares some similarities with these samples. Like the Meroitic period, Egyptian/Eurasian gene flow does not seem to have had a major influence on post-Meroitic Nubians. Substantial changes in cultural behaviour have been observed between the Meroitic and post-Meroitic (Edwards, 2019). As above, these changes have been associated with the prominence of groups like the Noba (Phillipson, 2012). The post-Meroitic samples reveal a high level of continuity with the Meroitic, especially those from the same region. Regionality in biological affinities has been noted in other studies (Irish, 2005; Phillips et al., 2022). Biological continuity suggests that any cultural changes between periods was not associated with population movement into Nubia or internally between regions. The Meroitic empire is thought to have been a Sudanic state, based on a prestige-goods economy controlled by the elite class (Edwards, 1998). In such a set-up, the underlying population would have comprised of groups indigenous to different regions controlled by the empire (Haaland, 2014). As such, there may have been biological and cultural diversity (Edwards, 1998). When the Meroitic empire fell, the power vacuum may have allowed a new elite to come to the forefront, such as the Noba (Williams, 1991; Török, 1988). Replacement of the elite class may not have been associated with substantial changes to the local Nubian populations. A scenario like this could explain biological continuity evidenced between the Meroitic and post-Meroitic.

The Medieval period in Nubia is associated with the conversion to Christianity, which was introduced from the Near East via Egypt (Crowfoot, 1927). Researchers believe the transmission of the religion into Nubia was not coupled with immigration (Adams, 1993). The data from Upper Nubia appear to support this suggestion, with none of the Medieval samples (3-J-18, 3-J-23 or Soba (SBA)) sharing close affinities with Egyptian/Eurasian (see Tables 6.17 and 6.19). This is illustrated in Figures 6.8, 6.9, and 6.10 where Medieval Upper Nubians are located on the other side of the x-axis from the Egyptians. The Lower Nubian Medieval sample (CHR) is similar to all

Egyptian samples bar Qurneh (QUR) and Saqqara (SAQ) and has a close relationship with Lachish (LAC). These data may suggest an influx of people into Lower Nubia from the north.

During the Medieval period Nubia was split into three Kingdoms, with Nobadia located in Lower Nubia, and Makuria and Alodia in Upper Nubia (Welsby, 2002). Nobadia was the first Kingdom to convert to Christianity (Welsby, 2002). As Egypt and Nobadia shared the same religion and were geographically proximate this could have encouraged the exchange of people between regions. Sirak and colleagues (2021) also found evidence of Eurasian admixture Medieval Lower Nubians, which was thought to have either been ongoing or initiated in the Meroitic period (Sirak et al., 2021). Although the Lower Nubian Meroitic sample is distinct from the Egyptians/Eurasians, the post-Meroitic X-Group (XGR) which shares some similarities with these collections. As such, there may have been admixing of the two groups in the post-Meroitic rather than Meroitic period.

Dissimilarity of Upper Nubian samples and those in Egypt/Lachish began in the Meroitic and progressed through into the Medieval period. As discussed, in the Meroitic period it is thought that the focus of trade moved away from Egypt and Mediterranean to the Indian Ocean (Haaland, 2014). Additionally, Makuria had a hostile relationship with Egypt at different points in its history (Spaulding, 1995), potentially preventing the movement of people between regions during. Lower levels of interaction between cultures, continuing from the Meroitic onwards, could account for the biological dissimilarities between Upper Nubians and Egyptians observed here.

The dental data reveal that although Nubian samples are often distinct from Egyptian/Eurasian collections, some similarities are evident. Therefore, the null hypothesis of no differences cannot be rejected. It appears that the relationship between cultural exchange and biological affinities is complex. Periods associated with distinct changes in culture thought to have spread into Nubia via Egypt/Eurasia (i.e., Neolithic (Bar-Yosef, 2013), or Medieval (Adams, 1993)) are not accompanied with stronger affinities to northern groups. Conversely, in the Kerma period when the two regions are culturally distinct the dental evidence suggests there may have been some admixture between cultures.

The relationship between Egypt/Eurasia and Nubian groups shows both geographical and temporal patterning. As neighbours, Egypt and Nubia interacted for millennia through trade, cultural exchange, and biological mixing (Buzon et al., 2016). The close biological affinities in this study between cultures are highly related to geographical proximity, i.e., Upper Nubia has few similarities with northern cultures relative to a stronger relationship between Lower Nubians and Egyptians.

7.6 Summary

Discussion of the results in light of the hypotheses has revealed both geographical and temporal patterning of Nubian groups. Often, the inter-group biological affinities have been contrary to shifts in cultural behaviour and geographical proximity. The disparity in patterns of biological affinity and behavioural changes highlights the importance of using both bioarchaeological and cultural data. Using both types of data furthers our understanding of how biological affinities influence cultural evolution. Final conclusions based on the research questions posed in Chapter 1 are reported in the next chapter, along with further research proposals.

8. Conclusion

This project provided a unique opportunity to further our understanding of the people from the 4th Cataract, and how they are related to other Nubian and neighbouring groups over time. Due to the large scope of new dental data available, geographical and temporal patterning was also investigated throughout Nubia. Additional data from Eurasia and Africa put the Nubian data in a regional context, offering further insight into whether human migration in Africa affected Nubian populations. Dental and archaeological data were combined to understand cultural evolution in Nubia and whether this was driven by changes in populations, cultural diffusion, or both.

Several broad research questions were posed in Chapter 1 and these are now revisited. The main findings from this study address themes and patterns in Nubian populations throughout the region's rich history. The main findings discussed in the previous chapter are:

- Evidence for biological continuity was found in the 4th Cataract collections, indicating a stable population in the area for around 4000 years.
- Biological differences were observed between Upper and Lower Nubians, mirroring the cultural distinctions in the archaeological record.
- Data suggest there was admixture between Upper Nubians from different regions (i.e. 4th Cataract, Dongola Reach, 6th Cataract).
- Shifts in cultural practice between time period were not always associated with biological changes. Where changes were observed did not affect all Nubian groups.
- Regional patterning was evident in Lower Nubia and the 4th Cataract, where intra-regional affinities were stronger than inter-regional. The opposite was

true for the 6th Cataract and Dongola Reach with settlement type identified as a potential influence.

- Sub-Saharan African influence on Nubian groups appears to be clinal, with strong affinities with Neolithic groups then diminishing over time.
- Biological affinities with Egyptian/Eurasian seem to be related to colonial rule of Nubia during the New Kingdom, additionally geographical proximity may also have affected biodistances.
- The model-bound quantitative analyses (both geographical and temporal) could not explain the biological affinities observed in the Nubian data.

8.1 Was there population continuity in the 4th Cataract region between the Kerma – Medieval periods?

The 4th Cataract collection is unique as the cemetery sites originate from a 30km wide area (Emberling, 2012). Its geographically-focused nature means the collection is perfectly suited for exploring biological continuity as geographical distance is not a variable. Dental data revealed strong biological affinities among 4th Cataract samples, implying population continuity. Some changes were noted in the post-Meroitic into Medieval periods, which may indicate an influx of people. The Medieval samples (3-J-18 and 3-J-23) shared close affinities with other Upper Nubian groups, but differed from northern and southern cultures, suggesting that any new groups which moved into the area were indigenous to Upper Nubia. While some changes were noted in these later periods, there is no evidence for total replacement. The results suggest that any new groups did not displace the local population. There is evidence of increased levels of habitation in the Medieval period, which is mirrored in Nubia as a whole (Welsby, 2002). This change occurred during a time of political instability, as relations with Egypt became more hostile (Welsby, 2002). Additionally, agricultural innovations meant that more land in the region became viable for farming (Fuller, 2014). Whether change in population size was due to political instability or an increase in viable land is unclear. Potentially both issues could be responsible for the variation in phenetic affinities observed.

Although located on the banks of the Nile, the 4th Cataract region was hard to reach due to its distinctive ecology and geology (Ahmed, 2014). As such, it was not on the main trade route, with desert roads used as alternatives (Auenmüller, 2019). This relative isolation may have meant that migration levels were lower than elsewhere in the Nile valley. Cultural links to Eastern desert groups were noted in the collection, which is uncommon in other Upper Nubia regions (El-Tayeb and Kolosowska, 2007; Emberling et al., 2014). These interactions may have been associated with the movement of people from the east. If there were biological interactions as well, these data would suggest they were ongoing from the Kerma period onwards.

Although dental data suggest that migration to the 4th Cataract region would have been minimal, cultural diffusion was evident. Distinct periods have been observed in the archaeological record (Emberling, 2012). These shifts in cultural behaviour are comparable to those reported in other areas of Nubia, with similarities in material culture and burial practices (Edwards, 2004). These sociocultural changes indicate that there were avenues for new ideas to reach the indigenous population, potentially via trade or marriage. As populations did not substantially change, these results may be suggestive that a relatively small number of people conveyed knowledge and goods into the region.

8.2 Are biological changes in Nubian groups correlated with diachronic changes in social and cultural practices, via architecture, funerary rights, and other archaeological evidence?

The link between the movement of people and diffusion of cultural ideas is often complex. To understand whether migration was associated with sociocultural shifts, Nubian samples compared when pooled by time-period. These dental data revealed similarities between samples from different periods indicating overall biological continuity from the Neolithic to the Medieval. Evidence for similar stability from the Neolithic onwards has been observed in other studies (Galland et al., 2016;; Irish and Usai, 2021; Schrader et al., 2014; Stynder et al., 2009). Some differences between periods were noted, but these were not wholesale across samples. This suggests migration associated with cultural shifts may have occurred but did not affect all samples studied.

The samples used in this study not only originate from across Nubia but represent groups from different settlements (e.g., large city vs. small town). Results indicate that inter-group affinities may also have been affected by settlement type. Samples from larger towns (i.e., Kerma) showed more evidence for the movement of people compared those from smaller communities. If settlement type is a factor in biological affinities, irrespective of period or region, this may have contributed to the varied results observed in the data. Results from studies using Nubian samples from the same time period or region have sometimes reported contradicting results (Galland et al., 2016; Godde and Jantz, 2017; Irish, 2005). The findings from this study and the mixed results from previous research suggest that the relationship between socio-cultural change and migration in Nubia is complex.

If cultural diffusion was not instigated by migration, changes to behaviour may have been the result of other stimuli. Trade between different regions has been noted (Edwards, 2004), which would have provided opportunities to not only exchange goods but also ideas and beliefs. Inter-group marriages would also have helped spread cultural developments. Additionally, in some areas/periods, there may have only been changes to the elite class, leaving underlying population stable. As such, socio-cultural changes may have occurred without altering a substantial part of the population.

8.3 What is the relationship with other ancient Nubian populations? Is geographical patterning evident?

Regional patterning within Nubia had been suggested in previous research (Phillips et al., 2021). As such, the samples were divided in regions (4th Cataract, Dongola Reach, 6th Cataract, and Lower Nubia). The analysis revealed that the 4th Cataract and Lower Nubia had stronger intra-regional affinities, whereas the Dongola Reach and 6th Cataract had more similarities with samples from other regions. As discussed above, the 4th Cataract was relatively isolated and sparsely populated (Emberling, 2012). The opposite could be said of the Dongola Reach and 6th Cataract, which contain large settlements, including the capitals of the two

Kingdoms of Nubia studied in this work. Additionally, these regions were agriculturally rich, able to sustain large populations (Edwards, 2004), and had strong trade links with northern cultures and those from the Indian Ocean (Haaland, 2014; Raue, 2019). The movement of people within Upper Nubia may have been accepted as the inhabitants shared common socio-cultural beliefs.

The movement of people in the Dongola Reach and 6th Cataract, inferred from dental data, may have influenced cultural development and diffusion. In areas like the 4th Cataract, a small amount of people may have brought in new ideas and material cultures. The opposite may have been true in the Dongola Reach and 6th Cataract, with larger populations and stronger trade links potentially encouraging new groups into the region. As such, socio-cultural change may have been more dynamic and could be why they were the centres of new cultures (i.e., Kerma and Meroitic).

Lower Nubian results also showed high intra-regional affinities, revealing that the samples were often distinct from the Upper Nubians. Results do not support the movement of people between Upper and Lower Nubia. Cultural differences between Upper and Lower Nubia and have been noted in the archaeological record (Edwards, 2007), mirroring the biological distinction observed. Additionally, Egypt had a greater influence over Lower Nubia, controlling the area during the Middle and New Kingdom (Hafsaas, 2021). These political and cultural differences may have created a barrier to migration between the regions. Contrary to all other periods, the Meroitic dental data are consistent with general biological homogeneity throughout Nubia, with no distinction between Upper and Lower Nubians. This contrasts the archaeological record, where high levels of regional variation have been observed (Edwards, 1998). At the end of Meroitic period, the Napatan/Meroitic empire had controlled the whole of Nubia for over 1000 years. Potentially prolonged control of both regions by one culture could have diminished the barrier to migration.

8.4 Can model-bound quantitative analyses be used to further explain any evidence of migration in Nubia and Africa from the Neolithic period onwards?

Models looking at both isolation by time and distance were used to quantify dental data. The isolation by distance model predicts that as geographic distance increases between samples so does biological distance. These dental data did not display a strong correlation between geographic and biological distance. Some correlations when using river distances were statistically significant but remained weak. This indicates that geographical distance and biological distance do not have a strong relationship and significance could be due to the large dataset (Schober et al., 2018). Similarly weak correlations were obtained when the Isolation by time model was tested. In this model, as temporal distance increases, biological distance should also, decrease. No correlations produced were significant. These models have been used in previous Nile valley research with similar results (Godde, 2013; Zakrzewski, 2012).

Both models have assumptions that may not have been met by the samples used in this study. A steady rate of migration is assumed for both models (Konigsberg, 1990; Vecchyo and Slatkin, 2019), and this may not have been the case in Nubia.

The dental data suggests that there were potentially larger movements of people associated with different areas or periods. Geographical distances were calculated as either straight-line or river, which may not accurately represent the routes used between areas. Although the Nile was the main transport route, desert roads were often used (Auenmüller, 2019) and a hybrid calculation may have better reflected the distance between samples.

Although the isolation by time/distance models did not explain the relationship between Nubian groups, predicted temporal outcomes were observed at the regional level. The 4th and 6th Cataract results show that the earliest samples (Neolithic and Kerma) share closer affinities with samples from the Medieval period than those temporally closer. This patterning is not observed in Lower Nubia or the Dongola Reach, the two regions most closely associated with migration from Egypt. As such, non-Nubian gene flow may have upset the temporal patterning in these areas.

The model-bound analysis was unable to explain population affinities in Upper Nubia or Nubia as a whole. Much like the model-free investigation into geographical and temporal patterning, the results reveal that the movement of people in Nubia is complex. Although there may be scope to use these models in specific areas, the varied nature of Nubian populations in the past means that they are not appropriate when considering the whole region.

8.5 Are Nubians indigenous to the region? Do these data indicate immigration and replacement from the north and/or south? Alternatively, do the assemblages infer a greater mixture of genetic information?

Dental data reveal that the Nubian samples share some similarities with both North African and sub-Saharan groups. This mirrors genetic research on Nubian individuals, which shows the presence of both Eurasian and sub-Saharan haplotypes (Fox, 1997; Breidenstein, 2019; Cherifi and Amrani, 2020; Krings et al., 1999).

The relationship with sub-Saharan African groups was investigated from both a geographical and temporal perspective. Temporally, sub-Saharan Africa groups share the closest affinities to the Neolithic samples, from both Upper and Lower Nubia. Similarities with groups from throughout sub-Saharan Africa were observed. As time progressed, biological affinities between Nubians and sub-Saharan groups decreased and became localised in East Africa (i.e., Ethiopia, Eritrea). Geographical patterning was also evident within Upper Nubia, with the regions further south sharing a closer affinity to sub-Saharan collections. When Lower Nubian data were also considered, geographical patterning was not apparent due to the close affinities of both the Neolithic and C-Group samples to sub-Saharan groups. This suggests that while sub-Saharan gene flow is an important influence in Nubians, the relationship was clinal as there is no support for substantial migrations from the south into Nubia after the Neolithic.

Biological affinities between Nubians and Egyptian/Eurasian groups were strongly associated with geographical proximity, with Nubian collections closer to Egypt more closely related. Additionally, Upper Egyptians shared closer affinities to Nubians than Lower Egyptians. This cline of genetic influence from north to south was also noted in a DNA study (Krings et al., 1999). Migration due to the Egyptian conquest of Nubia may also affected biological affinities. Lower Nubia shares the closest affinity to the Egyptians, followed by the Dongola Reach. These regions were occupied by Egypt in the Middle and/or New Kingdom (Spencer, 2014). The presence of Egyptians in New Kingdom Nubian towns has been noted in bioarchaeological and isotopic studies (Buzon, 2006; Buzon and Bowen, 2010; Buzon and Simonetti, 2013; Buzon et al., 2007). Dental data from the Nubian New Kingdom samples support these findings, sharing the closest affinities with the Egyptian collections. In subsequent periods, only Lower Nubians share a close relationship with northern groups. DNA research from Lower Nubia highlighted the presence of Eurasian admixture, potentially beginning in the Meroitic period (Sirak et al., 2021). Although dental data do not support admixture with northern groups in the Meroitic period, similarities between Lower Nubian post-Meroitic and Medieval samples and Egyptian collections suggest that admixture may have occurred in these later periods.

Results suggest that both sub-Saharan African and Eurasian/Egyptian groups are important genetic influences on Nubians. DNA analysis also identified haplotypes associated with groups from both regions in Nubian individuals (Fox, 1997; Breidenstein, 2019; Cherifi and Amrani, 2020; Krings et al., 1999). Whereas early groups (Neolithic and Kerma) are most similar to sub-Saharan African groups, there is no evidence for migration from the south after the Neolithic. In contrast, the Eurasian/Egyptian influence is mainly associated with migration into the region during the New Kingdom. Any migration from the north did not result in replacement, more likely admixture.

8.6 How can the theoretical and methodological approaches of this study be used by other researchers to illuminate population history in other world regions and periods?

Comparing biological data to cultural data is important to highlight whether shifts in behaviour are related to changes in populations. As this study included samples from across Nubia that covered a range of periods, regional and temporal patterning could be investigated. The results revealed that cultural diffusion and movement of people in Nubia in complex and not standardised, with regional differences apparent. Some contradictory results have been observed in previous studies of Nubian samples (Galland et al., 2016; Godde and Jantz, 2017; Irish, 2005). These could add support to the varied nature of the relationship between biological and socio-cultural change observed in this study.

Nubia is unique as it is positioned between two dentally distinct regions (North Africa/Eurasia and sub-Saharan Africa). In sub-Saharan Africa, the Afridonty dental complex contains mainly mass-additive traits, whereas North Africa groups often include mass-reduced traits (similar to Europeans/Eurodonty) (Irish, 1998; Scott and Dorio, 2010). The clear differences between the dentitions from these regions allows for inferences to be made about migration patterns. Using the same method in an area where only one dental complex is present could mean inter-sample trait frequencies would not be distinct enough to confirm either migration or biological continuity.

This study used methods (i.e., ASUDAS, MMD) proven to separate groups on a global and regional level, to understand how they performed when applied on samples from within the same region. These dental data revealed differences and similarities between groups from within Nubia. This supports their use in investigating migration patterns within one region. The inclusion of dental data from Africa and Eurasia helped to further understand patterning observed in the Nubian results. Adding non-Nubian samples to the analysis offered an insight into the relationship between cultures from the north and south, and placed the Nubian samples in a regional context. This highlights the effectiveness of the ASUDAS, a standardise recording method, which allows for published data from other researchers to be used to enhance our understanding of the movements of people in the past.

The model-bound approaches used in this study were not able to explain the biological affinities observed in the samples studied here. As discussed above, inconsistent migration patterns and complexity in the routes between regions potentially disrupted the outcomes of the models. There was some evidence that the models worked on smaller geographical scales, potentially where migration patterns are more simplistic.

Using nonmetric data, under the ASUDAS, allowed for multiple collections to be used as the technique is quick, standardized, cheap, and non-destructive (Scott and Irish, 2017; Scott and Turner, 1997). Additionally, dental nonmetric traits have been shown to be good proxy for neutral genetic traits (Irish et al., 2020). Obtaining genetic data from Nile valley collections has been difficult, due to the dry and hot conditions, and dental nonmetric traits offer an alternative to investigate relationships between groups in the past. Where DNA has been recovered from Nubian individuals, results from this study support the findings (Cherifi and Amrani, 2020; Fox, 1997; Krings et al., 1999; Sirak et al., 2021). This further supports the usefulness of dental non-metric traits to investigate migration patterns, inter-group relationships, and biological continuity alongside or in place of genetic data.

8.7 Final Comments

Results from this study have helped to illuminate the origins of the people of the 4th Cataract and how they relate to other Nubian groups. These data firmly place the samples from the 4th Cataract in Upper Nubia, but also reveal their unique character. Due to the comparatively isolated location of the 4th Cataract, the inhabitants may not have experienced the mixing and movement of people that was evident in other regions studied. Evidence for biological continuity was strong in the 4th Cataract, but distinct cultural shifts were also noted in the burial/archaeological record. This juxtaposition highlights the importance of using multi-discipline approaches when studying the origin/movement of people, allowing for patterns in cultural diffusion, migration, and admixture to be fully understood.

A wide range of Nubian samples were used in this study, allowing for the investigation of temporal and geographical patterning across the region. These data revealed that migration may have been influenced sample location, time-period, and related settlement type. The variation observed in this study reveals the complex nature inter-sample affinities, with shifts between periods often not comprehensive across Nubia. These findings suggest that conclusions from research which uses a limited range of samples (i.e., one from each time-period) may not be representative of the Nubian populations as a whole and should be viewed as such.

Nubia's location positioned between Egypt and sub-Saharan Africa offers a unique opportunity to study migration and genetic influence from these dentally and culturally distinct areas. This study supports previous genetic research which identified both sub-Saharan Africa and Egypt/Eurasia haplotypes in Nubian groups. The relationship between Nubians and sub-Saharan Africans appears to be clinal, with strong affinities in the Neolithic dissipating over time. Biological affinities with Egypt/Eurasia appear to be related to migration events linked to colonial rule in the Middle and New Kingdoms, although some geographical patterning is also apparent.

Nubian groups have been shown to have their own unique identity both biologically and culturally. This comprehensive study has revealed that although outside cultures have influenced Nubians, ultimately their origins and cultural development come from within Nubia.

8.8 Future research

This study included a wide range of samples from throughout Nubia and the wider region. However, there are some areas where additional collections would improve our understanding of the population history. Firstly, some periods are not represented, most notably the Napatan due to a lack of available collections. Such data would help explore how Nubian populations developed after Egyptian rule. Additionally, comparisons with the Meroitic would highlight if the shift of focus in the empire to the south (i.e., Meroe) was associated with any biological changes. The dearth of skeletal material and evidence of settlement in the southern reaches (6th Cataract region) from the Neolithic to Meroitic makes comparisons with other regions difficult. Further archaeological investigations in the area may reveal evidence for habitation/burial and could provide insight into this period, offering useful comparative data to that already collected elsewhere.

Secondly, samples from different areas of Nubia could enhance our understanding of the regional movement of people. Archaeological excavations have mostly focused on the Nile valley with little work in the hinterlands. Populations in these areas may have been quite different to those close to the Nile. Data from these areas could further contextualise existing results. Additionally, cultures from the Eastern Desert have been noted as influences in both the 4th Cataract and Lower Nubia. Samples from these cultures could help researchers understand if biological as well as cultural exchange occurred between these groups.

Lastly, archaeological collections from sub-Saharan Africa would provide more historically accurate reference samples for comparison to ancient Nubians.

Although the samples from the subcontinent were useful in contextualising the data from Nubia and Egypt, they are from 19th/20th century collections. As such they may not be an accurate representation of the indigenous populations at that time. Hopefully, in the future, collections from other African regions will be available for comparison with the large amount of data now compiled from the Nile valley.

The data collected in this study were used to calculate biological distances between samples, indicating phenetic (and assumed genetic) similarity to each other. They can also be used to investigate variation within and among groups. R-matrix (estimation of a genetic relationship) and Fst (the ratio of among-group variation to total variation) statistics have been modified for use with non-metric data (Irish, 2010; Konigsberg, 2006). Using these methods means that population differentiation can be investigated, as can estimations of kinship (Irish, 2010; Rathmann et al., 2017). Use of these data in this way would further an understanding of past Nubian populations and how they interacted.

Due to poor preservation, and high rates of dental wear in most collections used in this study, tooth measurements were not taken. Metric data could be collected from better-preserved collections, like those from the Medieval period in the 4th Cataract. The addition of odontometric data would add another dimension to understanding relationships in Nubia. Herrera and colleagues (2014) have suggested that metric and non-metric traits are correlated to different parts of the genome. Therefore, using both types of data could reveal a fuller picture of migration and biological continuity in Nubia.

Previous research on Nubian collections has helped to enhance this study, most notably those using genetic data. Although past attempts to extract aDNA on the collections in this study were unsuccessful, advances in the associated techniques may mean that future attempts will yield better results. Looking at the dental data alongside DNA can only improve the understanding of past populations from this region. Additionally, isotopic data can investigate the presence of non-locals. There is potential to use results from this study to target samples which showed signs of a population influx to confirm the presence of non-locals.

Research concerning respiratory (Davies-Barrett, 2018) and dental disease (Whiting, 2021) in the 4th Cataract and other Nubian collections has been completed in recent years. Findings from these studies can be used alongside the present data to further our understanding of past Nubian populations. Investigating whether increased levels of disease or changes in diet/agriculture are correlated with changes to phenetic/genetic make-up of populations can also contextualise the results of all research in this part of the Nile valley.

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Appendix 1. Inter-observer Error Test

	PRESENT		ABSENT		FISHER'S (P=0.05)
	ELWP	JDI	ELWP	JDI	
WNGK	0.00	0.00	3	8	1.00
LCK	5.00	6.00	18	21	1.00
TORUK	0.00	0.00	1	3	1.00
SHVK	2.00	1.00	17	19	0.60
DSHK	0.00	0.00	25	31	1.00
IGK	2.00	2.00	8	18	0.58
TDK	5.00	4.00	14	14	1.00
BUSK	0.00	2.00	30	30	0.49
CDRK	9.00	12.00	11	18	0.78
HYPK	57.00	59.00	4	5	1.00
C5K	7.00	4.00	34	26	0.75
CRBK	13.00	12.00	27	24	1.00
PARK	1.00	0.00	62	62	1.00
XK	2.00	2.00	23	5	0.20
ROUPK	1.00	5.00	10	9	0.18
ROUMK	18.00	20.00	4	4	1.00
PRK	0.00	0.00	28	33	1.00
ODK	0.00	1.00	86	81	0.49
CONK	0.00	1.00	68	70	1.00
MLDK	0.00	0.00	9	9	1.00
CPK	59.00	49.00	4	9	0.14
ANTK	12.00	10.00	25	17	0.79
TORLK	0.00	0.00	1	10	1.00
PATK	36.00	35.00	33	42	0.51
ROCK	0.00	1.00	3	4	0.14
MC1K	2.00	1.00	52	45	1.00
MC2K	35.00	41.00	34	23	0.16
DEFK	5.00	4.00	32	31	1.00
C12K	2.00	0.00	30	37	0.21
PRSK	12.00	6.00	39	36	0.30
C7K	6.00	8.00	44	46	0.78
TOMK	0.00	2.00	5	19	1.00
ROLCK	0.00	1.00	22	37	1.00
ROLM1K	0.00	0.00	40	44	1.00
ROLM2K	30.00	32.00	0	4	0.12
TMAK	0.00	0.00	30	57	1.00

ELWP = Author, JDI = Professor Joel Irish

Appendix 2. Intra-observer Error Test

INDIVIDUAL	KAPPA VALUE	SIGNIFICANCE
1	0.637	0.002
2	0.7	0.007
3	0.589	0.001
4	0.852	<0.001
5	0.833	0.003
6	1	0.002
7	0.637	0.003
8	1	0.003
9	0.814	0.006
10	0.778	<0.001
11	0.747	<0.001
12	1	<0.001
13	0.611	<0.001
14	0.831	<0.001
15	0.881	<0.001
16	0.449	0.009
17	0.925	<0.001
18	0.732	<0.001
19	1	0.003
20	0.593	0.004
21	0.75	0.007
22	0.679	0.001
23	0.903	<0.001
24	1	<0.001
25	0.684	<0.001
26	0.762	<0.001
27	0.836	<0.001
28	0.846	<0.001
29	1	<0.001
30	0.722	0.005

Appendix 3. Arizona State University Dental Anthropology System (ASUDAS)

TRAIT NAME	DESCRIPTION	BREAK POINT (POSITIVE =)	GRADE
UI1 WINGING	Mesio-lingal rotation of the upper central incisors.	Grade 1-3	Grade 0 (absence): if the line is parallel to the labial surfaces or if the distal margins fall below the line, winging is absent. Angle ≥180°.
			Grade 1 (trace winging): the mesial margins of the upper incisors fall slightly below the line. Angle 160–180°.
			Grade 2 (moderate winging): the mesial margins are more removed from the line. Angle 135–159°.
			Grade 3 (pronounced winging): there is a distinct distance between the line and the mesial margins. Angle <135°.
UI1 LABIAL CONVEXITY	Variation in the curvature of the labial surface of the upper incisors (from flat to convex)	Grade 2-4	Grade 0: labial surface is flat
			Grade 1: labial surface exhibits trace convexity
			Grade 2: labial surface exhibits weak convexity
			Grade 3: labial surface exhibits moderate convexity
			Grade 4: labial surface exhibits pronounced convexity
			Grade 5: pronounced convexity not observed in modern humans but present in earlier hominins (not shown on ASUDAS plaque)
PALATINE TORUS	Palatine torus is a bony exostosis that is expressed on both sides of the midline on the hard palate. Its point of origin is on the palatine bones. From a point of initial constric- tion, it expands in breadth onto the hard palate and generally narrows moving in the direction of the incisive foramen.	Grade 2-3	Grade 0: absence
			Grade 1: small (elevated 1–2 mm)
			Grade 2: moderate (elevated 2–5 mm)
			Grade 3: marked (covers more of palate, 5–10 mm relief) Grade 4: very marked (>10 mm high and broad)

UI1 SHOVELLING	Presence of lingual marginal ridges on the upper and lower anterior teeth.	Grade 2-6	Grade 0 (absence): it is rare for UI1 to express the complete absence of marginal ridges (see Figure 4.1a for example). For this reason, grade 0 on the UI1 shoveling plaque actually shows very slight marginal ridge expression.
			Grade 1 (trace): marginal ridges can be discerned, but expression is slight, with mesial marginal ridge not extending to the basal eminence.
			Grade 2 (low moderate): ridges more pronounced, with mesial marginal ridge extending further down on basal eminence.
			Grade 3 (high moderate): ridges more pronounced, almost coalescing at basal eminence.
			Grade 4 (low pronounced): well-developed ridges that converge at basal eminence.
			Grade 5 (medium pronounced): more pronounced marginal ridges meeting at basal eminence
			Grade 6 (high pronounced): pronounced ridges that meet at basal eminence, almost folding around on themselves.
			Grade 7 (extreme pronounced): any expression that exceeds grade 6 can be placed in grade 7.
UI1 DOUBLE SHOVELING	Presence of labial marginal ridges on the upper anterior teeth.	Grade 2-6	Grade 0 (absence): no labial marginal ridges present; surface is smooth
			Grade 1 (faint): very faint labial ridging, more evident on mesial than distal margin
			Grade 2 (trace): ridge more distinct than faint expression of grade 1 but still slight
			Grade 3 (slight): ridges distinct enough to be palpated

			Grade 4 (moderate): ridging clearly evident along at least one half of crown height Grade 5 (pronounced): very distinct ridging expressed from incisal edge to crown root junction Grade 6: (very pronounced): extreme double-shoveling with well-developed ridges along both the mesial and distal labial margins
UI2 INTERUPTION GROOVE	Grooves or distinct depressions that interrupt the normal course of the mesial or distal marginal ridges or even the basal cingulum.	Grade M, D, MD, Med	0 = absence of grooves on lingual marginal ridges and basal cingula M = groove on mesiolingual marginal ridge D = groove on distolingual marginal ridge MD = grooves on both mesiolingual and distolingual marginal ridges med = groove on medial aspect of basal cingulum, sometimes extending onto root
UI2 TUBERCULUM DENTALE	Cingular projections on the lingual surface of the upper anterior teeth. They typically take the form of ridges and/or tubercles.	Grade 2-6	Grade 0: labial surface is flat Grade 1: labial surface exhibits trace convexity Grade 2: labial surface exhibits weak convexity Grade 3: labial surface exhibits moderate convexity Grade 4: labial surface exhibits pronounced convexity Grade 5: pronounced convexity not observed in modern humans but present in earlier hominins (not shown on ASUDAS plaque)
UC BUSHMAN CANINE (CANINE MESIAL RIDGE)	Large mesial ridge and tubercle which have coalesced causing the lingual sulcus to be distal to the midline of the tooth.	Grade 1-3	Grade 0: mesial and distal lingual ridges are the same size. Neither is attached to the *tuberculum dentale,* if present. Grade 1: mesiolingual ridge is larger than distolingual and is weakly attached to the *tuberculum dentale*. Grade 2: mesiolingual ridge is larger than the distolingual and is moderately attached to the *tuberculum dentale*.

			Grade 3: Morris’s type form. Mesiolingual ridge is much larger than the distolingual and is fully incorporated into the *tuberculum dentale*.
UC DISTAL ACCESSORY RIDGE	The lingual lobe segment of the upper and lower canines typically expresses a medially positioned essential ridge, a mesial marginal ridge, and a distal marginal ridge. Between the essential ridge and distal marginal ridge, an additional ridge can be manifest on the lingual aspect of the distal lobe segment.	Grade 2-5	Grade 0: trait absence
			Grade 1: faint expression (not shown on UC DAR plaque)
			Grade 2: slight expression
			Grade 3: moderate development
			Grade 4: strongly developed
			Grade 5: pronounced expression
UM2 HYPOCONE	Variation in presence of the hypocone (disto-lingual) cusp of the upper molar.	Grade 3-5	Grade 0: no hypocone expression of any form; a true three-cusped tooth
			Grade 1: for this grade, there is a low-level expression of the hypocone, often expressed as no more than an outline on the distolingual aspect of the trigon. In Dahlberg’s original classification, this would be scored molar along with grade 0 as a three-cusped upper
			Grade 2: in the Dahlberg classification, 3+ was equivalent to a small conical hypocone on the distolingual border of the trigon; grade 2 reflects this phenotype, where there is basically a conical cusp, or tubercle, with a free apex
			Grade 3: the hypocone is reduced in size but assumes a normal ovate shape along with a distinct free apex
			Grade 4: this grade would be equivalent to 3.5 on the modified hypocone plaque; the hypocone is reduced in size but is moderate rather than slight in expression
			Grade 5: hypocone is well developed, a step beyond grade 4
			Grade 6: pronounced expression of the hypocone; often equals or exceeds the size of the major cusps of the trigon

UM1 CUSP 5	Cusp 5 takes the form of a conule that is expressed between the hypocone and metacone of the upper molars. To be scored as present, the cusp or conule should show two vertical grooves that run in parallel on the distal marginal ridge complex.	Grade 2-5	Grade 0: trait is absent, only one vertical groove on distal surface of upper molar between hypocone and metacone
			Grade 1: slight conule
			Grade 2: trace conule
			Grade 3: small cuspule
			Grade 4: small cusp
			Grade 5: medium cusp
UM1 CARABELLI'S CUSP	Carabelli's trait is a cingular derivative expressed on the lingual surface of the protocone. Expression ranges from a pit to a pronounced tubercle with a free apex.	Grade 2-7	Grade 0: mesiolingual cusp does not exhibit any grooves or pits on the lingual surface
			Grade 1: a vertical groove separates the protocone from the mesial marginal ridge complex; grade 1 expression occurs when there is a slight eminence that deflects distally from this groove
			Grade 2: when expression goes beyond a slight groove or eminence and takes the form of a pit
			Grade 3: expression is still slight but takes on a more distinct form than shown by grades 1 and 2
			Grade 4: the most pronounced expression of Carabelli's trait that does not involve a tubercle with a free apex; grade 4 takes the classic bird-wing form.
			Grade 5: small tubercle with a free apex
			Grade 6: moderate tubercle with a free apex
			Grade 7: pronounced tubercle with a free apex
UM3 PARASTYLE	Normally expressed on the paracone of the upper molars. It ranges in size from a pit to a large free-standing tubercle.	Grade 1-5	Grade 0: buccal surfaces of cusps 2 and 3 are smooth
			Grade 1: a small pit near the buccal groove between cusps 2 and 3
			Grade 2: small cusp but no free apex
			Grade 3: medium cusp with free apex
			Grade 4: large cusp with free apex
			Grade 5: very large cusp with free apex that may extend onto the surfaces of both cusps 2 and 3

			Grade 6: peg-shaped crown attached to root of second or third molar. This classic form of Bolk’s paramolar tubercle may represent a supernumerary tooth that is fused to the buccal surface of UM2 or UM3. Accessory cusps with all the charac- teristics of a paramolar tubercle have also been observed on LM2 and LM3, adding evidence to the possibility these are fused supernumerary teeth.
UM1 ENAMEL EXTENSION	Variation in the course of the cervical enamel line. The standard expression of this line is horizontal, In some instances the enamel extends toward the apex of the roots in the direction of the bifurcation of the two buccal aspects of the roots of either upper or lower molars.	Grade 1-3	Grade 0: cervical enamel line is horizontal Grade 1: enamel line extends about 1 mm toward root bifurcation Grade 2: enamel line extends about 2 mm toward root bifurcation Grade 3: enamel line extends 4 mm or more toward root bifurcation
UP1 ROOT NUMBER	Upper premolars have either two or three root cones. Sometimes the root cones can be bifurcated creating a two or three rooted tooth. Bifurcation has to extend from 1⁄4 to 1⁄3 of total root length.	Grade 2-3	Grade 1: one-rooted UP1 (root grooves separate cones but no inter-radicular projection) Grade 2: two-rooted UP1 (inter-radicular projection separates buccal and lingual root cones for 1⁄4 to 1⁄3 of total root length) Grade 3: three-rooted UP1 (there is an inter-radicular projection that separates the buccal root into two distinct roots, and another projection separating the two buccal roots from a single lingual root)
UM2 ROOT NUMBER	Upper molars often have three separate roots. Sometimes the roots can fuse creating a two or one rooted tooth. For a root to be independent bifurcation of at least 1⁄4 to 1⁄3 of total root length needs to be present.	Grade 3	Grade 1: one-rooted UM2 (root cones separated by grooves but there are no inter-radicular projections) Grade 2: two-rooted UM2 (one inter-radicular projection separates one root from two fused roots) Grade 3: three-rooted UM2 (three inter-radicular projections separate all three roots for at least 1⁄4 to 1⁄3 of total root length)
UI2 PEG-REDUCED	Upper lateral incisors can assume a variety of forms and exhibit many unusual morphological features. Variation in form is described in the grades.	Grade 1-3	Grade 0: UI2 normal in form and size Grade 1: UI2 normal in form but diminutive in size (less than 1⁄2 mesiodistal diameter of UI1) Grade 2: congenital absence Grade 3: peg-shaped UI2, conical in form, often with no morphological features Grade 4: talon cusp (in same location but much more pronounced and distinctive than a tuberculum dentale) Grade 5: triform UI2 with a large lingual structure that runs from basal cingulum to incisal edge Grade 6: unusual UI2 forms that do not fit any of the above categories
P1-P2 ODONTOME	Odontomes can be expressed on both he upper and lower premolars in the central sulcus of the tooth. Typically they are conical in shape.	Grade 1	Grade 0: absence Grade 1: odontome present in central sulcus (score all eight premolars)

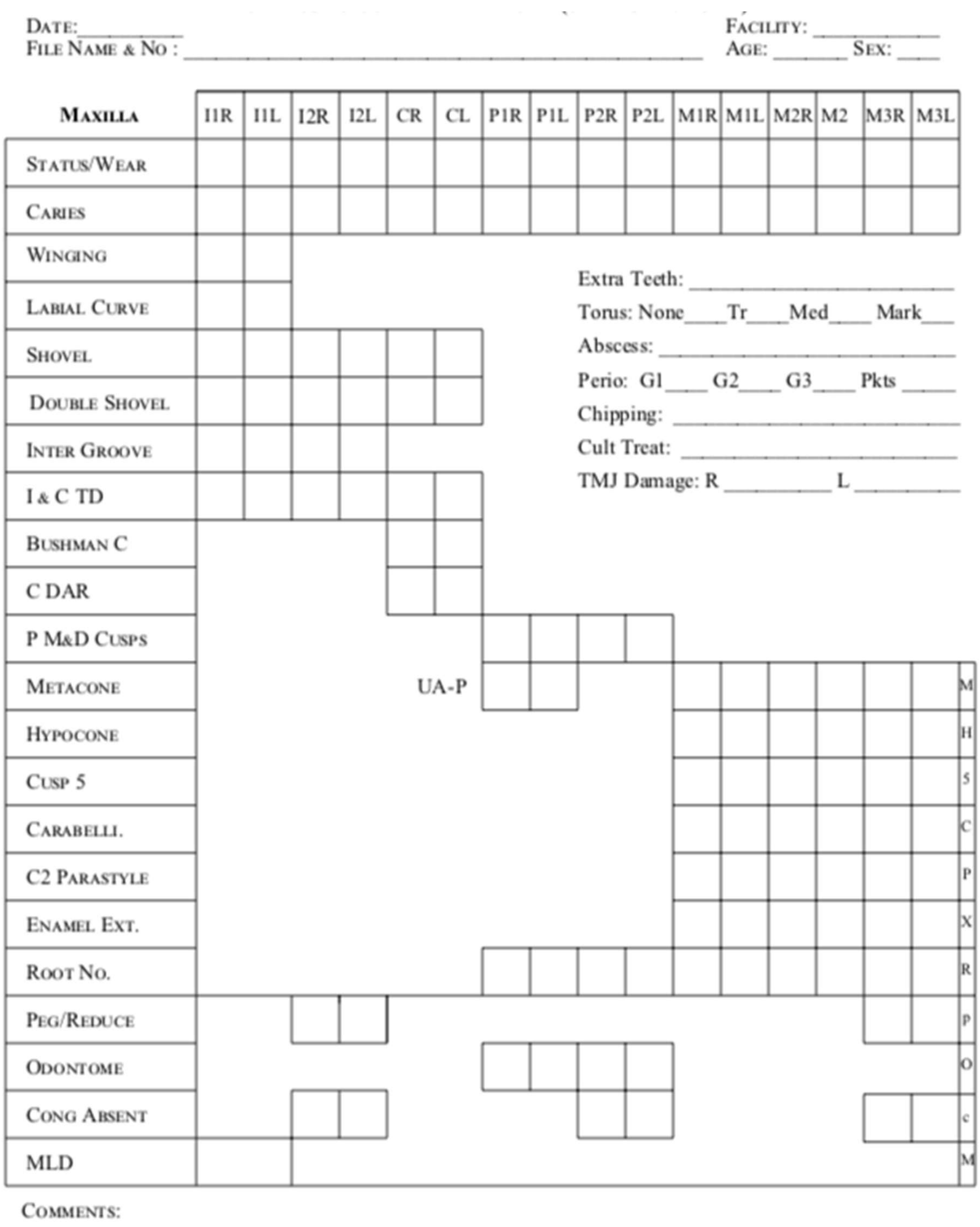
UM3 CONGENITAL ABSENCE	Loss and reduction of third molars are elements of the same phenomenon and are grouped together to form a single trait. Variations include pegged or reduced forms plus congenital absence.	Grade 1	Grade 0: third molar present and normal Grade 1: third molar significantly reduced in size (ca. 1⁄2 normal size, with two or more cusps) Grade 2: third molar peg-shaped (only a single cusp evident) Grade 3: third molar congenitally absent
UI1 MID LINE DIASTEMA	Presence of space between the upper central incisors midway between the base (or neck) of the tooth and the incisal edge. Crown can be worn down approximately 1⁄4 of its original (estimated) height and still allow recording.	Grade 1	Grade 0: no diastema (space < 0.5 mm) Grade 1: diastema (space > 0.5 mm)
LP2 LINGUAL CUSP	Lower premolars can have one, two, or three lingual cusps. The main cusp has a mesial placement relative to the buccal cusp. When there are accessory cusps, they are usually smaller and distal to the larger mesial lingual cusp.	Grade 2-9	Grade 0: lingual cusp has no free apex Grade 1: single lingual cusp (on plaque, grades 0–1) Grade 2: two lingual cusps (on plaque, grades 2–7) Grade 3: three lingual cusps (on plaque, grades 8–9)
LM1 ANTERIOR FOVEA	Trait expressed on the mesial aspect of the trigonid of the lower molars. It involves three primary elements: distinct essential ridges on the protoconid and metaconid that meet close to the center of the trigonid, and a mesial marginal ridge that is expressed to varying degrees. The conjoining of these three features produces a fovea, or depression, on the mesial section of the trigonid.	Grade 2-4	Grade 0: absence Grade 1: trace, with slight development of mesial marginal ridge Grade 2: essential ridges on trigonid better developed, as is marginal ridge Grade 3: essential ridges pronounced and marginal ridge well developed, producing a distinctive fovea on the anterior portion of the trigonid Grade 4: pronounced essential ridges and marginal ridge produce a well-defined fovea
MANDIBULAR TORUS	Mandibular torus is expressed as one or more lobes that originate on the lingual surface of the mandible below the canine. The torus varies from a small elevation below the canine and first premolar to a multi-lobed exostosis that extends back as far as the second molar.	Grade 2-3	Grade 0: absence of torus (palpation required) Grade 1: small (slight elevation below LC and LP1) Grade 2: moderate (larger elevation with more extended coverage, sometimes as two small lobes) Grade 3: marked (more pronounced expression, extends from LC to LM1) Grade 4: very marked (extends from LC to LM2, with very little separation of lobes across the mandible)
LM2 GROOVE PATTERN	Variation in pattern of contact between major cusps of the lower molars.	Grade Y	Y pattern: contact between cusps 2 and 3 X pattern: contact between cusps 1 and 4

			+ pattern: contact between cusps 1, 2, 3, and 4 at central sulcus
ROCKER JAW	When the left and right inferior horizontal rami are convex, causing the mandible to rock back and forth when placed upon a flat surface and pushed.	Grade 1-2	Grade 0: no expression. Both inferior horizontal rami are flat, or together are tri- pod-like in appearance; in the latter case, projections of the chin (i.e., gnathion craniometric measurement point) and the two distal-most points of the horizontal rami that transition into the vertical rami (gonion) form the base of the tripod. Grade 1: near rocker. The inferior horizontal rami are convex enough that the man- dible is unstable when laid on a flat surface. The mandible will “rock” for about a second when pushed. Grade 2: rocker. The horizontal rami are so convex that the mandible will easily rock back and forth on a flat surface for more than a second.
LM1 CUSP NUMBER	Trait is based on the number of cusps that make up the lower first molar. Lower first molars normally have 5 cusps (i.e presence of the hypoconulid). Variations also can include four cusped and six cusped teeth. Cusp 5 has to be present to score cusp 6 as present. As the break point for lower first molar is 6 cusp + details of scoring of cusp 6 are given.	6 cusps +	Grade 0: absence of cusp 6 Grade 1: cusp 5 is more than twice the size of cusp 6 Grade 2: cusp 5 is about twice as large as cusp 6 Grade 3: cusps 5 and 6 are about equal in size Grade 4: cusp 6 is slightly larger than cusp 5
LM2 CUSP NUMBER	Trait is based on the number of cusps that make up the lower second molar. The presence of cusp 5 on the lower second molar varies more than in the lower first molar. Variations also can include four cusped and six cusped teeth. Cusp 5 has to be present to score cusp 6 as present. As the break point for lower second molar is 5+ details of scoring of cusp 5 are given.	5 cusps +	Grade 0: hypoconulid is absent (four-cusped tooth) Grade 1: trace expression Grade 2: slight Grade 3: moderate Grade 4: strong Grade 5: pronounced
LM1 DEFLECTING WRINKLE	The deflecting wrinkle is expressed on the occlusal surface of the mesiolingual cusp (metaconid) of the lower molars. The essential ridge of the metaconid runs a direct course from the cusp tip of the metaconid to the central occlusal fossa. In some instances, the ridge changes course (or deflects) about halfway along its length before it terminates in the central sulcus.	Grade 2-3	Grade 0: deflecting wrinkle absent; essential ridge of metaconid runs a straight course from cusp tip to central occlusal fossa Grade 1: essential ridge is straight but with midpoint constriction Grade 2: essential ridge deflects at halfway point toward central occlusal fossa but does not contact hypoconid Grade 3: essential ridge shows strong deflection at midpoint and does contact hypoconid

LM1 C1-C2 CREST	The two major cusps (protoconid and metaconid) can exhibit ridges that are connected. If the location of the ridge runs from one essential cusp to the other, the trait is referred to as a mid-trigonid crest. A distal trigonid crest is present when the distal accessory ridges run a direct course along the distal portion of the cusps and come in contact at a point close to the central occlusal sulcus. Both crests can be continuous or discontinuous. Neither mid-trigonid nor distal trigonid crests are common in modern humans (<10%), but they are very common in earlier hominins, especially Homo heidelbergensis and Neanderthals. These groups have been studied through micro-CT scans, and the con- tact is apparent at the enamel–dentine junction, even with crown wear.	Grade 1	Grade 0: trigonid crest absent Grade 1: trigonid crest present
LM1 PROTOSTYLID	The protostylid is a cingular derivative, similar to Carabelli's trait but found on the mesiobuccal cusp of the lower molars. Expression ranges from a pit to tubercule.	Grade 1-6	Grade 0: no pit or positive expression on buccal surface of lower molar Grade 1: buccal pit (a pit of varying sizes, situated around the midpoint of the crown in the protoconid–hypoconid inter-lobal groove) Grade 2: a very slight swelling and associated groove coursing mesially from buccal groove Grade 3: slight positive expression on mesiobuccal cusp Grade 4: moderate positive expression Grade 5: strong positive expression Grade 6: pronounced positive expression Grade 7: most distinctive form of protostylid, expressed as tubercle
LM1 CUSP 7	Cusp 7 is a wedge-shaped accessory cusp expressed between cusps 2 (metaconid) and 4 (entoconid). Grade 1A is not included in the total frequency of cusp 7 as it has been found to obscure a distinctive pattern of geographic variation and may not be part of the cusp 7 expression.	Grade 2-4	Grade 0: no accessory cusp between cusps 2 and 4 Grade 1: small, wedge-shaped cusp between cusps 2 and 4 Grade 1A: this expression does not assume the typical wedge-shaped form of a cusp 7 but is marked by a groove on the lingual surface of the metaconid Grade 2: distinct but small cusp Grade 3: moderate cusp Grade 4: large cusp
LP1 TOMES ROOT	Lower premolars have a buccal root cone and one or more lingual cones, with the most prominent on the mesial boundary of the tooth. An LP1 may exhibit one, two, three, or	Grade 3-5	Grade 0: slight or no groove separating cones on mesial surface of LP1 root

	four root radicals. Tomes’ root constitutes that instance where a mesiolingual root cone exhibits an inter-radicular projection, producing an independent root.		Grade 1: slight V-shaped groove separating cones Grade 2: deeper V-shaped groove separating cones Grade 3: deep developmental groove separating root cones along at least 1⁄3 of root Grade 4: deep grooving on both mesial and distal surfaces of root Grade 5: inter-radicular projection present so LP1 has two roots, a large buccal root and a smaller mesial/lingual root
LC ROOT NUMBER	Upper and lower canines have two root cones despite typically being single-rooted teeth. In some instances lower canines can exhibit two roots. Although canines are single-cusped teeth, they are associated with two root cones. Root bifurcation needs to be at least 1⁄4 to 1⁄3 of total root length to be scored as separate.	Grade 1	Grade 0: one-rooted LC, with or without root grooves separating buccal and lingual cones Grade 1: two-rooted LC, with inter-radicular projection separating buccal and lingual cones by at least 1⁄4 to 1⁄3 of total root length
LM1 ROOT NUMBER	Lower molars generally have two roots, a mesial root associated with the trigonid and a distal root associated with the talonid. In the lower first molar sometimes these roots can be fused creating a one-rooted tooth. Additionaly sometimes an distinct distolingual accessory root can be present creating a three-rooted tooth.	Grade 3	Grade 1: one-rooted lower first molar (no inter-radicular projection separating roots) Grade 2: two-rooted lower first molar (distinct mesial and distal roots) Grade 3: three-rooted lower first molar (3RM1) (distinct distolingual accessory root)
LM2 ROOT NUMBER	Lower molars generally have two roots, a mesial root associated with the trigonid and a distal root associated with the talonid. In the lower second molar often these roots can be fused creating a one-rooted tooth. Separation of mesial and distal roots has to be at least 1⁄4 to 1⁄3 of total root length to be counted as independent roots.	Grade 2	Grade 1: one-rooted lower molar (mesial and distal roots of lower molars can be fused on either buccal or lingual aspect or both) Grade 2: inter-radicular structure produces clear separation of mesial and distal roots for at least 1⁄4 to 1⁄3 of total root length
LM3 TORSOMOLAR ANGLE	One or both lower third molars may be rotated either buccally or lingually relative to a line running through the center of lower first and second molars. It is independent of dental crowding; if the latter is present in a dentition, torsomolar angle should not be scored.	Grade 1	Grade 0: absent (torsomolar angle <10°) Grade 1: present (torsomolar angle ≥10° in either buccal or lingual direction)

Appendix 4. ASUDAS Recording Sheets



DATE:__________

FILE NAME & NO : ____

FACILITY: ____________

AGE: _______ SEX: ____

MAXILLA	I1R	I1L	I2R	I2L	CR	CL	P1R	P1L	P2R	P2L	M1R	M1L	M2R	M2	M3R	M3L	
STATUS/WEAR																	
CARIES																	
WINGING																	
LABIAL CURVE																	
SHOVEL																	
DOUBLE SHOVEL																	
INTER GROOVE																	
I & C TD																	
BUSHMAN C																	
C DAR																	
P M&D CUSPS																	
METACONE						UA-P											M
HYPOCONE																	H
CUSP 5																	5
CARABELLI.																	C
C2 PARASTYLE																	P
ENAMEL EXT.																	X
ROOT NO.																	R
PEG/REDUCE																	P
ODONTOME																	O
CONG ABSENT																	c
MLD																	M

Extra Teeth: ________________________

Torus: None____Tr____Med____ Mark___

Abscess: __________________________

Perio: G1____ G2____ G3____ Pkts _____

Chipping: __________________________

Cult Treat: _________________________

TMJ Damage: R __________ L __________

COMMENTS:

Mandible	I1L	I1R	I2L	I2R	CL	CR	P1L	P1R	P2L	P2R	M1L	M1R	M2L	M2	M3L	M3R	
Status/Wear																	
Caries																	
Shovel																	
C DAR																	
P Ling Cusps													← Anterior Fovea				
Groove Pat																	G
M Cusp No																	C
Def Wrinkle																	D
C1—C2 Crest																	T
Protostylid																	P
Cusp 5																	5
Cusp 6																	6
Cusp 7																	7
Enamel Ext.						Tomes →											X
Root No.																	R
Odontome											Torsomolar Ang						
Cong Abs																	c

Torus: None_____Tr_____Med_____Mark_____

Rocker: None_____ Near ______ Rocker ______

Gonial Eversion 0_______ 1_______ 2________

Abscess: ______________________________

Perio: G1_____ G2_____ G3_____ Pkts ______

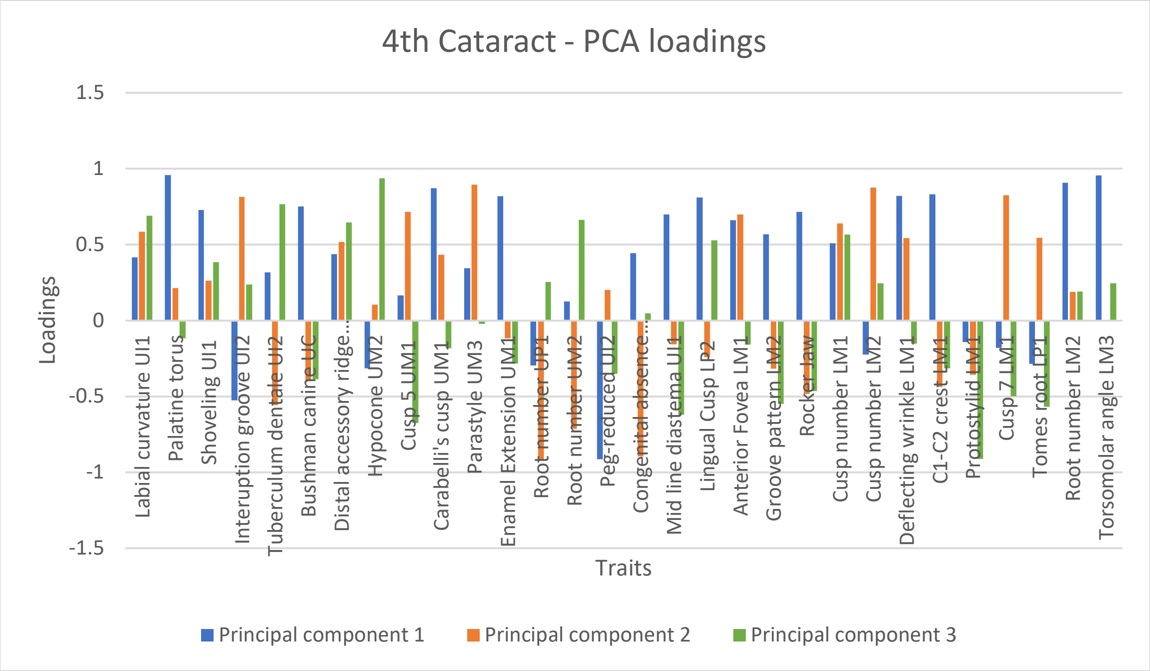
Chipping: ____________________________

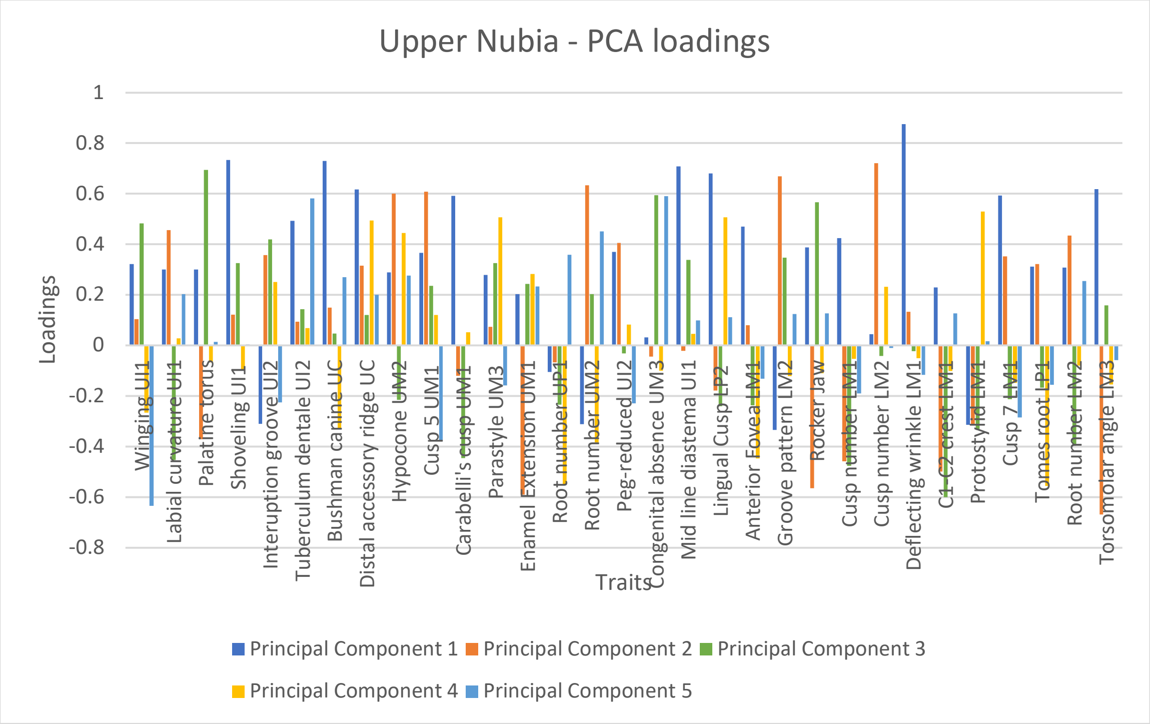
Cult Treat: ___________________________

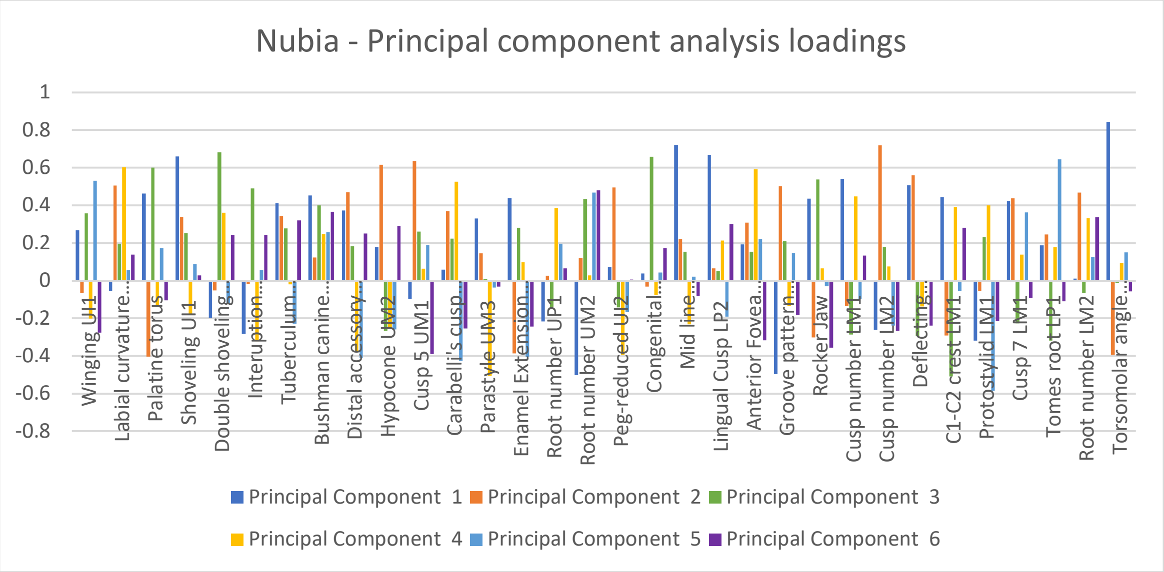
Extra Teeth: __________________________

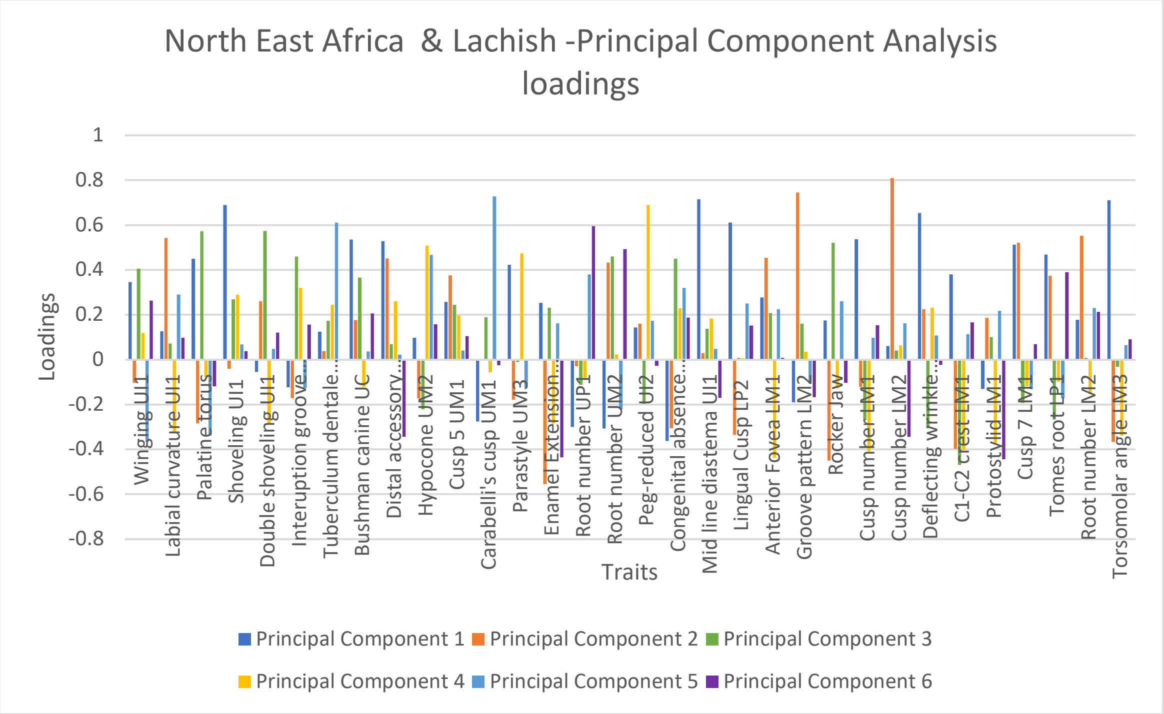
Comments:

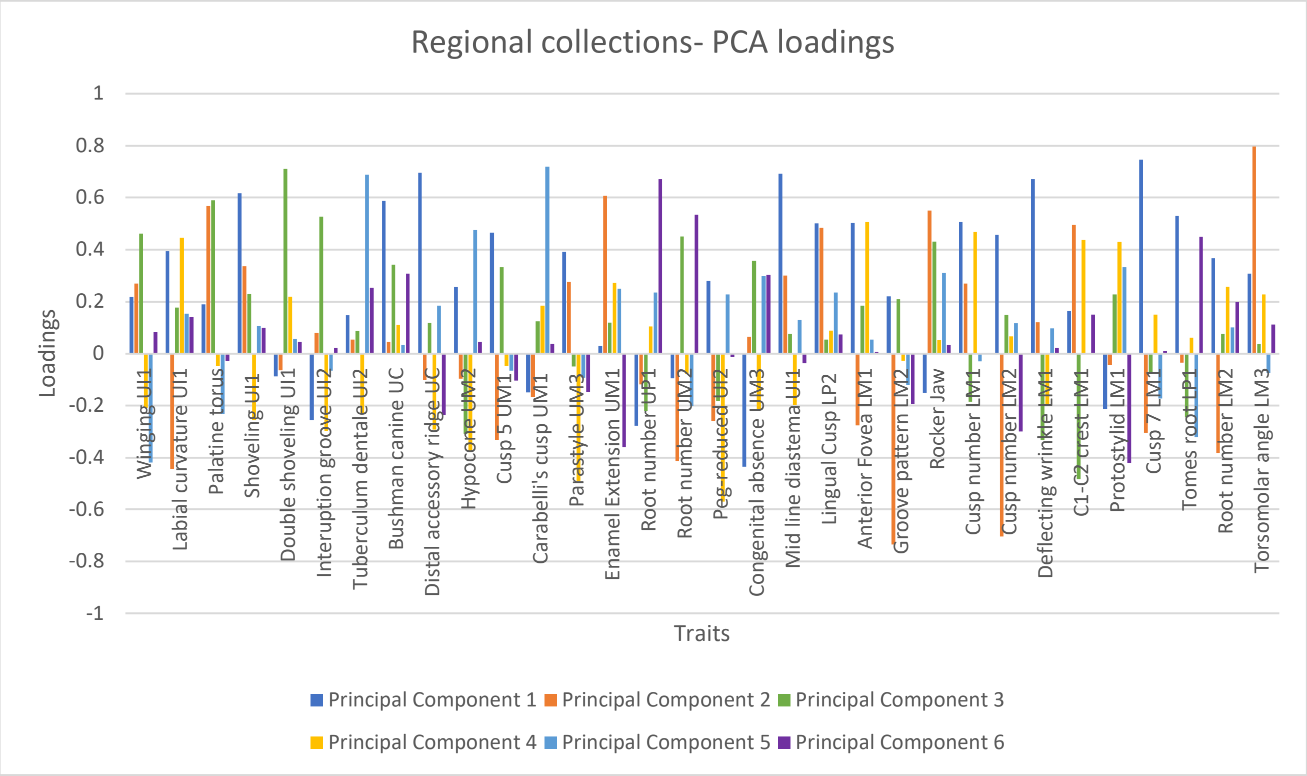
Appendix 5. PCA loadings






Nubia - Principal component analysis loadings


North East Africa & Lachish -Principal Component Analysis loadings


Regional collections- PCA loadings
Loadings
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Winging UI1
Labial curvature UI1
Palatine torus
Shoveling UI1
Double shoveling UI1
Interuption groove UI2
Tuberculum dentale UI2
Bushman canine UC
Distal accessory ridge UC
Hypocone UM2
Cusp 5 UM1
Carabelli's cusp UM1
Parastyle UM3
Enamel Extension UM1
Root number UP1
Root number UM2
Peg-reduced UI2
Congenital absence UM3
Mid line diastema UI1
Lingual Cusp LP2
Anterior Fovea LM1
Groove pattern LM2
Rocker Jaw
Cusp number LM1
Cusp number LM2
Deflecting wrinkle LM1
C1-C2 crest LM1
Protostylid LM1
Cusp 7 LM1
Tomes root LP1
Root number LM2
Torsomolar angle LM3
Traits
Principal Component 1
Principal Component 2
Principal Component 3
Principal Component 4
Principal Component 5
Principal Component 6