INFERRING THE SOCIAL ORGANIZATION OF MEDIEVAL UPPER NUBIA USING NONMETRIC TRAITS OF THE SKULL

By

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ABSTRACT

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Medieval Nubia was composed of three kingdoms located along the Middle Nile. Although biological distance (biodistance) research has demonstrated population continuity in this region, little is known about the population structure or social organization in any single era. The Medieval Period (550–1500 CE) was a particularly dynamic one in Nubia, since all three kingdoms converted to Christianity in the mid-sixth century CE, and neighboring polities converted to Islam a century later. The political ramifications of these conversions have been studied at a large scale, but little research has investigated the local processes that comprise social organization during this time. Minimal research has used contemporary populations to analyze regional, local, and family level social organization in Nubia. Biodistances were investigated through nonmetric traits of the skull in six cemeteries from three archaeologically defined sites in modern northern Sudan, using Mahalanobis D^2 distance, among other statistical tests. The six cemeteries in this study are from Mis Island (three cemeteries), Kulubnarti (two cemeteries), and Gabati (one cemetery). Mis Island and Kulubnarti were part of the same kingdom (Makuria) from the seventh century on, while Gabati was part of the far Upper Nubian kingdom of Alwa.

When cemeteries from the same sites are pooled, results show that the two more northerly sites were more closely related, while the third site, located in a different kingdom, was biologically distant. This suggests that political boundaries may have affected movement of individuals or families among rural villages. These results are highly, though insignificantly, correlated with a previously published three-site craniometric biodistance study of the same samples. When the relationships among all six cemeteries are considered, the two located at Kulubnarti are more distant from each other than expected. One Kulubnarti cemetery appears closely related to the three cemeteries at Mis Island, while

the other is biologically distant to that cluster. These findings, along with recently acquired carbon dates, suggest that the two Kulubnarti cemeteries represent two contemporaneous neighboring groups that were relatively genetically isolated from one another and that experienced life, health, and disease quite differently. An attempt to contextualize these regional results with data from across the continent failed to provide meaningful results. The continental analysis integrated novel data with a publicly available global dataset. However, the biodistance analysis primarily demonstrates clustering of the samples by analyst, suggesting problems with inconsistent data collection methods.

Biodistance was also studied in depth for Mis Island. This study is the first to include cemetery 3-J-18, which surrounded the Late Medieval (1100–1500 CE) church, in a bioarchaeological analysis of Mis Island. This sample is the most biologically heterogeneous of the Mis Island cemeteries, and preliminary spatial analysis suggests that all ages and sexes are represented in it. Compared to the closer-than-average relationship observed between the other two Mis Island cemeteries, cemetery 3-J-18 is a biological outlier. Still, all three Mis Island cemeteries are more closely related than the Kulubnarti cemeteries are to each other.

Results of sex-specific analyses of individual cemeteries, as well as pooled samples for each site, show similar levels of variability among same sex pairs. This suggests the practice of multilocal postmarital residence, where a husband and wife are equally likely to live near the husband's kin as the wife's kin, a pattern newly recognized to be common among human groups. In addition, all three cemeteries were spatially analyzed assuming uniform distribution of burials, and one was retested using previously identified spatial groupings. These analyses of the three Mis Island cemeteries are unable to detect the presence of kin groups, despite differing spatial demographic patterns among the cemeteries. This diverges from the patterns observed in pre-medieval cemeteries, where biological affinity is an important factor in burial location.

To Terry Streetman, for keeping me fed and (relatively) sane.
Even when everything is the worst, you are the best around.

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Dr. Todd Fenton was the chair of my dissertation committee but has also been an advisor, a professor, a manager, a collaborator, and a friend. We’ve dined at a Tuscan villa with a view of Chianti, and we’ve whiled away the hours driving across Michigan to distant morgues more times than either of us care to count. He made me a better anthropologist and researcher, a more introspective person, and (I fervently hope) a more pleasant colleague to be around. He is true of heart and provides his students with great and varied opportunities – to teach, to research, to make career-long connections. If it felt like a lot, and it did sometimes, my time at the MSU Forensic Anthropology Lab was absolutely worth it, knowing how rare and precious those experiences were. If it was an early morning, or a long drive, or a strongly “multi-sensory” case, what he asked of us was no more than what he offered of himself. Plus, he had to be the driver.

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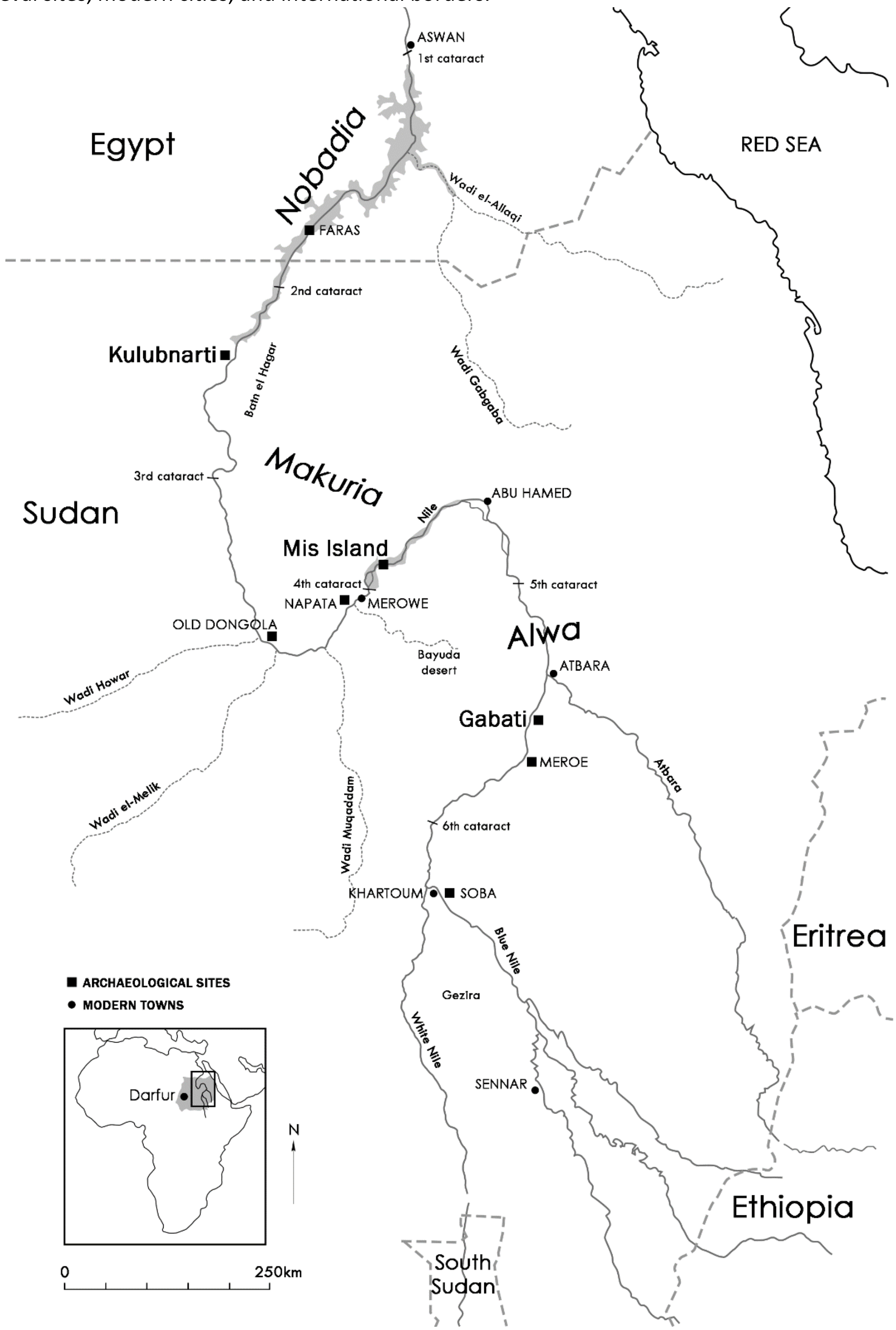
CHAPTER ONE: INTRODUCTION

The Nile flows north from central Sudan, where the Blue and White Niles converge near the modern capital of Khartoum, passes through Egypt, and empties into the Mediterranean. It is interrupted in six places by rocky, nearly impassible spans called cataracts, numbered from north to south (Figure 1.1). Ancient Kushites, and more recently Nubians, formed polities that controlled trade on the Middle Nile, that portion of the Nile that stretches from its beginning near Khartoum to the first cataract in modern Egypt (Török, 1997a). Until the introduction of camels for transport in the Medieval Period (550–1500 CE), the Nile was the only route of travel between Sub-Saharan Africa and Egypt, and by extension the Mediterranean and Levant. Over time, several urban population centers developed and expanded as a result of this strategic control of a major trade route. The rural population, meanwhile, was spread out over a rocky and harsh terrain.

The terms “Nubia” and “Nubian” in this dissertation will represent the people of the Middle Nile region throughout history, rather than an ethnic distinction. The people settled in parts of this region are known today as ethnic Nubians, although this term did not appear until around 350 CE (Edwards, 2004a). Indeed, Nubia was often divided into multiple kingdoms, and inhabitants would likely have identified as a variety of ethnicities. Ancient peoples of this region are often referred to by scholars as Kushites or *aethiopian,* which is a Greek expression meaning “burnt faced”. The term Kush is used in modern scholarship with varied meanings. Some use Kush or Kushites in a manner similar to the ancient Egyptians, indicating political entities and inhabitants of the region of Nubia from the third millennium BCE until the first millennium CE (Edwards, 2004b; Kendall, 1996; Smith, 2003). Others use the term to refer only to the political entities on the Middle Nile from the eighth century BCE until the fourth century CE (Dixon, 1964; Edwards, 2004c, 2004d; Kendall, 1997; Török, 1995, 1997b; Welsby, 1996a). For the sake of clarity, this dissertation avoids the term Kush and instead uses the term

Figure 1.1. A map of the Middle and Upper Nile, showing relevant geographic features, important medieval sites, modern cities, and international borders.



Nubia to refer to the region, Nubians to refer to inhabitants, and the centers of political power to refer to particular phases of Nubian cultural history (Table 1.1).

In the twentieth century, historical research and the archaeology of urban centers and royal burials defined the political history of the northeast African Medieval Period in broad strokes. Despite a wider interest in ancient Nubia in recent decades, broad swathes of time, desert, and river valley remain unknown to Western scholarship. Previous research in Nubian bioarchaeology tends to consider single sites in isolation, or conflate geographic with temporal changes, in an attempt to create a simple narrative of change over time in a broad region of the Nile. Families and villages do not exist in isolation, however. A single site cannot represent over 1000 kilometers of river valley, yet the totality of human skeletal remains from any period in Nubian history often come from only one or two sites.

Table 1.1. Chronology of Nubian political history, 1500 BCE to 1500 CE. Modified from Edwards (2004e).

Dates (approx.)	Nubia	Egypt
1500–1100 BCE	Late Kerma (New Kingdom annexation)	New Kingdom (XVIII–XX Dynasties)
1100–800 BCE	Post-Annexation	Third Intermediate Period (XXI–XXII Dynasties)
800–350 BCE	Napatan Kingdom	Third Intermediate Period and Late Period (Assyrian/Persian Rule) (XXIII–XXXI Dynasties)
740–660 BCE		*Napatan XXV Dynasty*
300 BCE–350 CE	Meroitic Empire	Ptolemaic (Greek) Period and Roman Empire
350–550 CE	Post-Meroitic	Byzantine Period and Sassanid Rule
550–835 CE	Early Medieval	Arab Rule (641–969 CE)
835–1170 CE	Classic Medieval	Fatimid Rule (969–1171 CE)
1170–1500 CE	Late Medieval	Ayyubid and Mamluk Rule (1171–1250 CE, 1250–1517 CE)

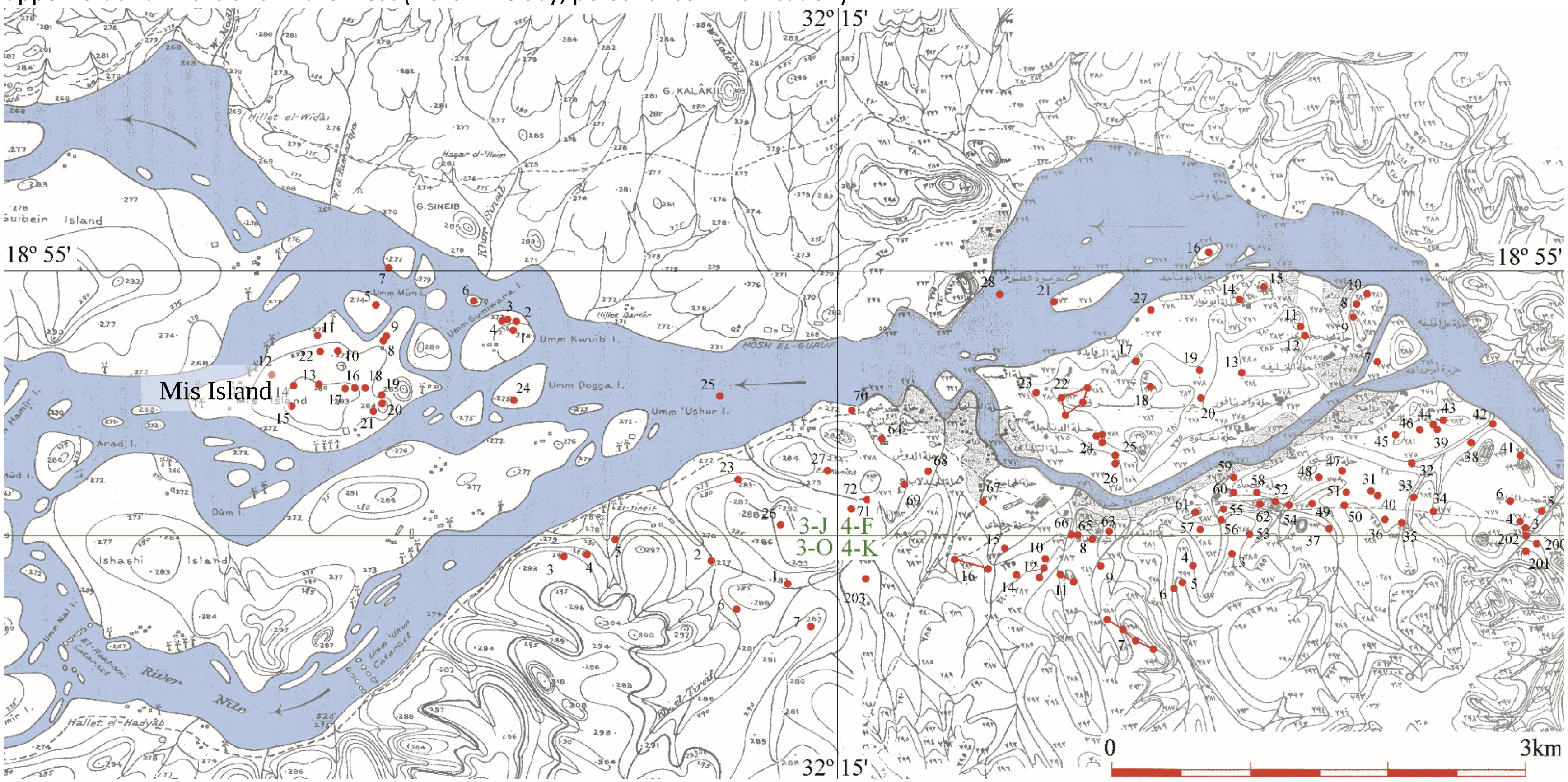
In addition to the impressive urban centers whose cultures and funerary ceramics have defined the Nubian timeline, rural agricultural communities have dotted the length of Middle Nile for close to twelve thousand years wherever climate and technology allowed. Yet little is known about such communities, especially upriver from the first cataract. Further, the Medieval Period (550–1500 CE), which was not renowned for monumental architecture like Pharaonic times, was largely ignored by twentieth century archaeologists. Nearly all of the first century of Nubian archaeology was performed as salvage archaeology between the first and second cataracts, in the region known as Lower Nubia. Upper Nubia represents the majority of geographic Nubia, spanning from the second cataract to the beginning of the Nile. The extensive Merowe Dam Salvage Archaeology Project, undertaken in the 2000s along the rocky fourth cataract, represents a wealth of new possibilities to investigate Upper Nubia, the Medieval Period, and Nubia as a whole.

MEROWE DAM ARCHAEOLOGICAL SALVAGE PROJECT

The Merowe Dam was completed in 2009, following three decades of salvage archaeological efforts surrounding the dam, reservoir lake, resettlement areas, and new power lines (Ahmed, 2014a). In anticipation of the flooding caused by the creation of the Merowe Dam's reservoir lake, the Sudanese National Corporation for Antiquities and Museums collaborated with foreign institutions to form a massive multi-national salvage archaeology project. The Merowe Dam Salvage Archaeology Project (MDASP) was composed of extensive excavations along 170 kilometers of the fourth cataract of the Nile. The main sample for this dissertation is the skeletal remains of 289 adults from three cemeteries on Mis Island (Figure 1.2), excavated by the British Museum and the Sudan Archaeological Research Society (SARS) as part of the MDASP.

Prior to the MDASP, almost no archaeology had been carried out along the fourth cataract (Gissema, 2014; Osypiński, 2014), and Nubian scholars commonly characterized this region as an uninhabited periphery (Adams, 1966, 1965, 1964). However, the MDASP identified many new sites that emphasize the long history of inhabitation of this region, as well as it strategic importance and regional connections (Welsby, 2006a). The reach of Lower Nubian Kerma culture is now known to have extended to the fourth cataract in the third millennium BCE (Paner, 2014). And although the presence of a series of forts along the fourth cataract had been known to European travelers since the nineteenth century,

Figure 1.2. Map of the central region of the SARS concession of the Merowe Dam Archaeological Salvage Project, showing section 3-J in the upper left and Mis Island in the west (Derek Welsby, personal communication).



MDASP excavations provided context. The forts date to a short period in the mid-first millennium CE and were likely built by a central government due to the large scale of construction and the strategic clifftop placement of the forts (Zurawski, 2014). Already, the MDASP has demonstrated that the fourth cataract more closely resembled a rural heartland than an "uninhabited periphery."

MIS ISLAND EXCAVATIONS

The Mis Island skeletal sample was excavated as a part of the Sudan Archaeological Research Society (SARS) Amri to Kirkeban concession (Welsby, 2007). The entirety of the SARS concession, located along the fourth cataract of the Nile, was surveyed and excavated from 1999 to 2007 (Ginns, 2007, 2006; Welsby, 2003). The SARS concession included sites ranging from the Neolithic (9800–4500 BCE) to the Post-Medieval Period (1500–2000 CE; Welsby, 2003). Mis Island itself was likely inhabited as early as the late Meroitic Period (Ginns, 2010b), and the Muslim portion of cemetery 3-J-10 was still in use at the time of excavations (Ginns, 2010c).

Excavations at Mis Island focused on the Medieval Period (550–1500 CE), especially: the church (Ginns, 2010d); cemetery 3-J-18 surrounding the church (Ginns, 2010a); cemetery 3-J-10, located 300 meters northwest of the church (Ginns, 2010c); cemetery 3-J-11, located near the northern edge of the island (Ginns, 2010b); cemetery 3-J-20, located at the highest point on the east side of Mis Island (Ginns, 2010e); and medieval settlement 3-J-19, 50 meters east of the church and north of cemetery 3-J-20 (Ginns, 2010f).

Subsistence agriculture and animal husbandry both contributed to life on Mis Island. The cultivation of sorghum and millet in Nubia dates to the late first millennium BCE (Edwards, 1996a), and it intensified with the spread of the *saqia* water wheel through rocky Nubia, where the floodplain *seluka* agriculture favored downriver in Egypt was not feasible. Ceramic evidence indicates that *saqia* water wheel irrigation technology was adopted by farmers in the fourth cataract in the late fifth and early sixth centuries CE, increasing the land available for agricultural use (Thomas, 2008), and evidence of a cluster of circular animal enclosures or pens was found with medieval ceramics on Mis Island (Ginns, 2010f).

Islands such as Mis have long been a favored settlement location because of their rich resources and naturally defensible positions (Ahmed, 2014a). Settlement sites may have been near the river or floodplains or seen reuse over decades or centuries – these factors would result in reduced survivability of settlement sites from antiquity to modern times, leading to a biased archaeological record (Ahmed, 2014a). Perhaps one or both factors explain why no medieval settlement sites were found on Mis Island. In modern times, the flora of the islands and riverbanks were represented by “oasis type vegetation” near the riverbanks, with a barren desert landscape beyond the immediate reach of the river. This pattern of inhabitation on the banks and islands would certainly affect communication, trade, and exchange of mates between villages. Multiple generations of families lived together in mud-brick residential compounds in modern times (Welsh 2013), but the organizing principles of who was considered kin and local relationships among families and between villages is unknown in the Nubian past.

THE MIS ISLAND NUBIAN BIOARCHAEOLOGICAL COLLECTION

The human remains from cemeteries 3-J-10 and 3-J-11 underwent initial inventory at the British Museum from 2007 to 2010, at which time they were shipped to the Department of Anthropology at Michigan State University. In the first year, remains were removed from their rough “field-packaging,” including mattress padding that had been sacrificed from the osteologists’ own beds to protect the fragile human remains when supplies ran short (Cate Bird, personal communication). Analysts working under the direction of Dr. Todd Fenton and Angela Soler followed British Museum protocols to clean, label, inventory, bag, and box the skeletal remains of 406 adults and subadults (Soler, 2012).

Following initial curation of the remains in 2010, three doctoral dissertations used the Mis Island Nubian Bioarchaeological Collection as their main sample. Soler's dissertation (2012) analyzed paleopathological indicators of stress and disease for adults and mortuary treatment for all individuals. She used published data on health and disease at Kulubnarti as a comparative sample. Soler (2012) found that mortuary characteristics of burials between the Mis Island cemeteries are similar, but the spatial organization of age cohorts is different in the two cemeteries, suggesting different guiding principles in the placement of new burials (Soler, 2012). Overall health and disease are not statistically significantly different between Mis Island cemeteries 3-J-10 and 3-J-11, but Mis Island experienced greater stress than Kulubnarti populations in the form of cribra orbitalia and maxillary sinusitis. Soler posited, but failed to find evidence to support, the presence of kin-based burial groups in cemetery 3-J-11. Cranial nonmetric data are more appropriate for investigating spatially-defined kin groups.

Hurst (2013) focused on growth and development as well as paleopathological indicators of stress and disease in subadults. Hurst (2013) found some evidence of age-related patterning of mortuary features, such as personal adornment being more often associated with infants and children. She also found that subadults of all ages experienced significant chronic stress in the form of cribra orbitalia, porotic hyperostosis, and localized hypoplasia of the maxillary canine, but there were few significant differences between the two Mis Island cemeteries (Hurst, 2013).

Most recently, Vollner (2016) completed a craniometric biological distance analysis of Mis Island adults. Vollner studied adults from Mis Island cemeteries 3-J-10, 3-J-11, Gabati, most of the Kulubnarti sample, and she used published craniometric data from other African populations to contextualize her findings. She found no statistically significant craniofacial differences between the two Mis Island or the two Kulubnarti cemeteries, so the each pair of cemeteries was grouped for further analyses (Vollner, 2016). Vollner largely rejected the traditional archaeological model where large-scale population migration was responsible for cultural change in Nubia, instead finding evidence for *in situ* development of a single biological population (2016). She also found no evidence to support either patrilocal (virilocal) or matrilocal (uxorilocal) postmarital residence and interpreted the trends surrounding statistically non-significant results as meaningful cultural differences. I provide the first evidence that cranial metric and nonmetric data from the same samples provide similar results in postmarital residence analysis, and I argue that non-significant results are important evidence for multilocality.

CEMETERY 3-J-18

Unlike Mis Island cemeteries 3-J-10 and 3-J-11, the human remains excavated from the cemetery surrounding the church (3-J-18) are housed at the British Museum because many of these remains retain significant amounts of naturally mummified soft tissue (Daniel Antoine, personal communication). Since the Mis Island cemeteries were all in use during the Late Medieval Period (1170–1500 CE), it is not immediately apparent why the microenvironment of only cemetery 3-J-18 would have caused natural mummification. No published studies have been completed on the human remains from cemetery 3-J-18, and this cemetery was not included in the three dissertations on Mis Island cemeteries 3-J-10 and 3-J-11 (Hurst, 2013; Soler, 2012; Vollner, 2016).

Soler (2012) provided maps of the spatial distribution of subadult and adult age cohorts for Mis Island cemeteries 3-J-10 and 3-J-11, but no comparable spatial-demographic plans are available for cemetery 3-J-18. The draft site report for cemetery 3-J-18 (Ginns, 2010a) is the only publication on these remains to date. It includes preliminary age assessments of each skeleton as “infant,” “child,” “adolescent,” or “adult.” To visualize the spatial distribution of age cohorts in 3-J-18, the present study used data from the burial registry (Ginns, 2010a) to create a new map of age cohorts on the cemetery plan (Figure 5.3). Adults, subadults, and infants appear to have been dispersed evenly throughout the cemetery, similar to the pattern seen in cemetery 3-J-11 and different from that observed in 3-J-10.

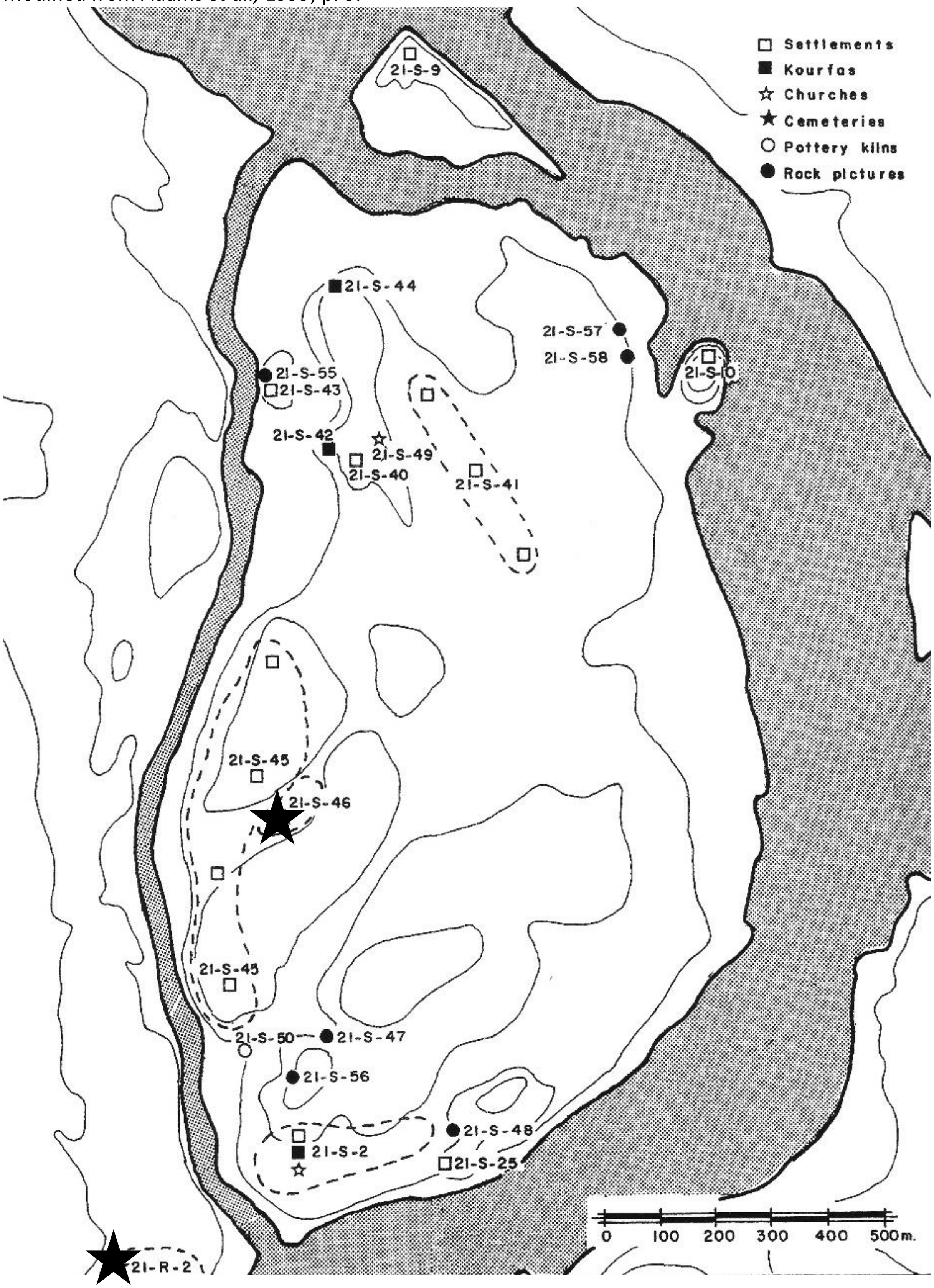
This study is the first to include cemetery 3-J-18 in an analysis of Mis Island. Any interpretation of "life on Mis Island" ought to include the remains from the cemetery surrounding the church, especially since it has been suggested that this late medieval cemetery contains political (Soler 2012) or medical (Anna Davies-Barrett, personal communication) refugees from the twelfth through fifteenth centuries CE. Instead, this research shows that the individuals buried near the church were closely related to locals and showed the same amount of variability as samples from the other two populations.

KULUBNARTI

Kulubnarti is located downriver of the third cataract, in the *Batn el Hajar* ("Belly of Rocks") and is about 290 kilometers northwest of Mis Island when travelling overland (Figure 1.1). Named for its rough and rocky terrain, the *Batn el Hajar* is notoriously difficult to traverse both by land and by water and stretches between the second and third cataracts. Kulubnarti was a headland jutting out from the left bank of the Nile in the Medieval Period (550–1500 CE) but became an island after the construction of the Aswan High Dam in the mid-twentieth century. The excavations at Kulubnarti were undertaken in 1969, 1970, and 1979 by the University of Kentucky and the University of Colorado-Boulder under the direction of W.Y. Adams. A total of 19 sites, including 10 settlement sites, were excavated at Kulubnarti (Adams, 2011; Figure 1.3; Adams *et al.*, 1999). Extensive reports of all sites excavated have been published in volumes on the architectural remains (Adams, 2011), artifactual remains (Adams and Adams, 1998), and the cemeteries, focusing on pathology and mortality (Adams *et al.,* 1999). However, spatial data is not available for Kulubnarti. Since the publication of the three-part site report, additional research has slowed, though molecular studies have recently been carried out, including on isotopic indicators of diet (Turner *et al., 2*007) and DNA optimization (Sirak, 2015).

Archaeological analysis of the finds at Kulubnarti suggests habitation from the Early Medieval Period (550–835 CE) and agricultural use from the early Classic Medieval Period (835–1170 CE) through

Figure 1.3. Map of Kulubnarti Island showing site locations. Solid black stars mark the cemeteries. Modified from Adams *et al.,* 1999, p. 3.



modern times (Adams *et al.,* 1999; Adams and Adams, 1998). As at other medieval settlements, agriculture and animal husbandry supported the local population, a tradition which continues to the current day. Few imported wares were found in medieval deposits at Kulubnarti, in contrast to the high frequency of imports seen at Lower Nubian sites (Adams and Adams, 1998). Textiles as well as ceramic and non-ceramic containers are described as utilitarian but of good workmanship, and luxury goods are rare. This evidence as well as the architectural remains from the Medieval Period suggest that the population was not extremely impoverished (Adams, 2011).

Most anthropological studies of Kulubnarti compare the two cemeteries, and sometimes nearby Wadi Halfa, to understand change in the Medieval Period, though no differences were found between early and late groups in craniometrics or dental nonmetrics (Adams *et al.*, 1999; Greene, 1982; Van Gerven, 1982; Vollner, 2016). An increase in health and a decrease in disease from the Early to Late Medieval Period was suggested to be due to increased village autonomy combined with the collapse of a central government (Adams *et al.*, 1999). Soler (2012) found no such difference between early medieval burials and later medieval burials at Mis Island cemeteries 3-J-10 and 3-J-11.

However, new carbon dates performed on samples from both Kulubnarti cemeteries (21-S-46 n = 9, 21-R-2 n = 12) showed calibrated dates with means in the eighth century CE and only a 36-year difference between the means of the two cemeteries (Van Gerven, personal communication). These carbon dates surprisingly show that the two cemeteries had contemporaneous use periods. The mainland Kulubnarti population (represented by cemetery 21-R-2) represents a relatively well-off group, both biologically and in terms of material culture, while inhabitants of the island (represented by cemetery 21-S-46) experienced greater physiological stress and were materially impoverished (Adams *et al.,* 1999). External political forces can no longer be considered a viable explanation for differences between the two Kulubnarti cemeteries. Were these two communities, living in close proximity in such different living conditions, interacting with one another biologically? Or could one have immigrated to the region from elsewhere in Nubia?

GABATI

The Gabati cemetery is located about 40 kilometers north of the ancient capital city of Meroe, between the fifth and sixth cataracts. The survey and excavations at Gabati were carried out by the Sudan Archaeological Research Society (SARS) from 1993 to 1995 in response to a planned road construction project that would cut through the cemetery (Edwards, 1998). The mortuary structures date to the Meroitic (300 BCE–350 CE), Post-Meroitic (350 CE–550 CE), and Medieval (550–1500 CE) Periods (Judd, 2012). No associated settlement was excavated at Gabati. Archaeologists at Gabati were interested in the shifts in burial practices from the Meroitic through the Medieval (Edwards, 1998). Contrary to the dates expected based on political history, carbon-dated samples and diagnostic pottery types show that Post-Meroitic-style burials continued at Gabati for centuries into the Early Medieval Period (550–835 CE; Edwards, 1998). The physical anthropology report for the site of Gabati is available (Judd, 2012), but little independent research has been completed on the skeletal material.

RESEARCH GOALS

The skeletal data available from three cemeteries at Mis Island, two cemeteries at Kulubnarti, and one cemetery at Gabati provide a unique opportunity to compare biological affinity and social organization of contemporaneous rural Upper Nubian groups. Consistent results based on local-level analysis at three distinct sites will provide generalizable conclusions about social organization across medieval Upper Nubia. Further, comparisons with existing data can provide methodological insights into the relative merits of cranial nonmetric and craniometric data at a local and a regional scale. The purpose of this study is to conduct biodistance analyses within and between medieval Upper Nubian sites and cemeteries using cranial nonmetric traits, and to provide statistical analyses comparing previous craniometric analyses to new cranial nonmetric analyses.

Social organization is the ordering of social relations through dynamic processes (Green, 1976). Stojanowski and Schillaci argue that "the dynamic ordering of social relations through individual or collective choice or action… may have consequences with respect to the distribution of material culture, architecture, and biological variation" (2006, p. 64). However, social organization at all levels of society, across Lower and Upper Nubia, in all prehistoric periods, is unknown. Archaeologists often use the distribution of architecture and material culture to reconstruct social organization. In this study, biological variation, as revealed by cranial nonmetric traits, will be used to reconstruct social organization.

The specific goals of the present research are to:

1. conduct biodistance analyses among medieval Nubian sites and individual cemeteries using cranial nonmetric traits;
2. compare cranial nonmetric results with craniometric results;
3. contextualize biological relationships in a wider African context;
4. determine whether postmarital residence practices at each site were virilocal, uxorilocal, or multilocal; and
5. identify kin-based burial groups, if they are present, in each Mis Island cemetery.

This dissertation provides insight into the lifeways and social structure of Mis Island specifically and medieval Nubia in general, with additional inquiry into the comparability of the conclusions reached using two types of phenotypic data on the same samples. The recent craniometric comparisons of cemeteries at Mis Island and Kulubnarti were unable to detect differences between cemeteries at the same sites (Vollner 2016). Cranial nonmetric data, however, show some nonrandom patterning between these pairs of cemeteries. The stark differences in health and disease between neighboring groups, at Kulubnarti especially (Adams *et al.*, 1999), suggest that biologically different living populations may have used the two contemporaneous cemeteries. Thus, the two cemetery samples *should* be considered separately, or differences between neighboring communities may be lost in the lumped sample.

As biological records of past populations, human remains provide a wealth of information about the living communities that created mortuary populations. Nonmetric traits have been demonstrated to reflect underlying genetic relationships among groups. They are relatively easy to collect on a large sample size, and data collection is non-destructive. The use of nonmetric traits of the skull allows investigation of biological relatedness at several levels of inquiry: within cemeteries to analyze spatial organization; within cemeteries or sites to analyze the relative homogeneity of males and females and extrapolate about individual mobility and postmarital residence; among cemeteries to see whether neighboring communities were more closely related than distant communities; and among sites to see whether more travel or exchange occurred upriver or downriver. This research provides a methodological comparison of cranial nonmetric and craniometric data, which has rarely been conducted at a regional level (c.f. Hubbard *et al.*, 2015). Although only three samples were compared across two datasets, the present study found a very high level of correlation among biological relationships at Mis Island, Kulubnarti, and Gabati as detected by cranial nonmetrics and craniometrics. However, an attempt to contextualize regional primary cranial nonmetric data with continental published data reveals a serious limitation of cranial nonmetric data – that of inconsistent definitions and data collection methodologies across studies.

Nubian archaeology and bioarchaeology has focused on questions of population history, determining overwhelmingly that Nubian populations from the Paleolithic to the mid-second millennium CE developed *in situ* (e.g., Godde, 2013; Irish, 2005; Schrader *et al.*, 2014; Vollner, 2016). But few studies have focused on synchronic population structure across Nubia, instead conflating distance both in time and geography in the name of constructing a population history. No other bioarchaeological research has provided an analysis of biology affinity and social organization of Middle and Upper Nubian synchronic populations in any period. Population history studies are by necessity broad, both in time and space, but the regional results they produce are used to inform our understandings of local populations. The reverse is true for local studies –the organization and relationships in and among a few neighboring communities can be extrapolated to inform a greater understanding of medieval Nubian culture.

Research Goal 1 will determine whether trade and social connections among rural villages such as those used in the present study were affected by political boundaries in the Medieval Period. The comparison is among three sites, and Mis Island is the central site geographically as well as the largest subsample. Thus, the distances calculated between Mis Island and Kulubnarti and Gabati, respectively, will shed light on which of the two latter sites was more closely tied to Mis Island. Gabati is the only site located in the far southern kingdom of Alwa. If it is relatively distant to the other two sites, there will be evidence for the impact of royal and state-level trade policies on non-elite rural populations. In addition, Research Goal 1 involves an intra-site study of the relationships among multiple contemporaneous cemeteries from the same site. If cemeteries cluster by site, then a simple isolation by distance model will be supported and the broad patterns of *in situ* population history found by studies like Vollner's (2016) will be supported at the local level as well as at the regional level. However, if cemeteries do not cluster by site, then other forces are at work that connect individual living populations with more distant communities than expected. One possible explanation is the migration of individuals and groups across the landscape.

The three-site comparison will be quantitatively compared to a similar analysis conducted using craniometrics at these three sites, in the main analysis for Research Goal 2. Results from the two datasets that correlate well will support the use of both craniometrics and cranial nonmetrics as useful for reconstructing population history at a regional level. Little previous research has compared these two data types at this level in a bioarchaeological sample, although a recent study tested population history against phenotypic and genetic data (Hubbard *et al.*, 2015).

Vollner (2016) contextualized her regional craniometric results by incorporating them into a global dataset. The analysis for Research Goal 3 will be a contextualization of the six-cemetery cranial nonmetric analysis within a global dataset of cranial nonmetric data. In her comparative craniometric distance analysis, Vollner (2016) found that the three Nubian sites clustered together, with more distant sites from the global dataset being more biologically distant from the main Nubian sites, supporting a continental-level isolation by distance model. Similar results in the present study would provide additional support for the use of cranial nonmetrics at the regional level and would further confirm the validity of combining cranial nonmetric datasets collected by different analysts. Differences would not likely suggest significant differences in the biological relationships revealed by each type of data but differences in the processes of combining categorical versus scalar datasets for cross-study comparison.

Nothing is currently known about kin-based social organization in Nubia. The postmarital residence analysis relating to Research Goal 4 will provide insight into one aspect of social organization in medieval Upper Nubia. If females are more variable at a single site, that suggests that they are the more mobile sex, since a woman is not living near her mother or sisters. This result is more likely to be present in a more patriarchal society, where a man will live near his father and brothers as an adult, because power is centered in the male members of the family group. Two factors point to this likelihood in this study: the male sex of nearly all rulers of Nubia in ancient and medieval times and the patriarchal traditions of the Christian religion, including the sects represented in medieval Nubia.

Postmarital residence patterns address the way communities were regionally integrated through mate exchange. Traditional assumptions and twentieth century ethnographies suggest that most human societies practice patrilocal (virilocal) postmarital residence practices where the woman leaves her family of origin at marriage. However, recent evidence of living humans suggests that flexible, multilocal residence patterns are quite common (Walker, 2015). The presence of stable heterosexual monogamy over the course of adulthood and terms like “husband” and “wife” represent assumptions about binary heteronormative gender roles within postmarital residence analysis, although these concepts may not be universally applicable (Konigsberg and Frankenberg, 2016). With this caveat in mind, the assumption is made in this research that medieval Christian communities recognized heterosexual monogamous marriage as the ideal presented by the church.

Aside from one or two possible references to royal sister-son inheritance being practiced in the second millennium BCE (Lohwasser, 2001), nothing is known about indigenous or medieval kinship structures in Nubia. Vollner's (2016) craniometric data showed an even exchange of mates among populations, with neither sex being significantly more closely related within a site. Such results are not "insignificant" culturally, although they may be so statistically. Instead, following Walker's (2015) framework, these results suggest that both sexes were recognized as having valuable knowledge of subsistence labor practices in medieval Nubia.

The final research goal is limited to the three cemeteries at Mis Island because spatial information is available in the site reports, and it can be linked to sets of individual skeletal remains. Kin-based burial groups are known from pre-medieval cemeteries in Nubia, but Soler (2012) suggested that spatial organization of Christian cemeteries differed from indigenous patterns based on demography. The present study uses biological relatedness to test this idea. The absence of kin-based groups in any of the Mis Island cemeteries would, in part, support Soler's (2012) hypothesis, although it would reject her specific interpretation of the spatial organization of Mis Island cemetery 3-J-11. This research goal will answer the lingering question of whether membership in a biologically defined kin group influenced burial location within one of several contemporaneous local cemeteries.

The Medieval Period was a vibrant and transformational one in Nubia. Early in the Medieval Period, the three Nubian kingdoms officially converted to Christianity, shortly before Islam swept through the Levant and North Africa in the seventh century CE. The presence of Christian buildings, cemeteries and ecclesiastical writings in Greek indicate extensive contact between medieval Nubia and the greater Mediterranean. The impact of a new state religion on the traditional cultural practices of the rural majority is unknown. Christian teachings may have altered local indigenous understandings of community, expanding it beyond kin-based family groups.

The first main contribution of this research is shedding light on the social organization of medieval Upper Nubia. The analyses of postmarital residence and spatial organization of cemeteries provide small-scale evidence for the large-scale impact of Christianity in medieval northeast Africa. These analyses incorporate the mortuary populations of three non-elite sites into the broader narrative of medieval Makuria and Alwa, revealing a disconnection between communities situated in each of the two kingdoms. Kin-based social organization received limited attention in late twentieth century archaeology, but twenty-first century bioarchaeological research is starting to pick up the standard and contribute to a more robust depiction of family and community in past cultures.

The second main contribution of this research are methodological contributions to biological distance studies. Methodological contributions in the present study include the results of a comparison of craniometric and cranial nonmetric data at a regional level and a consideration of the value and hazards of combining cranial nonmetric datasets collected using different standards. Most research using these two types of data has focused on whether they access the same underlying biological information, fairly consistently finding that they do. The present research incorporates aspects of this ongoing question in the field, in the comparison of the three-site analyses using each type of data. However, this is the first study to consider the relative merits of each type of data at different scales of analysis. Craniometrics are better suited to regional, continental, or global analyses, since data collected by multiple researchers are more easily combined. Meta-datasets can contribute significantly to population history studies at these larger scales. At smaller scales, cranial nonmetrics are better able to detect differences where craniometric data would suggest combining subsamples. At the local level, cranial nonmetrics are appropriate for comparing multiple contemporaneous cemeteries, as represented at Mis Island and Kulubnarti, and they can detect kin-based burial clusters within cemeteries.

ORGANIZATION OF THIS DISSERTATION

This dissertation is organized into seven chapters. The following chapter provides a background and review of biological distance studies in anthropology. The data analyzed in this dissertation are known as cranial nonmetric traits, which are one of the types of data commonly used in biological distance studies. Thus, Chapter Two reviews the history of biological distance studies investigating population structure and population history. In addition, the specific applications of biological distance studies to bioarchaeological contexts, and their relationship to anthropological theory, are considered.

Chapter Three provides a background of Nubian archaeology and geography, beginning with a description of the landscape and territories surrounding the archaeological sites in this dissertation. Next, the history of archaeology in the Middle Nile is reviewed, with a discussion of how the research agendas of early scholars have affected the field to the present day. The culture history of Nubia, as it has been reconstructed mostly from archaeological evidence is reviewed next, starting in the mid-second millennium BCE.

Chapter Four presents the each of the research questions asked in the present study. Each research question produced one or several expectations based on previous archaeological and bioarchaeological research. Each expectation is presented along with a justification based on existing research. Chapter Five presents the research materials and methods used in this dissertation. In total, six cemeteries from three sites were analyzed. The plan, basic mortuary features, and demographic profile of each cemetery and site are presented first. The methods of osteological data collection are presented next, including age and sex, nonmetric traits of the skull, and comparative data. Finally, the statistical methods used to test intraobserver error and explore and describe the data are presented, followed by the specific methods used to answer each of the research questions.

In Chapter Six, the results of preliminary tests such as intraobserver error are reviewed first. Then, the results of each research question are presented with a short explanation of the significance of the statistical results. Finally, in Chapter Seven, the results are considered in a broader perspective. Three subsections explore the results in the context of medieval Upper Nubia, the value of using multiple phenotypic datasets, and the constraints of working with a bioarchaeological sample. Future research and concluding thoughts are presented last.

CHAPTER TWO: BIOLOGICAL DISTANCE

This chapter will review the history of biological distance studies using nonmetric traits. The first section will summarize the meaning and applications of distance studies in general. Then, the genetic basis of cranial nonmetric traits will be considered along with a brief review of data collection and statistical approaches. The final section in this chapter will review the scales of application of biodistance studies in bioarchaeological contexts, including previous studies of Nubian skeletal material.

DISTANCE STUDIES

Population genetics is a field of study concerned with quantifying the genetic variation in populations and explaining how observed phenotypic diversity is caused by differences in genotype (Hartl and Clark, 2007). As a subset of population genetics, distance studies are a type of analysis that quantify the biological similarity or dissimilarity within and between groups of organisms – in this study, humans. Distance studies may use two types of biological information: genetic data, such as mitochondrial DNA (mtDNA), nuclear DNA, or Y-chromosome DNA; or phenotypic data, which in skeletal studies may be craniometric, odontometric, or skeletal or dental nonmetric. Distance studies using phenotypic data are referred to as biological distance (biodistance) studies (Buikstra *et al.,* 1990). Until the 1950s, phenotypic data were most often used in "varietal" or typological anthropology, that is to say studies intended to classify the human species into races or types (Hefner *et al., 2*016). Since the introduction of Washburn's New Physical Anthropology, bioarchaeological analyses have increasingly integrated population genetics models to achieve a more holistic and scientific picture of biological relatedness among human groups (Pietrusewsky, 2008).

Since population genetics primarily uses genetic data and biodistance studies use phenotypic data, the relationship between these should be explored in more detail. One goal of analyzing phenotypic data in distance studies is to reveal genetic (biological) relationships. However, a combination of genotype and environmental influences result in the phenotype expressed by an individual or a group. Phenotypic and genotypic data are not interchangeable, but they both reveal underlying relationships of groups of people. Nonmetric data were introduced with an unrealistically optimistic outlook (Berry and Berry, 1969) and disregarded when these claims of near-perfection were refuted (e.g., by Corrucini, 1974). A more nuanced understanding of what the strengths and weaknesses of nonmetric trait data began to emerge in the 1980s. And since the 1990s, DNA data and phenotypic data have been shown to be correlated in human samples at a variety of scales. Studies repeatedly support the use of nonmetric data as a useful proxy for genetic data because they successfully reveal biological relationships among groups.

Narrow sense heritability (h^2) is a measure of how much phenotypic variability expressed by a population is due to additive genetic variability (Falconer, 1960). It is calculated as

$$V_A/V_P$$

where V_A is the total additive genetic variance and V_P is the total phenotypic variance. Perfect correlation of genetic and phenotypic variance results in a score of 1, indicating that the phenotype is 100% genetically controlled and that environmental factors exert no influence. A score of 0 indicates that the phenotype is under no genetic control and 100% of variance is due to environmental influence.

Heritabilities are population-specific, since environmental effects vary among populations, but heritability studies of craniometrics and cranial nonmetrics provide evidence for the general level of genetic control over these phenotypic traits. Animal studies, where animals are raised in controlled environments and with known pedigrees, provided a baseline for researchers by demonstrating that skeletal nonmetric traits are under moderate genetic control. The heritabilities of nonmetric traits were found to be under moderate genetic control in animal studies on grey seals (Berry, 1969), macaques (Cheverud and Buikstra, 1982, 1981a, 1981b), and mice (Richtsmeier and McGrath, 1986). In a human sample, Sjøvold (1984) calculated heritabilities for craniometric and cranial nonmetric traits and reported that several traits from each category had high heritabilities. He cautioned that a trait did not necessarily have high heritability values by virtue of being a cranial measurement or a nonmetric trait. Rather, Sjøvold (1984) showed that both metric and non-metric traits *could* have high heritability. The results were not used to change trait lists because heritabilities are population-specific. The same pedigreed skeletal sample used by Sjøvold (1984) was re-examined by Carson (2006a, 2006b), confirming the presence of moderate levels of heritability.

Still, the meaning of these heritability estimates is far from clear. Despite only moderate individual heritabilities, skeletal metric and nonmetric traits provide valuable genetic information when a large number of traits are employed (Pietrusewsky, 2008; Saunders and Rainey, 2008). This was first demonstrated for nonmetric traits using a mouse model (Howe and Parsons, 1967), and subsequent studies using many traits have demonstrated strong correlations between: nonmetric data and archaeological and geo-linguistic data (Ossenberg, 1976); metric and nonmetric data (Corruccini, 1976; Richtsmeier *et al.,* 1984; Willmore *et al., 2*012); and craniometric and genetic data (Smith *et al., 2*016).

Distance studies, and comparisons thereof, may occur at several geographic scales, including: individual, family, local, regional, continental, and global (Scott and Turner 1997). On family and local scale, Ricaut *et al.* (2010) found close correlations among autosomal DNA, mitochondrial DNA , Y-chromosome DNA, and nonmetric data in a small Mongolian archaeological sample. Additional research using matched datasets (all types of data come from the same individuals) suggests that cranial nonmetrics are more closely correlated with Y-chromosome data, whereas craniometrics are more tightly linked to mitochondrial DNA (Herrera *et al., 2*014). However, both studies caution that nonmetric traits cannot be used to identify specific biological relationships or related pairs of individuals – only clusters of several related individuals.

Recently, a regional approach was used by Hubbard and colleagues (2015). They used matched dental nonmetric and DNA data from six living samples and tested each against a population history constructed using historic, linguistic, and archaeological data. They found the same pattern of relationships using genetic data and population history, but there were discrepancies between these and phenotypic data. Yet the study also found a high (though statistically insignificant) correlation between the biodistances produces by genetic and phenotypic data. Hubbard *et al.* (2015) present their study as supportive of the use of both genetic and phenotypic data to reconstruct population history at a regional scale. Finally, global analyses (e.g., Hanihara *et al.*, 2003), demonstrate the similarity of nonmetric traits to genetic and other phenotypic analysis across human populations. The evidence reveals geographic distinctions in nonmetric trait data and some clinal distribution of trait frequencies within continents. Overall, recent decades' improvements in the sequencing of ancient DNA confirm that cranial nonmetric traits function as acceptable proxies to examine underlying biological relationships of groups of people at several scales of analysis.

Nonmetric traits

Anthropologists commonly use one of several datasets in biodistance studies, including continuous (metric) data and categorical (nonmetric) data. These datasets can also be categorized by anatomical region: cranial, postcranial, and dental. The data used in the current study are cranial nonmetric traits, which over the past century of use have been variably known as quasi-continuous variants (Grüneberg, 1952), epigenetic variants (Berry and Berry, 1967; Hauser and De Stefano, 1989), discontinuous traits (Ossenberg, 1969), or discrete traits (Rightmire, 1972). Following the recommendations of Saunders (1989), Buikstra and Ubelaker (1994), and Pink *et al.* (2016), the discontinuously expressed skeletal traits used in this dissertation to estimate distance within and among biological populations will be referred to as nonmetric traits. Technically speaking, the term "nonmetric traits of the skull" is more accurate than "cranial nonmetric traits," since mandibular traits are also included in most datasets, but in the present study these terms will be used interchangeably. In addition, the present definition excludes macromorphoscopic traits (Hefner and Ousley, 2014), which are used by forensic anthropologists for estimation of ancestry of individual specimens in medicolegal scenarios. Traits now classified as macromorphoscopic traits were grouped with cranial nonmetric traits in some twentieth century literature (e.g., Hauser and De Stefano, 1989). However, recent osteological research uses one or the other, depending on the goal of particular study. Nonmetric traits are more appropriate for distance studies using large samples, while macromorphoscopic traits are used to classify individuals into *a priori* defined categories, such as continental ancestries.

Berry and Berry (1967) published what is arguably the most influential early study of cranial nonmetric traits in a human sample, where they enthusiastically proposed that nonmetric traits were superior to craniometrics for biodistance studies. The authors asserted, without having statistically tested their conclusions, that there were no sex, age, or ancestry-specific effects present in nonmetric data. Such variables have a known effect on craniometric studies, leading the authors to conclude that nonmetrics provided more accurate genetic information. Berry and Berry (1967) also introduced the Smith's Mean Measure of Divergence (MMD) to physical anthropologists, and it remained the most popular statistic in biodistance studies for decades. Smith's MMD is a measure of the difference between two samples when the data are dichotomous categorical (presence/absence), as nonmetric traits are. Yet critics such as Corruccini (1974) quickly determined that there *were* significant differences between the sexes when population was controlled for, and similarly, that racial differences appear when the sexes were separated. Since the 1970s, cranial nonmetric traits have been used to answer bioarchaeological questions, as well as forensic questions. Saunders and Rainey (2008) and Pink *et al.* (2016) provide more detailed narratives of the evolution of nonmetric traits in biodistance.

As discussed above, skeletal nonmetric traits have moderate heritabilities, indicating influence from genetic factors as well as environmental ones. In addition, the mode of genetic inheritance of nonmetric traits was first identified by Grüneberg in a series of studies using a mouse model (1963, 1955, 1954, 1952). Grüneberg examined the presence of the third molar in mice, where the size of the tooth germ is genetically controlled. The underlying distribution of tooth germ size is continuous, but a threshold size must be reached in order for the tooth to develop, so adult expression is discontinuous (Brothwell, 1963). Thus, nonmetric traits do not exhibit simple (Mendelian) inheritance. The type of inheritance described by Grüneberg in the mouse model studies is polygenic threshold characters by Falconer's definition (1967, 1965). Polygenic threshold characters are controlled by many normally-distributed traits, but only present two possible phenotypes, with presence occurring above a certain combined threshold. Non-Mendelian inheritance and the influence of environmental factors are often cited as reasons for the relatively low heritability observed in skeletal nonmetric traits.

Although they are controlled by the same mode of inheritance, the ontogeny of various cranial nonmetric traits may follow multiple paths. Ossenberg (1970, 1969) categorized skeletal nonmetric traits based on the growth pattern responsible for their formation. Hypostotic traits result from an ossification failure. For example, if the bony septum separating the foramen ovale from the foramen spinosum fails to ossify, this condition is referred to as foramen ovale incomplete. In contrast, hyperostotic traits result from excess ossification. For example, if an additional bony septum forms within the mental foramen, this normally single foramen will be divided. Although fontanelle and sutural bones are sometimes treated as a separate category (Hanihara and Ishida, 2001a), they may also be considered hyperostotic traits because they form due to the presence of extra centers of ossification (Hauser and De Stefano, 1989). Finally, only a few vessel- and nerve- related variations are neither hypostotic nor hyperostotic. Ossenberg labeled these emissary foramina (1970). Hanihara and team published the frequencies of nonmetric traits by Ossenberg formation category for 81 global human populations (Hanihara *et al.,* 1998; Hanihara and Ishida, 2001a, 2001b, 2001c, 2001d, 2001e). In a summary publication, Hanihara and colleagues (2003) present their findings that cranial nonmetric traits in global populations tend to mirror population history patterns determined by genetic data and that these traits are selectively neutral.

Nonmetric data collection

Nonmetric trait studies use a macroscopic visual approach and published standards to identify which character states are present for a series of traits. Character states may be defined as dichotomous (presence/absence) or display a series of discontinuous expressions. Berry and Berry (1967) provided definitions and descriptions of 30 traits, and their trait list provided an important data collection standard for the next two decades of cranial nonmetric trait studies in bioarchaeology. Others researchers have since clarified and added to the Berry and Berry (1967) cranial nonmetric trait list, including cranial nonmetrics defined by Dodo (1974) and Ossenberg (1969) and postcranial nonmetric traits standardized by Finnegan (1978) and Saunders (1977). Some postcranial traits are significantly correlated with biomechanical stress and are therefore not preferred for biodistance analysis, such as os acromiale, where the acromion process of the scapula does not fuse to the rest of the bone during growth and development (Hunt and Bullen, 2007), although they are still used by some researchers (e.g., Saunders and Rainey, 2008). The most detailed collection of cranial nonmetric traits and their character state definitions, including drawings and photographs, can be found in the influential volume by Hauser and De Stefano (1989).

There is no standard practice governing which specific cranial nonmetric traits should be collected from a sample. Hauser and De Stefano (1989) present their clear and detailed trait definitions to provide an international standard, but which traits are scored is still decided by each researcher. Buikstra and Ubelaker (1994, p. 86) present a selection of Hauser and De Stefano's traits, but they only detail "primary traits," excluding some "due to their rarity in most North American populations". While this approach is practical in terms of streamlining researcher effort and statistical treatment – the researcher does not waste valuable research time looking for a trait with 0% frequency – it complicates comparison among studies. On the other hand, global analyses have declined in popularity in this century (Saunders and Rainey, 2008), limiting the need for broad comparability of raw data. Perhaps the most parsimonious approach is, as Buikstra and Ubelaker (1994) imply, using recording criteria and traits that other studies have shown to be useful in the region being sampled.

Buikstra and Ubelaker (1994, p. 86) follow Hauser and De Stefano (1989) by recommending that researchers:

1) note presence, absence, and unobservable instances;
2) score both left and right instances of a trait; and
3) record on a multistage or graded scale.

The first recommendation is for a simple reason: without the number of total observations being known, it is impossible to calculate frequency. The failure to follow this recommendation is one of the main flaws with standard British recording practices, according to Tyrrell (2000).

The second recommendation is related to questions of asymmetry in nonmetric trait expression. Most nonmetric traits and all dental nonmetric traits are bilaterally expressed. Although traits on the left and right sides of the body are usually symmetrical, the sides sometimes present differing character states, known as trait asymmetry. There are several ways to handle bilateral and asymmetrical traits in data collection and analysis. In the two methods proposed by Saunders (1989), either only left or only right sides are scored, artificially shrinking the dataset, or both sides are scored, artificially inflating the dataset by providing two data points for each individual in the sample. The researcher may also opt to record the greatest level of expression, regardless of side (Sutter and Mertz, 2004) or score only one predetermined side (Zegura, 1975). However, each of these methods was found to bias the true frequency of the trait (Konigsberg, 1987). Konigsberg suggests that in cases of asymmetry, the side used in analysis be randomly selected (1990).

Finally, the third recommendation is to collect on a multistage scale when possible, which, it is argued, will enable one to capture the maximum amount of genetic data (Hauser and De Stefano, 1989). Because nonmetrics traits are polygenic, Hauser and De Stefano contend (1989) that the complex underlying genetic information is best captured with a multistage scale. However, many studies do not follow this recommendation and instead collect dichotomous data by re-using previously published presence thresholds (Herrera *et al., 2*014; Nikita, 2010). This is the approach used in the present study. This approach was supported by Carson (2006b), who found higher heritabilities using dichotomized data, versus the same data analyzed using a multistage structure .

Because the human skeleton is so plastic during growth and development, only adults are used in almost all studies of cranial nonmetrics traits. However, somewhat surprisingly, Buikstra and Ubelaker (1994) recommend scoring juveniles in addition to adults. This is likely an extension of Hauser and De Stefano's (1989) assertion that age can be ignored in adult samples, but not pre-pubertal material. When cranial nonmetric traits do appear correlated with adult age, they tend to be hypostotic or hyperostotic. These two Ossenberg categories (1970), being growth defects, are prone to continue changing over an adult's lifetime. In this study, only adults were included in the sample because growth and development are still quite active for juveniles, and the ontogeny of individual nonmetric traits has not been documented well enough to support inclusion of older subadults.

Statistics

The specific statistical approaches that will be used in this dissertation are described in detail in the Methods section of Chapter Five. Here, I will provide a brief overview of the application of multivariate statistical measures to human skeletal metric and nonmetric trait data. Multivariate statistics are well-suited to describe and analyze archaeologically defined groups because they treat multiple variables concurrently. Multivariate models have been described as treating populations as "swarms of varying individuals who compose them" (Howells, 1973). In contrast, earlier univariate statistics were limited to the comparison of means or centroids and condensed each population into simple descriptive values. The multivariate statistical procedures that physical anthropologists use most frequently for biodistance analysis include: factor analysis and principle components analysis, which consider underlying variation within a single group; and discriminant function analysis and generalized distance, which describe the relationships among multiple groups (Pietrusewsky, 2008). The focus here will be on generalized distance.

Two generalized distance measures appear frequently throughout the literature on biodistance: Smith's Mean Measure of Divergence (MMD) and Mahalanobis D^2. Smith's Mean Measure of Divergence (MMD) was the first commonly used multivariate statistic for nonmetric trait analyses in human skeletal samples (Pink *et al., 2*016). MMD had been applied to mice by Grewel (1962), and was used on a human sample for the first time by Berry and Berry (1967). Smith (1972) formalized and named the Mean Measure of Divergence (MMD). Despite an overall decline in popularity (Pink *et al., 2*016), some researchers continue to staunchly defend MMD (Irish, 2010; Nikita, 2015). Mahalanobis distance (D^2) (1936) was first used to analyze cranial nonmetric data from a bioarchaeological sample in the late 1980s (Konigsberg, 1990; Williams-Blangero and Blangero, 1989) and is now the preferred distance statistic for analysis of craniometrics (Pietrusewsky, 2008; Relethford, 2016) and cranial nonmetric traits (Pink *et al., 2*016). Each of these measures was developed for continuous data, but corrections are available to allow the use of both MMD and D^2 with dichotomous data. Of particular relevance for this study, the tetrachoric coefficient used in D^2 is argued to be "more appropriate [than MMD] for traits with an underlying continuous distribution that are scored dichotomously such as cranial nonmetrics" (Pink *et al., 2*016, p. 100). In biodistance studies, the Mahalanobis distance is calculated among sites in a pairwise fashion, resulting in a distance matrix containing a single value indicating dissimilarity between groups. The distance matrix may be visualized using a variety of possible clustering methods may be applied (Pietrusewsky, 2008).

In population and evolutionary genetics, genetic variation within populations is most commonly described using Wright's F-statistics (Holsinger and Weir, 2009; Wright, 1951). This value is meaningful in biodistance studies to answer questions about gene flow, migration, and admixture between populations. F_{ST}, or the fixation index, is a special case of Wright's *F*-statistics that measures of the proportion of genetic variance contained within subpopulations ($_S$) compared to the total genetic variance of the total population ($_T$). F_{ST} has a theoretical range between 0 and 1, where 0 indicates no genetic divergence, and 1 indicates total divergence of the subpopulations (Hartl and Clark, 2007). Put another way, an F_{ST} of 0 indicates that no difference is found between groups and 100% of variation is found within all groups, while an F_{ST} of 1 indicates that all 100% of difference is found between groups (Relethford, 2012). Values close to 1 usually indicate species-level differentiation and are therefore unlikely to occur in human population genetic studies. F_{ST} may be estimated from nonmetric trait data if the distance matrix is produced by Mahalanobis D^2, but not from the nonlinear distances produced by MMD (Konigsberg, 2006).

BIODISTANCE IN BIOARCHAEOLOGICAL CONTEXTS

> "Bioarchaeology is the contextual study of the biology, culture, and human evolution of human populations using skeletal remains interpreted within archaeological, historical, and contemporary problem orientations" (Stojanowski and Schillaci, 2006, p. 49).

Bioarchaeology is the study of human skeletal remains from archaeological contexts (Buikstra and Beck, 2006; Larsen, 2015). The main goal of bioarchaeology is to better understand the lifeways and culture of past peoples by combining information derived from skeletal biology with mortuary contexts, archaeological data, and historical and ethnohistorical documentation. Skeletal data allow bioarchaeologists to investigate health and disease, demography, diet and nutrition, social age, gender roles, and social organization, among other topics. North American scholars especially emphasize the importance of integrating anthropological theory in interpretations of skeletal data (e.g., Baadsgaard *et al.,* 2012; Baker, 2016). Since the mid-twentieth century, biodistance studies have been successfully applied to bioarchaeological contexts (Konigsberg, 2006). Bioarchaeological biodistance differs from forensic biodistance in that the former analyzes similarity and dissimilarity in subpopulations and populations, whereas the latter attempts to classify one individual into his or her socially ascribed ancestral category (Hefner *et al., 2*016).

Sample composition and bias

Biodistance analyses are well suited to bioarchaeological investigations, since both have tools to investigate population-level trends. However, the formation of bioarchaeological samples must be considered in their analysis and interpretation. That a skeletal sample is representative of its population is a stated assumption of biodistance analyses (Stojanowski and Schillaci, 2006). Therefore, the ways in which this assumption may be violated must be explicitly stated in a biodistance study. The osteological paradox, which states that a mortuary sample is representative of the dead and not of the living, remains applicable to all bioarchaeological analysis (Wood *et al.,* 1992). Generally, bioarchaeological studies are limited to the materials available. Past events have already affected the sample, so that even completely excavated cemeteries are biased in numerous and subtle ways, including the processes described below. As recommended by Wrobel and Graham (2013), acknowledgement of the biases present in each sample should result in more cautious interpretation of results.

There are a number of funerary, extra-funerary, and post-funerary formation processes that affect and transform the original mortuary sample into the skeletal sample recovered by archaeologists (Weiss Krejci, 2011). Culturally dictated funerary processes affect the decision concerning who is and is not initially included in a cemetery (Weiss Krejci, 2011, p. 70). Social rules define the catchment area, acceptable and unacceptable deaths, and class or status of individuals or families (Knudson and Stojanowski, 2008; Stojanowski and Schillaci, 2006). In sites with multiple deposition methods or mortuary contexts, any single context is unlikely to represent the whole community. Extra-funerary processes may result in a body being lost, abandoned, or deposited in a remote or alternative funerary context, as may happen with war dead. Finally, post-funerary processes, both natural and anthropogenic, also bias the skeletal sample(Weiss Krejci, 2011, p. 77). Postmortem taphonomic damage to the remains may occur because of natural disaster, construction, looting, or use of cemetery land as agricultural fields. Further, the ethical responsibilities of (foreign) archaeologists working in salvage archaeological scenarios often affects the work being undertaken in addition to influencing the sampling strategy (Hafsaas-Tsakos, 2011; Kleinitz and Näser, 2011). Archaeological sampling strategies significantly affect the composition of the bioarchaeological sample, since time and budget rarely allow complete recovery of a mortuary context (e.g., Ginns, 2010c). Sampling strategies may call for an attempt to randomly sample a site or may focus efforts on subadult, elite, or well-preserved burials.

These factors are especially relevant in bioarchaeological studies comparing cemeteries or sites, because each may exert a different influence on each site (Wright and Yoder, 2003). Sampling biases are especially critical to consider in such inter-site analyses (Jackes, 2011). For example, small samples are unlikely to be representative of a large community, as the social rules prescribing inclusion in one of many mortuary contexts likely group individuals who are similar in some culturally meaningful way. The inclusion of biologically or demographically similar individuals will logically result in exclusion of certain individuals, biasing the sample. However, neither should one large sample be used to represent an entire region or time period, when it may be atypical (Wrobel, 2014). This pitfall is especially predominant in bioarchaeology, where multiple or representative samples may not be available for all regions and all periods. Nevertheless, careful selection of comparative samples and an awareness of the biases involved with each prevent overinterpretation of biodistance results (Wrobel and Graham, 2013).

Special considerations of sampling biases also apply to biodistance analyses. First, population history studies must make note of sample formation processes, especially the temporal component. As Cadien *et al.* (1974) critiqued, mortuary samples form as “temporal aggregates” and represent a different analytical unit than a sample taken from a population at one moment in time. The temporal component is another factor that differentially affects sample formation across sites. In biodistance studies, the representativeness of phenotypic traits presents another possible source of bias. This scale of sampling bias is well known in population genetics (Hartl and Clark, 2007), but receives relatively little attention in bioarchaeological biodistance studies. While phenotypic traits are used as a proxy for genotype, we do not consider whether that portion of the genotype is representative of the genome of an individual. The success of cranial nonmetric traits in reflecting underlying biological relationships within and between groups indicates that this concern should not dissuade us from this type of analysis, however.

Population history and structure

Population history, which attempts to reconstruct past relationships among human groups, is arguably the dominant focus of biodistance studies. Nonmetric trait data are used in such studies to approximate phylogenetic relationships among groups and reconstruct past population movements and interactions. The scope of such studies can be very broad. Hanihara *et al.* (2003) use cranial nonmetric traits from 70 global populations to characterize global human diversity. They compress prehistoric, historic, and recent samples, focusing on geographic distance and phenotypic distance without regard to time. A similar approach has been used to reconstruct the peopling of the Pacific (Pietrusewsky, 1983) and North and South America (Herrera *et al., 2*014).

Population structure, on the other hand, describes the relationships among human groups during the same era. Population structure studies are practically nonexistent in Nubian bioarchaeology because there are so few eras represented by more than one or two skeletal samples. The skeletal sample from Tombos, for example, is one of the only samples dating to the late second millennium BCE, when the Egyptian New Kingdom controlled most of Nubia. The relationships between Lower and Upper Nubians during this time are unknown. So is the (biological) impact of the presence of Egyptian colonizers, administrators, or workers who might have lived or settled in Egyptian Nubia. Regional distance studies could answer some of these questions of population structure.

The historical record and previous archaeology reveal little about population structure or trade within Nubia in any period, including the medieval. The biological and economic relationships among the three medieval Nubian kingdoms is also a mystery – what sources exist focus on the external relationships negotiated between Nubia and Egypt and states in the Levant (e.g., Spaulding, 1995). By considering three contemporaneous villages in different regions of Middle and Upper Nubia, the present study reveals a closer link between Mis Island and Kulubnarti than between Mis Island and Gabati.

By further breaking down Mis Island and Kulubnarti into the individual cemeteries, this study recognizes the heterogeneity present in archaeologically defined "sites," especially those composed of several settlements or cemeteries. The three Mis Island cemeteries may represent three subgroups of a single settlement or community, or they may represent three neighboring but spatially or biologically distinct villages. Since medieval settlements were not excavated on Mis Island, the reason for three cemeteries being used contemporaneously is not known. Rather than assume homogeneity across cemeteries, the present study investigates the differences among the cemeteries. This approach allows a finer grain of analysis and the statistical benefit of comparing more similar sample sizes across cemeteries.

While a large-scale approach to biodistance can shed light on the origin or history of a region, small-scale (intra-site) analyses are also valuable tools used by anthropologists to better understand the biocultural adaptations of a single population in the past (Stojanowski and Schillaci, 2006). A benefit of working at this scale is that rather than condensing the variability of populations to a centroid, the insights gained from investigating a single site in depth can be extrapolated to the regional level (Stojanowski and Schillaci, 2006).

The identification of kin clusters, whether families, bands, or moieties, at the intra-site level provides a layer of analysis that is most powerful when combined with other data. When combined with spatial information, mortuary data, or disease and nutrition data, the intersections reveal new information about the social organization of past societies. For example, Howell and Kintigh (1996) discovered new aspects of the political structure of an ancestral Zuni settlement by overlaying mortuary information and biodistance analysis of kin clusters. Kin clusters may be identified in cemeteries with or without hypothesized clusters being identified prior to testing, although this significantly impacts which analyses are appropriate (Stojanowski and Schillaci, 2006). If spatial segregation is apparent, burial groups may be tested as potential family groups, bands, or moieties (Birkby, 1982; Stojanowski, 2005; Strouhal and Jungwirth, 1979). If, however, burials are uniformly distributed in space, other methods can attempt to identify nonrandom distribution of phenotypic traits (Paul *et al., 2*013; Pilloud and Larsen, 2011; Smouse and Long, 1992).

Postmarital residence contributes to social organization, defining relationships between families and communities and contributing to complex societies. Thus, determining postmarital residence pattern is valuable at the local level, but it can also add to an understanding of regional integration. According to Adam's (1947) definitions, a virilocal pattern of postmarital residence involves a husband and wife living near the husband's place of birth or biological kin, whereas an uxorilocal postmarital residence pattern describes a husband and wife living near the wife's place of birth or biological kin. As Stojanowski and Schillachi (2006, p. 64) note, "The dynamic ordering of social relations through individual or collective choice or action… may have consequences with respect to the distribution of material culture, architecture, and biological variation."

Postmarital residence analysis has been applied to bioarchaeological samples since the 1970s (Lane and Sublett, 1972) and has continued to be used on skeletal samples from around the world (Konigsberg and Frankenberg, 2016). Phenotypic data sheds light on postmarital residence by analyzing the variability within each sex. Assuming heterosexual monogamous adult relationships ("marriages"), a newly married couple, who prior to marriage had each lived near their respective kin, will have their postmarital residence location prescribed by social norms. Where virilocal postmarital residence dominates (so that couples live near the husbands' biological kin), males in the community will be more closely related to one another. In the same instance, females in the community, who migrated to live near their husbands' families from a variety of original kin groups, will be less closely related. Phenotypic data can determine which sex is more homogenous at a site and therefore the less mobile sex (Spence, 1974a, 1974b).

The same phenomenon can be tested across communities. In the same virilocal scenario described above, males in each community are more closely related to each other while being isolated from males of other communities, and therefore more heterogeneous across sites. Females are distributed more evenly across communities and appear more homogenous across sites. When examining phenotypic data, the sex with smaller average distances (more homogeneity) between the subsamples will be the more mobile sex (Lane and Sublett, 1972). These assumptions are the basis of postmarital residence analysis using both craniometrics (Petersen, 2000) and cranial nonmetrics (Konigsberg and Frankenberg, 2016).

The biocultural approach

The results of biodistance studies are meaningless without an interpretive context. The biocultural approach promotes consideration of several lines of evidence to understand bioarchaeological results (Buikstra, 2006). Kakaliouras (2017) argues that this is insufficient without integration of archaeological and sociocultural theory. In the present research, theory of community, as promoted by Kakaliouras (2017), is a key factor in biodistance research at the intra-site level. As articulated by Johnson and Paul (2016), a modern theory of family allows for flexible and inclusive definitions that the incorporation of social relatedness into bioarchaeological studies of kinship and permit a deeper understanding of family-based social organization. In the present study, this framework is necessary for interpretation of postmarital residence patterns as well as spatial distribution of kin-based groups within individual cemeteries.

Kin-based social organization, although a major focus of early ethnographic research, is a difficult structure to access via material culture (Johnson and Paul, 2016). However, biological remains, the focus of bioarchaeology, are well-suited to investigating kin-based social organization in past cultures. Problematically, Western notions of kinship as synonymous with biological relatedness have often been projected into the past with little consideration for the variable relationship between these two concepts across cultures (Johnson and Paul, 2016). Where architectural or historical evidence provides information about kin-based social organization, this is less likely to be an offense committed by bioarchaeologists. At regional, continental, and global scales, biodistance research can successfully reveal relationships among broadly defined populations. Following the early continental and global studies, the methods of biodistance analysis were applied at local and family levels with little consideration given to the social construction of family or community, even in well-executed biodistance studies (e.g., Ricaut *et al.*, 2010). It is at these levels that the split between socially constructed kinship, as envisioned by sociocultural anthropologists, and biological affinity, as defined by bioarchaeologists, should be reconciled (Meyer *et al.*, 2012).

The term “community” has a complex etymological past in general usage and in archaeology (Kakaliouras, 2017). In the present study, the interactionalist definition proposed by Canuto and Yaeger (2003), wherein community is a social process bounded in part by shared space and practice and which interacts with individual and local identities. This definition is fluid and maps inexactly onto archaeologically defined sites. In the case of Mis Island, groups that practiced funerary ritual in three spatially distinct cemeteries may be considered distinct communities. No landscape or settlement archaeology can shed light on other aspects of community identity in this geographically isolated region yet differing uses of space within a cemetery suggest differences in religious practice on Mis Island (Soler, 2012). The same is likely true at Kulubnarti, where the two cemeteries differ in location, and significant health differences are apparent in the mortuary populations (Adams *et al.*, 1999). No definition of community as a circumscribed social unit is appropriate for all places and times (Kakaliouras, 2017, p. 19). However, at Kulubnarti and Mis Island, whether or not they lived in close proximity (unknown at Mis Island), multiple communities were present at each archaeologically defined site, and these consisted of individuals who practiced funerary ritual in discrete spaces.

Spatial organization within cemeteries is a central focus of the present study. The goal is to determine whether biological affinity significantly influence burial location within a cemetery. Pre-medieval Nubian cemeteries display spatially distinct burial groups within cemeteries, which have been shown to have a strong within group biological affinity (Nado and Baker, 2013). In the case of this research, the search is for family groups within larger communities (represented by different cemeteries) on Mis Island. In addition, the analysis of postmarital residence is a search for the socially directed choice of a married couple to live near the husband's versus the wife's kin. It is fundamentally a question of family and kin-based social organization. Research on modern humans shows that even when social norms prescribe postmarital residence near either the husband's or the wife's kin, most humans practice a flexible "multilocality" (Walker, 2015).

Kinship research in the twenty-first century continues to emphasize methodological improvements in the detection of biological kin (e.g., Konigsberg and Frankenberg, 2016; Kuba, 2006; Ricaut *et al.*, 2010), with varied integration of theoretical developments in kinship (Johnson and Paul, 2016). In the present study, the archaeologically defined site is considered the "local" level of investigation. It is recognized as an artificial grouping based on geography and the vagaries of site formation and preservation – other nearby villages may have been present and had close social ties with the remains represented by the archaeological assemblage, but we are only aware of what has been recovered. Within each site, intra-site comparisons are possible at the community level, defined here as the living population from which each of the discrete mortuary populations are derived. Finally, the family level can only be identified biologically, although in reality several group and individual identities would have contributed to the social identity of a family.

At the family, community, or local level, it would be ideal to be able to distinguish between biological affinity and other measures of identity as they contribute to kin-based social organization. However, this task is exceedingly difficult in medieval Nubia, where the only grave good in adult burials is a simple shroud. Without grave goods or differentiation of superstructures, social identity, as ascribed by survivors performing the funerary rituals, is practically inaccessible. Scott (2012) argues that characteristics shared by many or all burials reveals a community sense of religious identity. Her case study of medieval Christian Ireland applies well to medieval Christian (and Muslim) cemeteries in Africa. What is otherwise seen as an absence of individual identity a choice to follow religiously prescribed burial norms, which present individuals from all strata of society as equal in death. Although kin-based social organization cannot be determined fully by assessment of biological affinity, a careful consideration of the limitations of biological affinity analyses will prevent overinterpretation of the results.

Nubia

Biodistance studies in Nubia began as tests of archaeological hypotheses. For example, early Nubian scholars posited successive waves of migration to explain the changes in pottery. Reisner famously used a framework of competing populations. In his narrative, "Caucasoid" Egyptians to the north were correlated with times of centralized political power ("civilization"), and "Negroid" Africans from the south were correlated with times of decentralized political power (Reisner, 1923a). Reisner and other early scholars suggested that Libyans migrated to Nubia at the beginning of the first millennium BCE, explaining the rise of the Nubian Pharaohs, who ruled Egypt as the XXVth Dynasty (Larsen, 2015). Diachronic, usually regional, biodistance analysis was applied to questions of population history in ancient Nubia, with findings supporting *in situ* development of local populations and little evidence of population replacement from the Neolithic (9800–4500 BCE) through Medieval (550–1500 CE) samples (Fuller, 1997; Godde, 2009a, 2012; Irish, 2005; Johnson and Lovell, 1995; Prowse and Lovell, 1995; Stynder *et al., 2*009; Van Gerven *et al.,* 1977). These population history studies repeatedly demonstrate that indigenous Nubians were responsible for developing state-level political structures and constructing monumental architecture in the Middle Nile. The presence of *in situ* population development contradicts and rejects the racist ideas of the early twentieth century that posited that only an influx of light-skinned migrants and Mediterranean ideals could explain Nubian civilization. Medieval Nubia, then, is represented by three kingdoms in a region with a long history of self-rule and centralized regional power. Nubia, now firmly established by biological evidence as a cultural center in its own right, is a valid subject for further independent study, not merely a peripheral sometime-territory of ancient Egypt.

Little intracemetery biodistance work on Nubian skeletal remains has been independently published, with the exception of recent studies by Nikita (2015, 2010; Nikita *et al.,* 2012) and Vollner (2016). The former includes medieval populations in a diachronic regional analysis, however, and the latter generally takes a regional perspective. Vollner (2016) tests sex-specific variation, but her results were inconclusive as to postmarital residence pattern. As critiqued by Stojanowski and Schillachi (2006) and Tyrrell (2000), site reports do not integrate biodistance analyses into interpretations of past peoples (Van Gerven and Greene, 1999), or they provide only descriptive accounts of nonmetric traits in the skeletal sample without providing frequency counts (Judd, 2012; Welsby *et al.,* 1998). Instead, small-scale biodistance analyses in Nubia have used a forensic anthropological model to place individuals from frontier regions into “Egyptian” or “Nubian” categories (Buzon, 2006; Irish and Friedman, 2010).

Overall, little is known about the social organization or social structure of any of the medieval Nubian kingdoms, although the presence of Christian architecture and mortuary patterns indicates contact with the greater Mediterranean region. Regional studies have been necessary to craft a population historical narrative with more nuance than that provided by traditional history (e.g., Fage and Oliver, 1978). Yet they are too broad in scope to shed light on the lived experiences of individual people, as they engaged with kin and neighbors within and among villages. Multi-local studies, such as the approach used in this dissertation, allow fine-grained analysis and extrapolation of local results to regional scale. Furthermore, comparison of scalar (metric) and categorical (nonmetric) epigenetic data show that they are both effective mechanisms for revealing biological relationships among groups at a regional scale, while only nonmetric data identify non-random distribution of traits and family groups in intra-site investigations.

CONCLUSION

Biodistance studies provide an alternate path of inquiry in a skeletal sample when genetic testing is prohibited, unfeasible, or unavailable. Biodistance studies are grounded in population genetics theory and provide important information about within and between group differences using phenotypic data. They increase our understanding of social organization in the bioarchaeological contexts, and can intersect with political organization, health and disease patterning, and other aspects of past cultures. Integration with sociocultural theory and archaeological data is uneven across bioarchaeology, but advocates of the biocultural perspective emphasize the importance of interpretive contributions beyond simple description. Nubian scholarship has overall fallen short in this regard, as most biodistance studies have attempted to test old theories of population replacement and mass migration, with little attention paid to social organization, especially in the Medieval Period (550–1500 CE).

CHAPTER THREE: ARCHAEOLOGY AND GEOGRAPHY OF NUBIA

The Middle Nile stretches for hundreds of kilometers, snaking through northern Sudan as a rocky river interrupted by cataracts, then widening into the Lower Nile below the first cataract, where it enters Egypt. The vast majority of archaeology in Sudan has been done in Lower Nubia, and the majority of that focused on Pharaonic times. The broad region stretching from the barren and rocky *Batn el Hajar* (between the second and third cataracts) to the rich riverine region known as the Gezira (the wedge of land between the White and Blue Niles) encompasses Upper Nubia. Archaeology in this region is spotty at best, although recent efforts have enriched our understanding of the ancient and medieval kingdoms in Upper Nubia. Historical references are sparse, as well. Nevertheless, medieval Nubia had several dynamic cultural centers engaged with the greater Mediterranean. The medieval Nubian kingdoms were also politico-religious players in the dramatic expansion of and competition between Christianity and Islam in northeast Africa in the late first millennium CE.

In European and Levantine historical and travelogue sources (Fauvelle-Aymar, 2013; Hess, 1965; Vantini, 1975), Nubia features as the kingdom unexpected in the African wilderness. These writings do not tend to differentiate among peoples in northern Sudan and modern Ethiopia. Early twentieth century racist thought asserted that Nubians were merely passive, savage recipients of “culture” imported from Egypt and Greece (Reisner, 1923a). Nubian archaeology finds its roots in scholarship of the nineteenth and twentieth centuries, which presumed the supremacy of European bodies, culture, and political structures. By extension, the light-skinned Egyptians, whose ancient ancestors were known to have been great artists and monument-builders, were assumed to be superior to their dark-skinned neighbors to the south. However, when Nubia is placed at the center of its own cultural history, it becomes clear that it was a free-standing state-level culture that had diplomatic relations with not only Egypt to the north but the Roman, Byzantine, Assyrian, and Arab Empires in their times.

The Medieval Period is a politically defined period beginning in the mid-sixth century CE across Nubia, when the three medieval kingdoms were simultaneously coalescing. The Christian Period is archaeologically defined as the period of use of Christian mortuary practices, which were variably adopted across Nubia and within individual communities and used between the fifth and sixteenth centuries CE. The use of Christian (archaeological) as synonymous with Medieval (political) is traditional in Lower Nubian scholarship. However, this usage is problematic in Upper Nubia, especially in the Early Medieval Period, due to the tempo of the spread of Christianity and the imperfect correlation between a change in religious beliefs and a change in funerary tradition

This chapter is intended to provide an overview of Nubian archaeology and geography. A summary of the geography of Nubia situates the collections used in this study on the landscape. The history of Nubian archaeology is also reviewed, highlighting the basic need for investigation of non-elite lifeways and social organization across Upper Nubia. Finally, a historical perspective is provided by a review of Nubian kingdoms and cultures in the eras leading up to and including the medieval. The center of Nubian power and culture shifted over time, and periods of centralized power and empire were interspersed with periods of decentralization. Strong, centralized self-rule is associated with selective adoption of foreign cultural practices, including mortuary practices, a pattern visible in the study sample in the Medieval Period.

By studying the human remains associated with several rural medieval villages, I access a bottom-up view of how Nubian culture was organized. Social organization influences the ways in which individuals interact and indirectly affects the distribution of material culture across the landscape. Perhaps the patterns of kinship and mate exchange seen across Upper Nubia can shed light on the ruling elite, about which little is known. By virtue of the naming conventions, Upper Nubia is sometimes treated as if it were a single culture, but differences in rural patterns could reveal differences between the better known Lower Nubian kingdoms and the less well known kingdom of Alwa to the south.

NUBIAN GEOGRAPHY

The Egyptian Nile is known for being easy to travel, since the prevailing winds aid travel upriver/South, while the current pushes downriver/North. The geographic terms “Upper” and “Lower” in Nubia and Egypt refer to the flow of the Nile, with upper regions being furthest upriver or south and lower regions being downriver or north (Edwards, 2004a). Cataracts are rocky granite regions along the Nile, which, especially at low water levels, require careful navigation or portage of goods and vessels. They are used by archaeologists to define geographic stretches of the Nile and commonly represent political boundaries (e.g., Adams *et al.,* 1999). For example, the traditional southern border of Egypt was (usually) around the first cataract (Edwards, 2004a). The region between the first cataract and the Nile Delta is known as the Lower Nile. The Middle Nile is the region between the first cataract and the confluence of the White and Blue Niles near modern Khartoum, Sudan (Edwards, 2004a; Welsby, 2002a).

Lower, Middle, and Upper Nubia, then, are divisions of the Middle Nile. Lower Nubia stretches from the first to the second cataract and spans the modern Egyptian-Sudanese border. Much of Lower Nubia was flooded by the creation of Lake Nasser after the construction and expansion of the Aswan Dam in the 1900s and 1960s. The region between the second and third cataracts is sometimes included in Upper Nubia (Adams, 1977; Edwards, 2004e; Welsby, 2002a), but designated Middle Nubia by some scholars working in that region (e.g., Adams *et al.*, 1999). As Adams *et al.* (1999) point out, the use of the second cataract to differentiate between Lower and Upper Nubia is more an artifact of the history of Nubian archaeology than a distinction based on the culture history of Nubia. It splits Nubia into two grossly uneven parts, the larger of which (Upper Nubia) is quite culturally diverse. Thus, it is better to follow Adams *et al.*’s (1999) definition of Upper Nubia as the region from the third cataract to the confluence of the Blue and White Niles.

The landscape of Nubia is extreme, limiting subsistence and settlement options for its inhabitants, who have relied on a mix of settled agriculture and seasonal pastoralism since the Neolithic Period (9800–4500 BCE). The cultural importance of livestock was especially evident in the second millennium BCE in the form of hundreds of cattle skulls found in royal tombs (Edwards, 2004b). Early grains including wheat and barley were imported from the north as early as the Neolithic (Edwards, 2007), while indigenous crops such as sorghum were not developed until the first millennium BCE (Fuller, 2004). These became widespread in Lower Nubia around the fourth century CE (White and Schwarcz, 1994). Evidence for bakeries and the preservation of fish dates to the early first millennium BCE (Edwards, 2004d). In Upper Egypt and some parts of Lower Nubia, annual inundations permit *seluka* agriculture, which relies the silt and nutrients deposited on the floodplain by annual inundations. Elsewhere, irrigation is required for successful agriculture. In arid regions without a wide floodplain, including the areas where Kulubnarti and Mis Island are situated, use of the *saqia* waterwheel has been common since the fourth century CE (Edwards, 2004f).

The site of Gabati is in Upper Nubia, near the ancient capital of Meroe, between the fifth and sixth cataracts. Below the fifth cataract, the Nile bends at Abu Hamed, temporarily flowing south (Figure 3.1). Along this stretch, where the normal direction of the Nile is reversed, lies the extraordinarily long and rocky fourth cataract. Mis Island is situated within the fourth cataract region, where upriver travel is nearly impossible, such that the preferred route of travel between Napata and Meroe was over the desert known as the Bayuda. Between the fourth and third cataracts, where the Nile bends again and resumes a northerly course, the region is known as the Dongola Reach, an ancient seat of power and location of Old Dongola, a medieval capital. The rocky *Batn el Hajar* region between the third and second cataracts is either included as part of Upper Nubia (Edwards, 2004a; Welsby, 2002a) or distinguished as Middle Nubia (Adams, 1994; Adams *et al.,* 1999; Adams and Adams, 1998).

Neighboring polities included Egypt to the north, Libya to the northwest, and Ethiopia and the Red Sea littoral to the east. Nubia's relationship with Egypt is the best known and best documented of these, although Nubian kingdoms also had documented diplomatic relations with other kingdoms of the Levant. The kingdom of Axum is the state that ruled northern Ethiopia for most of the first millennium CE (Burstein, 2009). Nomadic peoples inhabited the deserts East and West of the Nile and at times settled portions of the Nile valley, usually in frontier regions between existing polities (e.g., Weschenfelder, 2014). Nubia's relations with its sub-Saharan neighbors to the west and the south are relatively unknown through the Medieval Period.

NUBIAN ARCHAEOLOGY

Most Nubian archaeological excavations have been undertaken as salvage efforts in response to the construction and expansion of dams on the Nile. The building of the original Aswan dam at the first cataract in Egypt at the turn of the twentieth century precipitated interest in Lower Nubia by American archaeologist George A. Reisner (1910, 1909a, 1909b, 1908). Reisner's approach was both progressive and typical of his time: he focused on political history, monumental architecture, and royal tombs. His surveys were methodical, extensive, and remain important to all later archaeology in Lower Nubia. Reisner's later research included excavations at the ancient Upper Nubian capitals of Kerma and Napata (Reisner, 1923a, 1923b, 1920). His chronology of Lower Nubian pottery consists of groups labeled A to Z and is still the basis of the Nubian culture timeline (Table 3.1), albeit with some modifications (e.g., the present study refers to Reisner's X-Group as Post-Meroitic).

Because it was a pioneering effort in the early days of Nubian scholarship, much of Reisner's work has been accepted wholesale, even though large parts would benefit from a critical review. As the field continues to expand, problem areas become more visible. For example, Reisner viewed Nubia as a poor peripheral region, entirely reliant on the superior Egyptians for culture or "civilization." In contrast, Nubian scholars now argue that the Nubian pharaohs who ruled a unified Nubia and Egypt as the XXVth Dynasty selectively and strategically adopted of Egyptian religious iconography to legitimize their rule (Morkot, 2000). There is also ongoing debate about Reisner's king lists, which are based on Upper Nubian royal cemeteries (Kendall, 1999a, 1999b; Török, 1999). Furthermore, although his assumptions about human sacrifices accompanying royal burials at Kerma are often repeated by modern Nubian scholars (e.g., Kendall, 1996), the skeletal evidence does not support such an interpretation of the secondary burials found at Kerma. Edwards unexpectedly suggests that secondary burials represent ritual killing of enemy combatants on the death of a royal (2004b). Yet osteological research on these so-called sacrificial victims finds no evidence of violent or unexpected death (Buzon and Judd, 2008; Judd and Irish, 2009; Judd, 2006).

Around the same time that Reisner was surveying Lower Nubia, John Garstang was directing excavations at the Upper Nubian capital of Meroe (Garstang, 1913, 1912, 1910; Garstang and George, 1914; Garstang and Griffith, 1911). Although he is not recognized as often as Reisner, Garstang was also a pioneering practitioner of modern archaeological methods. Certainly, his work is as foundational to Upper Nubian archaeology as Reisner's is to Lower Nubia. While Garstang's geographically broad interest meant that he was never perceived exclusively as an Egyptian or Nubian scholar, the difference in legacy must in part be ascribed to the continued interest in Lower Nubia encouraged by the nearly constant need for salvage archaeology.

The premier Nubian archaeologists of the 1930s and 1940s were Emery and Kirwan, who together surveyed a series of Lower Nubian sites (Emery and Kirwan, 1935). Lower Nubian royal tombs at Ballana and Qustul were excavated by Emery (1948), while Kirwan constructed a history of medieval Nubia combining written sources with archaeological data (Kirwan, 1935). Additional excavations were completed at the Middle Nubian sites of Sesebi and Amara West around this time (Fairman, 1948, 1939, 1938). Thus, by the mid-twentieth century, the history of Nubia over the past twelve thousand years had received at least some treatment. A political history of Lower Nubia, though with significant Egypto-centric bias, was beginning to coalesce. Still, relatively few archaeologists were working in Nubia, and they generally did not consider themselves Nubian scholars *per se*, but Egyptian scholars who had an interest in Nubia.

In the 1960s, the Aswan Dam was expanded to what is today known as the High Dam, resulting in extensive excavations at sites such as Meinarti (Adams, 2001, 2000), Debeira West (Shinnie and Shinnie, 1978), and Kulubnarti, Abu Simbel, and Philae (Säve-Söderbergh, 1987). Until this time, excavations had exclusively centered on monumental architecture and royal tombs. This frenzy of new excavations energized scholarship on ancient Nubia and Ethiopia. The first modern comprehensive archaeological reviews were published in the mid-1960s by W.Y. Adams (1966, 1965, 1964), Shinnie and Shinnie (1965), and Trigger (1965). While these reviews provide a political timeline and compendium of known archaeological evidence, they only superficially cover the region between the Third and Sixth Cataracts, with a greater focus on major urban and religious centers. The fourth cataract in particular was considered inhospitable and peripheral (Zurawski, 2014), and almost no archaeology was done there until the 1990s (Emberling, 2012). In addition, cultural history was built on series of funerary ceramics, with little investigation into wares traded and used in daily life.

Since the late twentieth century, Nubian scholars have expanded their focus to include more recent periods, from the first millennium BCE through the Medieval Period (550–1500 CE; Edwards, 2004e; Welsby and Anderson, 2004). Beginning in the 1990s, the international Merowe Dam Archaeological Salvage Project (MDASP) was undertaken to preserve the cultural heritage of the Middle Nile ahead of the construction of the first major dam in Sudan, built at Merowe just downstream of the fourth cataract (Ahmed, 2003, 2014a). Excavations completed through the MDASP focused on the Medieval Period (550–1500 CE) more than previous Nubian efforts had, with this study contributing to a nascent understanding of medieval non-elite lifeways.

Although the Aswan Low Dam, Aswan High Dam, and Merowe Dam salvage archaeology projects have largely defined the focus and scope of Nubian archaeology in the twentieth and twenty-first centuries, academic excavations have also made important contributions to Nubian archaeology. Excavations at the Middle Nile site of Sai Island began in the 1950s and have proceeded intermittently to the present day (Geus, 1995; Azim, 1975; Doyen, 2009). The medieval Upper Nubian capital at Soba was excavated by the British Institute in Eastern Africa from 1981 to 1986 and 1989 to 1992, where evidence of a major settlement dates from the sixth to the thirteenth century CE (Welsby *et al.,* 1998; Welsby and Daniels, 1991). A German-led expedition excavated a religious center at Musawwarat al-Sufra, southwest of the ancient capital of Meroe, in the 1990s (Wolf, 2004). Lastly, the city and cemeteries at Tombos, a major urban center dating to the late second to early first millennium BCE, was excavated in 2000–2004 by a team from the University of California Santa Barbara (Buzon, 2006).

Nubian archaeology has expanded in scope and scale over the past century, yet it is still plagued with significant gaps in knowledge. In addition to the pressures of salvage archaeology, a fascination with monumental, religious, and Egyptian-style architecture has influenced the choice of sites and of periods examined. Transitional periods and times of decentralized power remain either unrecognized or unexcavated, so that a three-hundred-year period in the early first millennium BCE is still referred to as the Nubian "Dark Age."

Little is known about the social organization or social structure of ancient Nubian communities. Sites are too often considered in isolation. In reality, a network of connections made by biology, friendship, and trade stretched among families and villages up and down the Nubian Nile. Even at Tombos, where Buzon (Buzon, 2006) has done some interesting work on frontier identities and individual performance of ethnicity during the New Kingdom annexation (1500–1100 BCE), it is the connection between two abstracted polities that are meeting rather than individual communities.

Aspects of Egyptian culture and Christian culture were each adopted by Nubians for centuries, and the process and pattern of selective integration of these foreign lifeways into local culture is understudied.

Settlement archaeology is still lacking in most regions and periods, and few non-elite cemeteries have been excavated and published. Moreover, while Upper Nubia from the third to the fifth cataract has received increased attention in recent years, Upper Nubia south of the fifth cataract has not enjoyed the same treatment. The medieval capital at Soba remains the *only* significant excavation in the entirety of the vast medieval kingdom of Alwa (Welsby *et al.*, 1998; Welsby and Daniels, 1991). Desert sites away from the Nile also remain difficult to identify and excavate.

Bioarchaeological research in Nubia shares the same limitations as the rest of Nubian archaeology. Royal cemeteries and urban centers have been the focus of both archaeology in general and bioarchaeology specifically, with non-elite material culture and burials poorly represented. Cemetery excavations have produced collections of human skeletal remains representing much of Nubian history, but knowledge of a given period often comes from one or only a few sites. The human remains from Kerma, for example, represent almost all Nubian bioarchaeology from the third millennium BCE. However, recent excavations in the fourth cataract region have uncovered a wealth of skeletal and archaeological materials that will enhance the geographic and temporal coverage of Nubian bioarchaeology (Anderson and Welsby, 2014).

NUBIAN CULTURAL HISTORY

This section will present the history of Nubia as revealed primarily via archaeological evidence. The archaeological findings that inform and characterize each historical period derive from successive and geographically distant urban centers and royal burial grounds. Connections to the extensive internal written history of Egypt and other Mediterranean and Levantine records occasionally allow exact years to be connected to particular rulers, associated artifacts, and monumental architecture (Table 1.1).

Archaeological periods are still largely based on Reisner's ceramic chronology and king lists, developed in the early twentieth century, and based on Lower Nubian grave goods and Upper Nubian elite burials. As the centers of political power shift in time, so too does the topography of archaeological evidence available for certain periods. As a result, significant portions of Nubian history are ahistorical.

Although indigenous writings are scarce in many periods, some indigenous and foreign writings may contribute to Nubian scholarship. For example, Egyptian hieroglyphics are found on Nubian New Kingdom temples and in mortuary contexts, and hieroglyphics are again used in the seventh and eighth centuries BCE by Upper Nubian pharaohs (Edwards, 2004d; Reisner, 1921). After this, there is no evidence that Nubians kept written records until the third century BCE. Medieval writers detail the relationships between Mediterranean polities and Nubia, including historical accounts by Herodotus, Strabo, and Pliny the Elder (Török, 1997c). In addition, medieval scholars benefit from indigenous graffiti (de Voogt and Döhla, 2011), travelers' accounts (Fauvelle-Aymar, 2013; Hess, 1965), and Nubian religious texts.

The Meroitic script, developed around the third century BCE and in use until the fourth century CE, was deciphered a century ago (Griffith, 1911), but its language is not understood. Therefore, unfortunately, the only period with a Nubian language represented by a Nubian script remains inaccessible. In the Medieval Period (550–1500 CE), Greek, Coptic, and Old Nubian were in use as written languages (Łajtar, 2014; Shinnie and Shinnie, 1965). Greek and Old Nubian, which more often appear together, were perhaps preferred by indigenous Nubians. Coptic, then, may have been used by the clergy, who perhaps included individuals who had emigrated from Egypt (Edwards, 2004g). Although Nubians were likely literate and kept accounts and histories, some of the only non-religious Nubian texts known for the Medieval Period come from Qasr Ibrim, and not all of these have been published (Welsby, 2002a). Medieval Arabic historians and travelers wrote about the relationship between Egypt and the Nubian kingdoms, detailing what were by then centuries-old battles and trade agreements.

Although these are valuable resources in their rarity, their biases limit their usefulness in reconstructing a political history (Burstein, 2009; Spaulding, 1995; Vantini, 1975).

Egyptian New Kingdom annexation (1500–1100 BCE)

New Kingdom Egypt controlled parts of Nubia from the XVIIIth through to the XXth Dynasty. Egyptian influence reached as far as Kurgus, south of Abu Hamed, as evidenced by Egyptian inscriptions there (Morkot, 1991). The Egyptian expansion south, which stretched much farther than their control ever had before, was strongly resisted by Nubians. This is shown through studies of the skeletal evidence. Traumatic injuries decreased when Egyptian rule was firmly established in Kerma, whereas interpersonal violence was more common immediately preceding this administrative shift (Buzon and Richman, 2007).

North Africa became more arid during the time of the New Kingdom annexation, resulting in an inhospitable and largely unoccupied Lower Nubia. This low population density continued from the end of New Kingdom rule through the mid-first millennium CE. In contrast, the Dongola Reach appears to have remained largely unaffected: New Kingdom Egyptian rule is clear in the environs of Kerma, as major settlement shifts away from the Kerma Period temple and toward the Nile port.

Evidence of New Kingdom influence in the form of Egyptian-style temples is known in the Napata region (Edwards, 2004b), but little is known about the indigenous religion of Nubia (Edwards, 2004b). Monument building was rare before the Egyptian New Kingdom annexation, when Egyptian state ideology was accepted with some modifications. This pattern is common in Nubian archaeology. Scholars observe the presence of Egyptian-influenced architecture, art, religious iconography, and writing, yet do not seek out the Nubian version of these cultural artifacts.

Over the centuries of Egyptian rule, Late Kerma material culture gradually disappears from the archaeological record, being replaced by Egyptian cultural artifacts (Adams, 1964). Thus, while, Kerma mortuary practices such as contracted bed burials and tumuli are retained through the end of the New

Kingdom, these burials are filled with Egyptian grave goods (Morkot, 2000). This suggests that the Nubian population was culturally assimilated into the Egyptian state architecture, causing the indigenous artifacts to disappear from the record. Indeed, biological data corroborates this view that Nubians were still present, despite the Egyptianization of material culture. Buzon (2008) found that residents of Tombos, near Kerma, were both Egyptianized Nubians and colonizing Egyptians. Isotopic studies, material culture analyses, and written sources suggest movement of Egyptian and Nubian individuals and families up and down the Nile during the New Kingdom annexation and later (Buzon *et al., 2*007; Buzon and Bowen, 2010; Buzon and Simonetti, 2013).

As the Egyptian New Kingdom government began to collapse internally, its hold on peripheral territories weakened and Nubia ceased to be under Egyptian control (Morkot, 2000, 1991). Until this time, an Egyptian-appointed Viceroy of Kush held power in Lower Nubia and the Dongola Reach (Török, 1997d). The decentralization of Egyptian administrative power resulted in a Nubian Post-Annexation Period (1100–800 BCE) of which little is known via archaeological evidence or written sources. It is likely that local rulers and power structures remained in place during this time, especially in far Upper Nubia above the fourth cataract.

Post-Annexation Period (1100–800 BCE)

The collapse of the Egyptian New Kingdom administrative system was accompanied and precipitated by rising powers in Libya and Western Asia, with Libyans and Nubians even attempting to coordinate a joint attack on Egypt (Morkot, 2000). No unifying Nubian or Egyptian State is known during the Nubian Post-Annexation Period, which coincides with the Egyptian Third Intermediate Period. Indeed, much of northeast Africa and the Levant went through a period of restructuring between the late second millennium and early first millennium BCE (Morkot, 2000). The associated sudden absence of written records is more problematic for scholars of peripheral territories such as Nubia, so that the period between the end of Egyptian rule and the rise of the Napatan kings has been referred to as the

Nubian “Dark Age.” This term is problematic for a number of reasons, most importantly the Egyptocentric nature of this assumption and the belief that “civilization” retreated out of Nubia with the end of the Egyptian New Kingdom annexation and did not arise again until centuries later (Morkot, 1994). These undocumented centuries, during which there were certainly significant Nubian inhabitation as in the preceding and following periods, are skipped over entirely by some authors (e.g., Edwards, 2004b, 2004d).

No royal chronology is known in the Dongola Reach during the New Kingdom (1500–1100 BCE) or the Post-Annexation Period (1100–800 BCE). The royal cemetery at el-Kurru is located near Napata and traditionally dated to the seventh century BCE. Its elite burials might shed some light on the pre-Napatan rulers, but there is significant debate surrounding its dating and chronology. Reisner excavated the royal burials at el-Kurru, developed a chronology, and was the first to posit the Nubian “Dark Age.” His chronology remained unquestioned for most of the twentieth century (Welsby, 1996b). However, a robust debate developed surrounding this interpretation (Kendall, 1999a, 1999b; Morkot, 1999; Török, 1999). The traditional Reisner “short chronology” of el-Kurru includes a gap of about 300 years between the end of Egyptian annexation and the rise of the Napatan kings (Kendall, 1999b). The short chronology posits that many early royal Napatan tombs contained 300-year-old “heirloom” pottery grave goods (Török, 1999, 1997d), and an unheard of rate of change in mortuary customs with each successive generation of early Napatan rulers modifying previous practices. Evidence for destruction of some royal tombs throws the question of chronology into further disarray. Morkot is critical of a short royal chronology, insisting that the royal burials must bridge the Post-Annexation Period (1999). There are a number of solutions posited for the existing discrepancies (Morkot, 2000; Welsby, 1996b). One, which cannot be ignored, is the suggestion that undiscovered royal burial grounds exist. While the question of the royal chronology at el-Kurru is not yet decided, local elites likely still ruled Post-Annexation Upper Nubia.

The disagreement over the political history of Nubia in the Post-Annexation Period has in some ways obscured other archaeological data that may shed light on this time of settlement, economic development, subsistence, and cultural change (Török, 1997d). Through the end of the twentieth century, there was almost no archaeological or documentary evidence attributed to the Post-Annexation Period, but lack of data and misinterpretations of existing data may contribute to this apparent gap in archaeological evidence (Edwards, 2004d). New excavations are beginning to fill in the gaps. For example, settlement at Middle Nubian Amara West, previously believed to have ceased at the end of the New Kingdom, is now known to continue through the Post-Annexation Period (Binder, 2014). Fortunately, some researchers are reassessing old data and critically examining new findings to continue filling in the Post-Annexation Period, so that it will no longer be a “Dark Age.”

Napatan Kingdom (800–300 BCE)

When a state-level polity emerged as a regional power in the ninth century BCE, it was at Napata, near the fourth cataract. This Napatan Kingdom quickly unified a fragmented Egypt with Nubia and ruled the Lower and Middle Nile for most of a century as the XXVth Egyptian Dynasty. In total, six Nubian rulers comprised the XXVth Egyptian dynasty. Their combined rule from Piankhy to Tanwetamani lasted from about 740–660 BCE (Edwards, 2004d). Dental evidence suggests a Nubian origin for the Napatan pharaohs, who were likely to have been descendants of local kings left in place when the Egyptian rule ended (Schrader *et al., 2*014). When the Nubian pharaohs fell to the Assyrians in the mid-seventh century BCE, they relinquished state and later religious power in Egypt. Later diplomatic ties linked the Napatan state with Assyrians and Persians (Edwards, 2004d). The fourth cataract was inhabited during the Napatan Kingdom; excavations of settlements and cemeteries indicate continuous inhabitation and contact with regional centers of power (Ahmed, 2014b).

The royal cemeteries for this period are at el-Kurru and Nuri, both located near Napata; with mortuary architecture that was distinctly Nubian (Adams, 1964). The earliest royal tombs at el-Kurru, which likely predate the Napatan Kingdom, are comparable to the Late Kerma tumuli in style and scale: semi-flexed bodies are placed on a bed with a tumulus superstructure (Kendall, 2002). Treatment of royal remains in the Napatan Period takes on an Egyptian character, including supine body position and anthropogenic mummification, both traditionally Egyptian customs, appearing for the first time in the eighth century BCE (Török, 1997d). Five of the six XXVth Dynasty pharaohs were buried in this manner at el-Kurru in square tombs, beneath steep-sided pyramidal superstructures (Welsby, 1996c; Kendall, 2002). At the end of the XXVth Dynasty, royal burials were moved to nearby Nuri. While no major settlement is associated with el-Kurru (Edwards, 2004d), a large temple of Amun was constructed around this time at the nearby holy mountain Jebel Barkal, indicating the continued religious significance of this area. The same mortuary variability found in royal burials is also seen in cemeteries at Kerma, Sanam, and Meroe, where a combination of indigenous and Egyptian-influenced mortuary practices is found, even within the same burial (Adams, 1964; Edwards, 2004d).

Following their reign as XXVth Dynasty pharaohs in Egypt, Napatan kings continued to rule Upper Nubia for three centuries. These rulers continued to apply Egyptian writing to monuments, although derivations from Egyptian style and grammar indicate isolation from contemporary Egyptian writing (Török, 1997e). This isolation is also evident in the depopulation of Lower Nubia from the late Napatan Kingdom through the middle of the Meroitic Empire. Archaeological evidence and written sources are scarce from the sixth to the third centuries BCE, although temple construction continued during this time. In the fourth century BCE, the royal burial ground moved from Nuri to nearby Jebel Barkal. The political disruption indicated by such a move foreshadows the next shift in Nubian power from the Napata region to Meroe, far upriver.

Meroitic Empire (300 BCE–350 CE)

The traditional distinction between the Napatan Kingdom and the subsequent Meroitic Empire is based upon the movement of the royal burial ground from Jebel Barkal in the Napata region to

Meroe. There is no decentralization of power when the capital moves almost 300 km, although this move must represent significant political upheaval. In fact, the Meroitic Empire not only consolidated Upper Nubian political power but expanded its territory. Meroitic rulers reestablished Nubian control of Middle Nubia and expanded their southern and western frontiers. In the north, they ceded the barren first cataract region known as the *dodekaschoinos* to the Roman Empire, which controlled Egypt from about 30 BCE. The Meroitic Empire was the most extensive African kingdom known until the nineteenth century: it stretched as far north as the second cataract and as far south as the Gezira, the region of desert south of the confluence of the White and Blue Niles (Edwards, 2004c).

Meroe was already a major urban center in the Napatan Period, and early burials date to the mid-eighth century BCE. Cultural continuity between the Napatan and Meroitic states is broadly supported by the retention of symbols of kingship and religion, but some distinctions are apparent (Edwards, 2004c; Török, 2006). Meroitic rulers used and modified Egyptian religious iconography to legitimize their authority and built many new temples for worship of both Egyptian and indigenous gods using Egyptian architectural styles (Welsby, 1996c). Apedemak, the three-headed lion god, is a Nubian deity co-opted into otherwise Egyptian iconography during the Meroitic Period, and “Lion temples” dedicated to this deity are common in Upper Nubia, especially near Meroe (Adams, 1974). New handmade pottery types appear, integrating Egyptian and Greco-Roman stylistic influences, but the craftsmanship is particularly fine and has no precursor in the Napatan Period (Adams, 1964). In addition, the development of a Meroitic script signals a break from the past, when written traditions of Egypt were borrowed for use in Nubia.

Settlement and even palatial architecture do not cease in the Napata region, and scholars remain uncertain as to the nature of the complex relationship between Napata and Meroe during the Meroitic Period. Sites near Meroe suggest a dense population in the capital region, intriguingly not centered on the royal residences or Meroe itself (Wolf, 2002). As a region with little monumental architecture, the region between the fourth and fifth cataracts is only referred to in passing in modern Nubian scholarship as a “very inhospitable area” (Edwards, 2004c, p. 154). Recent scholarship has supported the interpretation that there existed a fluctuating but relatively low population density. The pattern of abandonment and re-occupation is attributed to minimal logistical support as well as possible outbreaks of disease, a phenomenon for which records exist in contemporary Egypt (Edwards, 2004c).

The administrative structure of the Meroitic Empire differed from that of Egypt and may have more closely resembled medieval Sudanic kingdoms (Ahmed, 1984). El-Tayeb suggests that regional centers of power were used by the central administration at Meroe to control such a vast empire (el-Tayeb, 2010). And whereas subsistence control was of primary importance in Egypt, this was not a focus of Meroitic control (Edwards, 1996b). Instead, “embassy trade” is thought to be critical to the maintenance of royal power. Other Sudanic and Mediterranean polities also used the embassy trade system. It confirmed royal control over exotic resources, thereby controlling provincial elites. It also linked kings diplomatically with other states and seemed to foreshadow medieval trade agreements (Edwards, 2004c). It is during the Meroitic Period that ironworking reached the Middle Nile, and the state-controlled ironworking industry was prolific (Edwards, 2007).

Mortuary contexts were varied during the Meroitic Empire. Elite burials used Egyptian body treatment, grave goods, and inscriptions within the mortuary chapel (Török, 1997f). Royal Meroitic superstructures include the famous steep-sided pyramids at Meroe, while lesser elite burials used mastabas. The mastaba is a stone or mud-brick platform superstructure found in Lower and Middle Nubia and at Meroe, but not in rural Upper Nubia (Edwards, 2004c). The last royal burials at Meroe used the indigenous tumulus superstructure (Welsby, 1996d). Non-elite Upper Nubian burials were simple, often unmarked by any form of superstructure. Presence of a mastaba usually coincides with an Egyptian-style extended supine east-west body position. Mortuary patterns of the non-royal elite and non-elites mixed Egyptian and indigenous elements, for example, both Egyptianized and Meroitic-style burials often included Egyptian scarab amulets as grave goods (Török, 1997f).

Early Nubian scholars believed that the end of the Meroitic Empire was the result of military incursions from the east (Kirwan, 2002). Based on a victory stelae erected by an Axumite king in the fourth century, historians agreed that the neighboring Ethiopian kingdom of Axum invaded the Meroitic Empire in two waves leaving a devastated Meroe in its wake (Burstein, 2009). However, archaeological evidence indicates a gradual decline in prosperity and power in Meroitic Nubia in the third and fourth centuries CE, with no evidence for a catastrophic event (Edwards, 2004f; Welsby, 1996e). The most likely scenario is that shifting trade routes were a contributing factor in the decrease in power of the Meroitic Empire. The kingdom of Axum may still be to blame, because development of the Red Sea trade benefited Axum and connected them more directly with the Mediterranean world than travel across the Eastern Desert and on the Nile.

Post-Meroitic Period (350–550 CE)

The reasons for the decline of the Meroitic Empire are not well understood, but the Post-Meroitic Period certainly represents a time of decentralized power. In some places in Nubia, cultural continuity is evident through the Post-Meroitic Period (Adams, 2001, 2000; Edwards, 1998; Judd, 2012; Stynder *et al.*, 2009). In others, settlements were entirely abandoned, or saw the immigration of new populations (Edwards, 1994). Cultural traditions from this period have been labeled using the Lower Nubian royal burial ground at Ballana as the type site (Emery, 1948; Trigger, 1969) and Reisner's middle Nubian pottery tradition known as X-Group. But scholars continue to disagree about the relationships between archaeological evidence and the historically referenced Lower Nubian ethnic groups of Beja (Medjay), Blemmyes, Noba, and Noubadae (Dann, 2009). These labels are associated with populations the mid-fourth through mid-sixth centuries CE. This period in Nubia is also rarely called the Late Antique, a term normally associated with European and Mediterranean history (Dann, 2009; Kirwan *et al., 2*002).

Here, the term Post-Meroitic will be used to refer to the culturally heterogeneous Middle Nile following the decline of Meroe and preceding the Medieval Period (Edwards, 1998, 1994).

Small kingdoms may have existed along the Middle Nile during the Post-Meroitic Period. The best known of these is the early Nobadian kingdom, centered near the second cataract. Evidence of the presence of elites comes in part from the lavish burials at Qustul and Ballana in Lower Nubia (Dann, 2009; Emery, 1948). During the Meroitic Period (300 BCE–350 CE), Ptolemaic Egypt had occupied the *dodekaschoinos,* a region of Lower Nubia stretching for 120 kilometers south of the first cataract. During the Post-Meroitic period, the Roman Ptolemies who ruled Egypt retreated from this region, and a nomadic people known as the Blemmyes moved in from the east desert, establishing settlement and rule (Welsby, 1996e). The Blemmyes represented a new population bringing their distinct cultural tradition into Lower Nubia, interrupting the fraught but established Egyptian-Nubian cultural flow. Post-Meroitic and medieval evidence demonstrates close links between the Post-Meroitic Blemmyes (also known as the Beja) and Red Sea Hills people of the Medieval Period (550–1500 CE; Edwards, 2014). The medieval kingdom of Nobadia would eventually reassert control over the *dodekaschoinos* (Edwards, 2004g).

The Post-Meroitic Period saw the divergence of regional traditions within the Middle Nile, something not seen during the unified rule of Meroe in preceding centuries. For example, Meroitic was no longer a state language. Instead, Greek was used in Lower Nubia and local Nubian dialects, related to the modern ethnic Sudanese Nubian language group, became common in Upper Nubia (Edwards, 2004f). And whereas Lower Nubian burial practices had been quite homogenous in the Meroitic, a mix of Nubian and Egyptian mortuary traditions are now seen (Edwards, 2004f). Tumulus burials re-emerged as the most common burial superstructure in the Post-Meroitic Period throughout the Middle Nile, but even within cemeteries, variations are seen in the entrance type, ramp style, burial pit shape, and body placement. Although their popularity declined later, tumuli continue to be used occasionally in Nubian cemeteries until the later Medieval Period (Edwards, 2004f). Regional pottery traditions visible in everyday use items and grave goods foreshadow the cultural divergence of the three medieval Nubian kingdoms (el-Tayeb, 2010).

Settlement changes are varied in the Post-Meroitic Period. Several Meroitic settlements were abandoned (Welsby, 1996e), and deliberate destruction is visible at some temples near Napata (Welsby, 1996d). At the same time, new major urban centers such as Soba, later the capital of Alwa, and Old Dongola, later the capital of Makuria, were established (Welsby and Daniels, 1991). Despite these many changes, the archaeological evidence does not support large-scale migration or population replacement by desert peoples (Edwards, 2014). At Meinarti, near the second cataract in Lower Nubia, population and cultural continuity is present between the Meroitic, Post-Meroitic, and Medieval Periods (Adams, 2001, 2000). Increased settlement in the Dongola Reach and further upstream represented the repopulation of a region that had been too arid for agricultural activity for most of the first millennium BCE (Edwards, 2004f; Thomas, 2008; Godlewski, 2014). Changes in settlement patterns there may have been in part due to the new *saqia* water wheel, permitting irrigation agriculture for the first time along the Nile, a likely driving force of population expansion in Lower Nubia during the late Post-Meroitic (Rowley-Conwy, 1989). The use of irrigation technology permitted year-round agriculture, markedly changing the subsistence strategies and agricultural calendar of Nubians, besides changing the pattern of settlement on the otherwise inhospitable landscape (Edwards, 2004f).

Medieval Period (550–1500 CE)

The Medieval Period in Nubia represents a period of relatively rapid political change compared to earlier periods. The Medieval Period may be divided into three kingdoms and into three phases. The Early Medieval Period (550–835 CE) begins with the conversion of the Nubian kingdoms to Christianity in the mid-sixth century CE. The centuries that fall into the Early Medieval are a time of growth and consolidation of power. Adams (1965) defines the beginning of the Classic Medieval Period (835–

1170 CE) based on the presence of a Nubian embassy in Baghdad, a sign that that Nubian kingdoms were a stable and significant political power in the Arab world. The Late Medieval Period (1170–1500 CE) begins in the late twelfth century, when the Ayyubid Dynasty was established in Arab Egypt. At this time, the stability of the Nubian Classic Medieval Period begins to deteriorate, in part because of the military raids and counter raids at the Nubian-Egyptian border (Welsby, 2002b). Other shifts in state power, such as a dynastic union between Makuria and Alwa, signal change in the architecture of the Nubian kingdoms (Godlewski, 2014). Eventually, political interference from Egypt contributes to the collapse of the Nubian kingdoms in the fifteenth century.

During the Early Medieval Period, the Lower Nubian kingdom of Nobadia (Nobatia) held its capital at Faras (Pachoras), and the Upper Nubian kingdoms of Makuria and Alwa (Alodia) had capitals at Old Dongola and Soba, respectively. The kingdoms of Nobadia and Makuria unite into one Makurian kingdom in the Early Medieval Period (Adams, 1991). This significant unification, which occurs in the first centuries of the Medieval Period, is often overlooked in favor of highlighting an independent Nobadia (e.g., Edwards, 2014, 2004g), in large part because of the disproportionate amount of archaeology conducted in Lower Nubia (later the province of Maris in the kingdom of Makuria). For most of the Medieval Period there are only two Nubian kingdoms: Makuria, ruling from the first cataract to perhaps Abu Hamed; and Alwa, the political boundaries of which are not known, but which perhaps ruled from Abu Hamed or the fifth cataract to as far south as the Gezira (Welsby, 2014; Godlewski, 2014). Changes in Makurian royal succession, royal insignia, and the location of the capital in the eleventh century CE signal dynastic change in the Classic Medieval Period. Makuria transforms into the kingdom of Dotawo, with its capital at Dongola (Godlewski, 2014).

In northerly Makuria and Nobadia, there is evidence that many rural communities had converted to Christianity as early as the late Post-Meroitic (350–550 CE; Edwards, 2001). In contrast, in far Upper Nubia, near Gabati, some rural communities did not convert to Christianity until well after the royal conversion in the mid-sixth century (Edwards, 2001). The term medieval is preferred in the present research because it is more closely linked to established political chronologies. This asynchronicity of the terms Medieval and Christian also suggests that care should be taken when cross-referencing sources and when inferring use period from mortuary characteristics.

Religion

Much of the political evolution of the Medieval Period may be framed by the spread and political influence of sects of Christianity and of Islam. The adoption of Christianity as the state religion in the mid-sixth century CE signals the beginning of the Medieval Period for Nubian scholars, yet there is evidence that cemeteries in the North converted to Christian burial practices before Christian missions were sent to the southern kingdoms (Adams, 1998; Edwards, 2001; Welsby, 1996d). Following Shinnie and Shinnie (1965), the present research will refer to the period of 550–1500 CE as the Medieval Period, rather than attempt to define it by association with a dominant religion. Although some aspects of Egyptian ideology were adopted by Nubians in the New Kingdom period and by rulers of the Meroitic Empire, the Medieval Period is the first time that religious ideals spread independently of political conquest. And yet, politics and Abrahamic religions (Judaism, Christianity, and Islam) are clearly entangled with one another, evident from their impact on the political history of the Medieval Period. Further, these religious ideals carried with them social constructs, from spousal and gender roles to those leveraged by "divinely appointed" political rulers.

The Early Medieval Period is usually said to begin with the Roman Emperor Justinian's and Empress Theodora's dispatch of missionaries to the Nubian capitals (Edwards, 2001; Kirwan, 1987). Two types of Christianity were imported into Nubia. Justinian practiced to diophysite Christianity, which is also called Melkite or Chalcedonian and is later known as Eastern Orthodox Christianity, led by a patriarch who was seated in Constantinople. Theodora, on the other hand, subscribed to Monophysite

Christianity, which is also called Jacobite, led by a patriarch who was seated at Alexandria. The division between these two sects derived from debates at the Council of Chalcedon, a theological council held in 451 CE to resolve disputes over the divinity and nature of Jesus Christ. Diophysitism argues that Jesus had both a divine and a human nature in one body, whereas monophysitism argues that he had only a divine nature (Welsby, 1996d). When the Emperor sent emissaries to convert the Nubian royals to diophysite Christianity, Empress Theodora responded by sending emissaries of her own. Makurian royals were baptized into the Diophysite Eastern Orthodox church and adopted Greek as the language of both church and state (Godlewski, 2014).The monophysite mission was successful in Nobadia and Alwa (Welsby, 2014).

Islam entered Africa immediately after its founding in the seventh century CE, and became the ruling religion in Egypt within decades (Sijpesteijn, 2007; Spaulding, 1995). Although Arab armies continued to conquer vast territories across North Africa and the Iberian Peninsula, their attempt to penetrate Nubia was thwarted at the Makurian capital of Old Dongola. The military defeat at Old Dongola was unprecedented in the campaigns of the mid-seventh century, and a loosely formed treaty, the *Baqt*, was established between Muslim Egypt and Makuria. Makuria by this time had absorbed the Lower Nubian polity of Nobadia, now called the province of Maris (Adams, 1991; Welsby, 2002c). Arabic written sources suggest that the *Baqt* was a form of tribute, paid by Makuria to Egypt in ivory, slaves, and gold (Vantini, 1975). But it is unclear why, having won the conflict, Makuria would agree to a one-sided payment of tribute. More recent interpretations suggest that the *Baqt* represented a formal iteration of Embassy Trade, continuing an existing regional tradition of exchange between kingdoms (Spaulding, 1995; Welsby, 2002c). A good relationship with Egypt contributed to Makuria's ability to interact and trade with polities in the Mediterranean and the Levant as Nubian kingdoms had in the past (Godlewski, 2014). Islam continued to spread to neighboring regions in the Medieval Period, including the Red Sea coast. However, Makuria did not have diplomatic or trade relationships with all of them. A lack of contact between the Nubian Christian kingdoms and the Red Sea littoral is evidenced in the presence of Egyptian trade goods but no corresponding Nubian imports (Welsby, 2002c). Although Arab and Islamic cultural influences unofficially spread from Egypt into Nubia during the Medieval Period (Welsby, 2002c), evidence for a Muslim minority is known only from tombstones and documentary evidence, without differentiation in other material culture (Adams, 1966; Welsby, 2002c).

Mortuary practice, which had included many variations of indigenous traditions in the Post-Meroitic, became simpler and more homogenous in the Medieval Period, largely due to the adoption of Christian funerary ritual and mortuary customs. Most sites show a gradual transition from Post-Meroitic to Christian burial practices, including at Gabati (Edwards, 1998; Judd, 2012; Welsby, 2002d). Where settlement was continuous, Post-Meroitic cemeteries continued to be used with Christian mortuary practices, while community churches were rarely the center of cemeteries (Edwards, 2004g). In Christian burials, body position was nearly always oriented with the head to the west in an extended supine position. Grave goods are entirely absent, except for occasional religious amulets (Welsby, 2002d). A low, sub-rectangular superstructure corresponds with Christian burial rites, replacing the large tumuli common in the Post-Meroitic. Instead, broad stone mastabas or cairns of smaller stones were often placed over the grave (Edwards, 1994; Zurawski, 2006). However, there are some regional differences between the medieval Nubian kingdoms, mostly in rate of adoption of Christian customs (Adams, 1998). For example, tumulus superstructures persist along the Blue Nile through the Early Medieval Period (Welsby, 2014).

Muslim burials are very similar to Christian burials, also using a single inhumation with the body extended and supine and without grave goods. Graves are oriented so that the body points towards Mecca, which in northeast Africa largely coincides with west-east burial alignment of Christian burials. At Mis Island, locals indicated to archaeologists the line of rocks that separated Christian from Muslim burial areas, with the Muslim cemeteries being strictly off limits to excavation (Derek Welsby, personal communication). Because of the homogeneity of burial practices and the overwhelming absence of grave goods in both Christian and Muslim traditions, social identity and social organization are difficult to investigate via mortuary archaeology in the Medieval Period.

Settlement

New territorial organization in the Early Medieval (550–835 CE) is evident in the increased settlement in the Dongola Reach and the Fourth Cataract, Makuria's heartland, especially in large fortified settlements and urban centers (Godlewski, 2014). Several fourth cataract fortresses were built in the sixth century, largely where cultivable land and settlements were found (Zurawski, 2014). Fortified settlements are also known in Nobadia during the Early Medieval and some of these may have served as monasteries (Edwards, 2014). Some of these, such as at Meinarti, had a special role controlling trade and transport on the Nile between Egypt and the Dongola Reach (Adams, 2001, 2000). Whereas new regions were settled in the Dongola reach, continuity in small-scale settlement is more the rule in the Nobadia (Edwards, 2014).

Little remains known about the medieval kingdom of Alwa. Extensive excavations at Soba represent nearly all Alwan settlement archaeology (Welsby and Daniels, 1991). Few other sites have been identified or excavated in the upper reaches of Upper Nubia (Welsby, 2014). Nevertheless, the geography of the Alwan heartland differs significantly from that of Nobadia and Makuria. Because of a more temperate climate (savannah), scholars expect that settlement was not restricted to the river valley and agriculture was widespread (Welsby, 2014).

Late Medieval settlement changes include cycles of abandonment and reoccupation in Lower Nubia. However, uninviting and rocky areas are increasingly inhabited in the Late Medieval Period (1170–1500 CE), both in the Middle Nubian *Batn el Hajar* and along the third and fourth cataracts. These have been suggested to represent refuge areas from contested border regions (Edwards, 2014). Late

Medieval Nobadian settlements include fortified “castle-houses” and communal structures, including storage rooms that were only accessible through the roof (W. Y. Adams, 1994). The Upper Nubian population, on the other hand, invested in girdle walls and southward-facing lookout towers to protect their settlements (Adams, 1966).

Collapse

In part as a result of Egyptian intervention in Makurian politics, the first Muslim king was enthroned at Old Dongola in 1317 CE (Edwards, 2004g). After this, it is possible that the Christian Makurian kings moved their court downriver to Dotawo (Welsby, 2002b). The kingdom known in the Early and Classic Medieval Periods as Makuria is sometimes known as the Kingdom of Dotawo in the Late Medieval (1170–1500 CE). In the fourteenth and fifteenth centuries, the Kingdom of Dotawo was significantly reduced following another change in royal residence from Old Dongola to Daw, near the second cataract. The religious power of the kings of Makuria and later Old Dongola is diffused in this last shift, and major churches at Dongola were transformed into mosques before the official abandonment of Christianity (Godlewski, 2014). Documentary and archaeological evidence from the kingdom of Alwa is extremely scarce throughout the Medieval Period, which continues to make meaningful interpretations of the decline of that kingdom extremely difficult (Welsby, 2014). Economic factors further weakened the Nubian kingdoms: until this time, the Nile had been the only trade route between sub-Saharan Africa and the Mediterranean, Levant, and Europe, contributing significantly to Nubian power (Welsby, 2002e). The new trans-Saharan caravan trade, made possible by the use of camels, diluted the importance of controlling travel on the Nile. The end of the Medieval Period is around 1500 CE, when the newly consolidated Funj Kingdom, whose political center was in the Gezira region of far Upper Nubia, spread north and took control of much of Upper Nubia (Edwards, 2004g; Welsby, 2002b).

CONCLUSION

The archaeological history of Nubia reviewed here spans three millennia. When New Kingdom Egypt expanded its political control in the mid-second millennium BCE, some of its iconography, religious institutions, and mortuary practices were adopted by Nubians. After its collapse, Nubia experienced a period of decentralized power, then somewhat suddenly Nubian Napatan kings reunify Nubia and Egypt in the seventh century BCE. Following the reigns of the expansive and powerful Napatan Kingdom and Meroitic Empire, both centered in Upper Nubia, three Christian medieval kingdoms coalesced in the mid-first millennium CE. In the Medieval Period, Makuria participated in the greater Mediterranean political sphere with diplomatic contacts in Baghdad and religious ties to Constantinople and Alexandria. The third Nubian kingdom was Alwa, whose capital was at Soba. Largely absent from written sources and with only a few archaeological excavations, Alwa's political and cultural history are largely unknown.

Modern scholars have broadened the scope of interest in Nubia geographically, temporally, and beyond political history. However, Nubian archaeology is still growing. Next to nothing is known about the medieval kingdom of Alwa. Settlement archaeology is lacking in almost all periods and regions of Nubia. And work was so scarce for so long that old assumptions with no evidentiary support are still canon. The history of Nubian archaeology is rooted firmly in a Eurocentric scholarly tradition. Salvage archaeology, especially the salvage of monuments, royal burials, and elite goods, is responsible for most excavations completed in Nubia since the beginning of the twentieth century. For decades, Egypt influence was seen as the most important feature of Nubian cultural history, with little interest shown in studying indigenous traditions or the strategic ways in which Egyptian mores and iconography were employed. This includes indigenous or Christian-imported patterns of social organization, both within and between residential communities or villages. The role of biological kin in social identity or in shaping social organization is unknown in all periods of the Nubian past.

Although Nubian kingdoms and empires had a long history of engaging with neighboring polities on a regional scale, the world became a little smaller in the medieval period. Language and shared religion connected Nubia to sects in Egypt and to the ruling elite of the Byzantine Empire, while trade and diplomacy connected Nubia and the dominant, widespread Arab empire. The political history states that the royal conversion to Christianity occurred in the three Nubian kingdoms in the mid-seventh century. Yet in Lower Nubia, Christian burial practices are seen well before this transition, and in far Upper Nubia, indigenous practices continue well after. Rural individuals may or may not have traveled great distances in a lifetime, but ideas, language, and architecture certainly connected rural Nubian communities with urban centers in northeast Africa and the eastern Mediterranean. The extent to which the sweeping political and religious changes reorganized local and regional social networks is one that remains unanswered in Nubian scholarship.

CHAPTER FOUR: RESEARCH QUESTIONS & EXPECTATIONS

The present research considers the biological relationships among human remains excavated from six cemeteries from three Post-Meroitic and medieval Nubian archaeological sites. Although the Nubian Medieval Period (550–1500 CE) has received increased attention in the past twenty years, there are still significant gaps in our knowledge of social organization and population structure in all periods of Nubian history. By investigating the biological relationships among these cemeteries and sites, we can gain new insight into organizing principles of medieval Nubian culture. Unlike in many other Nubian biodistance studies, contemporaneous samples are used here, because a synchronic study allows investigation of population structure and social organization, rather than population history.

The analyses in this study are conducted in a specific time and place, namely three rural agricultural sites in Medieval Middle and Upper Nubia. However, the non-elite communities that buried their dead in the six cemeteries located at these sites are likely representative of the broader rural Nubian population, about which little is known. This is not to say that the *individuals* are necessarily representative of all rural Nubians, but that the organizing principles in these communities would have been part of a larger culture operating under similar organizing principles. While results from these individual sites can be extrapolated to cover a broader geographic area, they should not be extended temporally. The adoption of Christianity from the pre-medieval to the Classic medieval likely brought with it changes in social organization and the community-forming processes at these sites. Later conversion to Islam may have further altered trends in mate exchange and kin-based social structure, so modern ethnographic research should only be applied to the Medieval Period with extreme caution, and is not done in this study. The methodological analyses presented in Research Questions 1b and 2b also contribute to biodistance research across periods and regions.

This study uses samples from three medieval Upper Nubian sites. The cemeteries are dated to broad periods within the medieval, making questions of diachronic change difficult to access. However, local, or intra-site, analyses reveal small-scale patterns in social organization that may be extrapolated to other rural communities across medieval Upper Nubia. This chapter reviews the research questions and expectations of this dissertation. The main goals of this research were to: 1) conduct biodistance analyses among medieval Nubian sites and individual cemeteries using cranial nonmetric traits; 2) compare cranial nonmetric results with craniometric results; 3) contextualize biological relationships in a wider African context; 4) determine whether postmarital residence practices at each site were virilocal, uxorilocal, or multilocal; and 5) identify kin-based burial groups, if they are present, in each Mis Island cemetery. For some comparative analyses, quantitative comparisons were not possible, usually due to the differences between statistical procedures for continuous (metric) data and dichotomous (nonmetric) data. In such cases, traditional qualitative comparisons were made between new and existing results in Chapter Seven. In each of the subsections below, the existing archaeological and physical anthropological evidence will be used to support expectations for the research questions.

The research questions for this dissertation are as follows:

1. a. When cemeteries from the same site are pooled, what are the biological relationships among Mis Island, Kulubnarti, and Gabati as revealed by biodistance analysis of nonmetric traits of the skull?

   b. Do the results of biological distance analyses using cranial nonmetric traits and craniometrics correlate when cemeteries from the same site are pooled?
2. a. What are the biological relationships among the six cemeteries at Mis Island, Kulubnarti, and Gabati as revealed by biodistance analysis of nonmetric traits of the skull?

   b. How closely are the six medieval Nubian cemeteries related, when regional comparative data is included in cranial nonmetric trait biodistance analyses?

3. Is there cranial nonmetric trait evidence of virilocal or uxorilocal postmarital residence practices at Mis Island, Kulubnarti, or Gabati?
4. a. Assuming uniform distribution of burials, can kin-based groups be detected in any of the Mis Island cemeteries using cranial nonmetric traits?

   b. Assuming the presence of spatially structured burial groups, are individuals in Mis Island cemetery 3-J-11 buried according to kin-based groups as determined by cranial nonmetric traits?

RESEARCH EXPECTATIONS

Research Question 1a

When cemeteries from the same site are pooled, what are the biological relationships among Mis Island, Kulubnarti, and Gabati as revealed by biodistance analysis of nonmetric traits of the skull?

Expectation: Mis Island and Kulubnarti will be more closely related based on cranial nonmetric traits, with Gabati relatively biologically distant to both.

Mis Island, Kulubnarti and Gabati are similar in that each represents a non-elite medieval agricultural community on the middle Nile, and they are often grouped together as “Upper Nubian” sites. However, they also differ in significant ways. Following the political unification of Nobadia and Makuria in the seventh century, Mis Island and Kulubnarti both fell within Makuria’s sphere of influence. Gabati, in contrast, was located far upriver in the kingdom of Alwa. Pottery and other small finds at Gabati suggest trade with the Alwan capital at Soba, as well as tentative links to Egypt in the early medieval and to the Red Sea Hills in the later medieval (Edwards, 1998). The quality of household items and pottery at Kulubnarti, on the other hand, is utilitarian and was locally produced, suggesting that this community did not interact with regional trade networks to acquire exotic or luxury goods (Adams and Adams, 1998). The medieval pottery and small finds from Mis Island have not yet been analyzed. Using craniometric biodistance analysis, Vollner (2016) concluded that Mis Island was more closely related to

Kulubnarti than to Gabati, with additional evidence that Gabati interacted more frequently with Egypt than with Kulubnarti or Mis Island. Thus, archaeological and osteological evidence support the expectation that cranial nonmetric traits suggest a closer biological relationship between Mis Island and Kulubnarti, since they were joined by a common central power at the Makurian capital of Old Dongola, while Gabati is located far upriver and near the Alwan capital at Soba.

Research Question 1b

Do the results of biological distance analyses using cranial nonmetric traits and craniometrics correlate when cemeteries from the same site are pooled?

> Expectation: The distance matrices produced by craniometric and cranial nonmetric data will be significantly correlated when cemeteries from the same sites are pooled.

The same biodistance methods will be applied to the present cranial nonmetric data as were applied to Vollner's craniometric data (2016), allowing for relatively straightforward statistical comparison of results. Previous work on both types of phenotypic data and genetic information support the expectation that craniometric and cranial non-metric data will correlate well when cemeteries from the same site are pooled. Other inter-site studies have superficially compared cranial nonmetric and craniometric results in Asia and the Pacific (Pietrusewsky, 1983), but overall, the use of both metric and nonmetric traits is more common in dental biodistance analysis (Godde, 2009b; Passalacqua, 2015; Wrobel, 2004) than in skeletal analysis. Herrera *et al.*'s (2014) recent study represents a deeper and more statistically-oriented approach to the comparison of multiple data types. Based on their results, which show a significant correlation between the biodistance matrices produced by craniometrics and by cranial nonmetrics, I expect to find no significant difference between the results produced by these two phenotypic datasets in Nubia.

Research Question 2a

What are the biological relationships among the six cemeteries at Mis Island, Kulubnarti, and Gabati as revealed by biodistance analysis of nonmetric traits of the skull?

> Expectation: No significant differences will be detected among the three Mis Island cemeteries using cranial nonmetric traits.

Mortuary analysis indicates that the use periods of the three cemeteries excavated on Mis Island overlap by many centuries. Cemeteries 3-J-10 and 3-J-18 were both only used during the Late Medieval (Ginns, 2010c, 2010a), and though 3-J-11 starts much earlier, it also continues use through the Late Medieval (Ginns, 2010b). Despite being geographically distinct, few mortuary, demographic, or paleopathological differences are observed between individuals from Mis Island cemeteries 3-J-11 and 3-J-10 (Soler, 2012). Furthermore, Vollner (2016) found no significant craniofacial differences between the cemeteries 3-J-10 and 3-J-11, and only two of her individual cranial measurements were statistically significantly different. Ginns (2007, 2006) suggests that individuals buried in close proximity to the church in cemetery 3-J-18 may have held some prestige within the community, but the lack of grave goods has prevented further analysis of this suggestion. In the absence of a clear reason for these three cemeteries to co-exist, my expectation is the null hypothesis that the three Mis Island cemeteries will be indistinguishable from each other via cranial nonmetric traits.

> Expectation: No significant difference will be detected between Kulubnarti cemeteries 21-R-2 and 21-S-46 using cranial nonmetric traits.

Mortuary analysis indicates that both Kulubnarti cemeteries were formed in the mid-sixth century. While use of cemetery 21-S-46 ceased in the mid-ninth century, cemetery 21-R-2 continued to be used through the fourteenth century (Adams *et al.,* 1999). Despite being established at the same time, these cemeteries have been used for decades to represent “early” and “late” subsamples and to test diachronic change (e.g., Soler, 2012; Van Gerven, 1982; Van Gerven *et al.*, 1981). However, recent carbon dating of materials from Kulubnarti produced adjusted carbon dates from both cemeteries with means in the mid-seventh century (Van Gerven, personal communication). The point estimates of the carbon dates for cemetery 21-S-46 range from the sixth to the ninth century and those for cemetery 21-R-2 from the seventh to ninth century (Van Gerven, personal communication). Vollner (2016) found insignificant craniofacial variation between the two populations, leading her to conclude that reasons other than biological differences led to the creation of two contemporaneous cemeteries. Although paleopathological and growth data suggest very different lifeways for each of the cemetery populations (Hummert, 1983a-b; Van Gerven *et al.,* 1990), they cohabited Kulubnarti Island and exhibited no craniofacial differences. I expect not to reject the null hypothesis that no significant differences will be found between these subsamples via cranial nonmetric traits.

> Expectation: In the six-cemetery analysis, cemeteries will show greater affinity within sites than between sites.

The six-cemetery analysis consists of three cemeteries from Mis Island, two cemeteries from Kulubnarti, and one cemetery from Gabati. Because each of these sites represents rural agricultural communities, it is likely that the cemeteries will demonstrate an isolation-by-distance effect (Konigsberg, 1990) where geographical distance and biological distance are inversely correlated. I expect cemeteries from the same site to be more closely related to each another than to cemeteries from another site.

Research Question 2b

How closely are the six medieval Nubian cemeteries related, when regional comparative data is included in cranial nonmetric trait biodistance analyses?

> Expectation: In the eleven-sample analysis, Nubian samples will be very closely related compared to other African samples.

This analysis will contextualize the cranial nonmetric trait biodistances among medieval Nubian samples. Due to the nature of the statistics involved, biodistance analyses (using non-bias-corrected Mahalanobis D^2) will always produce a positive result. However, the actual values of biodistance results are not directly comparable among studies because they are influenced by sample size and number of traits used. By comparing the six medieval Nubian cemeteries with raw data from additional samples (outgroups), I can better assess the relative biodistance seen among the primary Nubian samples. This is done as a separate analysis from the six-cemetery analysis because the trait definitions used by the comparative sample differ for some traits, resulting in a cropped dataset.

Vollner (2016) found that Mis Island, Kulubnarti, and Gabati clustered closely together when considered with additional African craniometric samples. For this dissertation, African populations from the global cranial nonmetric trait database collected by Nancy Ossenberg (2013) were used as a comparative sample. The present analysis differs from Vollner's (2016) in that the cemeteries are not clustered by site but considered individually. I expect cemeteries from the same site to cluster together and the six Nubian cemeteries to show affinity compared to other African samples.

Research Question 3

Is there cranial nonmetric trait evidence of virilocal or uxorilocal postmarital residence practices at Mis Island, Kulubnarti, or Gabati?

> Expectation: The sexes will not show statistically significant differences in variance as determined by mean pairwise differences in cranial nonmetric trait expression at Mis Island, Kulubnarti, Gabati, or individual cemeteries at Mis Island or Kulubnarti.

This analysis will attempt to determine whether postmarital residence patterns in medieval Nubia were virilocal, where the married couple resides at the husband's place of birth or uxorilocal, where the married couple resides at the wife's place of birth (Adam, 1947). Virilocal postmarital residence is linked to male-dominated and patriarchal societies and is commonly associated with Abrahamic religions and the greater Mediterranean (Salih, 2004). Salih argues that the importance of the maternal lineage is evident in modern ethnic Nubians as well as ancient kings, who would introduce themselves by their maternal lineage (2004). However, this aspect of social organization remains contested at all levels of society in ancient to medieval Nubia, with scholars disagreeing even on the manner in which royal power was passed down (Lohwasser, 2001; Salih, 2004). Vollner (2016) tested within-site variability of males and females at Mis Island, Kulubnarti, and Gabati. She found equal mobility of males and females at Kulubnarti, greater mobility of males at Mis Island, and greater mobility of females at Gabati, though none of these trends reached statistical significance. With little historical, archaeological, or osteological support for an expectation of greater female or greater male variance at individual sites or cemeteries, I expect that female and male variance in cranial nonmetric traits will not be statistically significantly different at any of the Nubian sites or cemeteries in this study.

Research Question 4a

Assuming uniform distribution of burials, can kin-based groups be detected in any of the Mis Island cemeteries using cranial nonmetric traits?

> Expectation: Burials at Mis Island cemetery 3-J-10 are biologically homogenous and not spatially organized according to biologically defined kin groups.

Soler (2012) tested the spatial distribution of mortuary and demographic variables in Mis Island cemetery 3-J-10. She found that mortuary treatment was not significantly correlated with sex and that the sexes were randomly distributed across the cemetery. However, subadults received different mortuary treatment, and their burials were concentrated in the east part of the cemetery. Soler concluded that this distribution of burials indicated that all community members were treated equally in burial regardless of kin affiliation (2012), a practice which is known in other Christian cemeteries (Scott, 2012). My expectation supports her conclusion by predicting that in cemetery 3-J-10, biological distance between individuals will not be closely correlated with spatial distance. Instead, kin groups will be randomly distributed in space.

> Expectation: Burials at Mis Island cemetery 3-J-11 are spatially organized according to biologically defined kin groups.

Soler (2012) identified burial clusters based on subtle differences in grave placement and orientation. These form the basis for testing cemetery 3-J-11 as a spatially structured cemetery in

Research Question 4b (below). Kin-based groups were detected in this analysis by methods assuming uniform spatial distribution without *a priori* burial groups being defined. Below, Soler's spatially defined burial clusters are tested. However, while her reasoning is strong, her burial cluster boundaries may not accurately represent the biologically defined kin groups present in the cemetery. Testing for kin-based groups using an assumption of uniform spatial distribution of burials allows for alternate burial groups to be identified.

> Expectation: Burials at Mis Island cemetery 3-J-18 are biologically homogenous and not spatially organized according to biologically defined kin groups.

No large scale analysis has yet been published on Mis Island cemetery 3-J-18, with the exception of the draft site report (Ginns, 2010a). Soler (2012) concluded that cemetery 3-J-10, which was in use in the Late Medieval Period (1170–1500 CE), reflected community-based burial practices. This contrasts with kin-based burial practices, which she suspects dominated burial placement in cemetery 3-J-11, in use throughout the Medieval Period (550–1500 CE). The community-based practices of cemetery 3-J-10 are explained by the increased emphasis of community membership over family membership in Late Medieval Christian funerary practice (Soler, 2012, pp. 258–260). Mis Island cemetery 3-J-18 has also been dated to the Late Medieval Period and surrounds the major church on the island (Ginns, 2010a). Based on this information, I expect that biological distance between individuals will not be closely correlated with spatial distance and kin groups will be randomly distributed in space.

Research Question 4b

Assuming the presence of spatially structured burial groups, are individuals in Mis Island cemetery 3-J-11 buried according to kin-based groups as determined by cranial nonmetric traits?

> Expectation: Burials at Mis Island cemetery 3-J-11 are spatially organized according to biologically defined kin groups.

In cemetery 3-J-11, sex and age cohorts were randomly distributed throughout the cemetery. As at 3-J-10, subadults received different mortuary treatment, but unlike at 3-J-10 subadult burials were not restricted to one region of the cemetery. Soler (2012) hypothesized the presence of 8 kin-based burial clusters in cemetery 3-J-11 based on subtle differences in grave orientation and mortuary variables. However, her spatial analysis did not identify any statistically significant demographic differences among these burial clusters. My expectation supports Soler’s conclusion by predicting that in cemetery 3-J-11, cranial nonmetric trait data will show that burial clusters are the result of kin-based burial placement.

CHAPTER FIVE: RESEARCH MATERIALS & METHODS

This chapter introduces the skeletal samples used in this dissertation. It also describes the data collection methods and statistical analytical methods used to answer the research questions detailed in Chapter Four. The first section will describe the methods of osteological data collection, including age and sex estimations and cranial nonmetric traits. The second section includes information on the medieval (550–1500 CE) skeletal samples on which new data were collected: three cemeteries from Mis Island, two cemeteries from Kulubnarti, and the cemetery at Gabati. The demographic composition and mortuary practices of each cemetery will be detailed. The data used include primary cranial nonmetric data collected from three skeletal samples, craniometric results from Vollner's recent dissertation (2016), and a global catalogue of cranial nonmetric data for regional context. Finally, statistical methods will be detailed, including intraobserver error testing and the statistical approaches used to answer each research question.

OSTEOLOGICAL METHODS

This section will review the skeletal data collected by this author both directly from skeletal material and indirectly, from existing records. Age and sex estimates were collected from published data or reliable existing records when possible. When these were not available, standard osteological criteria were used to estimate age and sex (Buikstra and Ubelaker, 1994). Comparative data used in this research consists of previously published craniometric results and a global cranial nonmetric trait database.

Nonmetric traits of the skull

A suite of 37 cranial nonmetric traits were assessed on all fragmentary and complete adult skulls, using the trait list and threshold definitions used by Nikita (2010; Nikita *et al., 2*012) and novel three-letter abbreviations (Table 5.1). These traits were found to be useful in biodistance analysis of northeast African populations (Nikita, 2010) and are a combination of traits described by Hauser and De Stefano (1989), Dodo (1974), Hanihara and Ishida (2001a), Ossenberg (1969), and Kennedy (1986). Sutural ossicles were marked as unobservable if more than 50% of the suture was obliterated or bones were disarticulated, even if refitting was possible. Detailed trait descriptions and the presence thresholds are presented in Appendix A. Additional character states beyond presence and absence increase interobserver error without a corresponding increase in analytical power, thus trait dichotomization is preferred (Nikita, 2015). Character states were recorded for both right and left sides for the 32 bilateral traits. In cases of asymmetry, the side used for analysis was randomly determined (Konigsberg, 1990). For intraobserver testing, 48 individuals (10% of total sample) were rescored after an interval of at least 8 weeks.

Sex

Humans display only moderate sexual dimorphism in comparison with other primate species. Nevertheless, differences in both size and function allow sex to be reliably determined from the adult skeleton using gross morphological methods. For this analysis, I used standard anthropological methods to estimate sex using a combination of pelvic (Buikstra and Ubelaker, 1994; Phenice, 1969) and skull traits (Acsádi and Nemeskéri, 1970; Buikstra and Ubelaker, 1994), with greater emphasis placed on pelvic morphology. Following sex estimation, individuals were placed in one of the following categories: male, female, probable male, probable female, and unknown/ambiguous. Unknown indicates that not enough sex traits were present to make a sex estimation and ambiguous indicates that available traits did not suggest either male or female. The male and probable male categories were combined for analysis, as were the female and probable female categories.

There are three features of the pubic bone first reported by Phenice (1969) to be useful in sex estimation: the presence or absence of the ventral arc on the infero-medial corner of the anterior pubic body, the curvature of the sub-pubic border from the posterior aspect (sub-pubic concavity), and the

Table 5.1. Cranial nonmetric traits used, abbreviations, and references (modified from Nikita, 2010).

Trait name	Abbreviation	Reference
aperture in floor of acoustic meatus (tympanic dehiscence)	AAM**	Hauser and De Stefano (1989)
auditory torus	AUT*	Kennedy (1986)
coronal ossicle(s)	COO	Hauser and De Stefano (1989)
divided infraorbital foramen	DIF	Hauser and De Stefano (1989)
divided mental foramen	DMF**	Hauser and De Stefano (1989)
divided occipital condyle	DOC	Hauser and De Stefano (1989)
divided parietal bone	DPB*	Hauser and De Stefano (1989)
divided temporal squama	DTS*	Hauser and De Stefano (1989)
epipteric bone	EPI	Dodo (1974)
foramen of Vesalius	FVS	Dodo (1974)
foramen ovale incomplete	FOV	Dodo (1974)
foramen spinosum incomplete	FSP	Hauser and De Stefano (1989)
hypoglossal canal bridging	HCB**	Dodo (1974)
lambdoid ossicle(s)	LDO	Dodo (1974)
lesser palatine foramen multiple	LPF	Hauser and De Stefano (1989)
mandibular torus	MNT	Hauser and De Stefano (1989)
marginal tubercle	MAR	Hauser and De Stefano (1989)
maxillary torus	MXT*	Hauser and De Stefano (1989)
metopic fissure	MFS*	Hauser and De Stefano (1989)
metopic suture	MET**	Hauser and De Stefano (1989)
mylohyoid bridging	MHB**	Dodo (1974)
occipitomastoid wormian(s)	OMW**	Dodo (1974)
ossicle(s) at asterion	ASO**	Ossenberg (1969)
palatine torus	PLT	Hauser and De Stefano (1989)
parietal foramen	PAF	Hauser and De Stefano (1989)
parietal notch bone	PNB**	Dodo (1974)
posterior ethmoidal foramen absent	PEF*	Hauser and De Stefano (1989)
pterygo-alar bridge	PAB**	Ossenberg (1969)
pterygo-spinous bridge	PSB**	Ossenberg (1969)
sagittal ossicle(s)	SGO	Hauser and De Stefano (1989)
squamous ossicle(s)	SQO	Hauser and De Stefano (1989)
supranasal suture	SNS	Hauser and De Stefano (1989)
supraorbital osseous structures	SOS	Dodo (1974)
symmetrical thinness of parietal bones	STP*	Hauser and De Stefano (1989)
trace biasterionic suture (Inca bone)	TBS	Dodo (1974)
trace transverse zygomatic suture (os japonicum)	TZS**	Dodo (1974)
zygomaxillary tubercle	ZYG	Hauser and De Stefano (1989)

**trait removed from final analyses*
***trait used with Ossenberg (2013) comparative data*

width of the ischiopubic ramus as viewed from the medial aspect (pinched or broad). The shape of the pubic body, the width of the sub-pubic angle, and the width of the greater sciatic notch are additional pelvic morphological traits commonly used in sex estimation from the pelvis (Buikstra and Ubelaker, 1994). Morphological sex estimation from the skull uses a series of characteristics identified by Acsádi and Nemeskeri (1970)and later summarized by Buikstra and Ubelaker (1994). These traits include: profile of the nuchal crest; width and length of the mastoid processes; profile of the glabella area; width of the superolateral supra-orbital margins, and expression of the mental eminence. Additional morphologies include the slope of the forehead and overall size and rugosity of the skull.

Soler estimated sex for all adults from Mis Island cemeteries 3-J-10 and 3-J-11 for her doctoral dissertation (2012). The sex estimations she produced were collected from her datasheets (with permission) for use in this research. Reliable sex estimates were not available for Mis Island cemetery 3-J-18 at the time of data collection. Thus, sex estimations are based on the methods listed above at the time of nonmetric data collection. Sex estimates for adults from both Kulubnarti cemeteries were published by individual in the site monograph (Adams *et al.,* 1999). However, the sex estimates used in the present research were collected from an updated inventory provided to the author at the time of nonmetric data collection (Van Gerven, personal communication, 2016). Sex estimates are published by individual in the "Osteobiographies" section of the Gabati site monograph (Judd, 2012).

Age

Age is an important factor in bioarchaeological analyses. For the purposes of this research, estimation of age served two purposes: 1) to determine whether an individual is an adult and should be included in the study sample; and 2) to identify age-correlated nonmetric traits for removal from further analysis. Only adults were used in this study because many nonmetric traits change over time (Saunders, 1989). Anthropological standards define an adult as an individual over the age of twenty (Buikstra and Ubelaker, 1994). Following Soler's criteria (2012, pp. 93–94), adults were identified for this study by eruption of the third molars and fusion of all long bone epiphyses. The medial clavicle is one of the last epiphyses to fuse in the developing skeleton and provides a helpful landmark for adulthood (Scheuer and Black, 2000). The adult age groups used in the present research are consistent with previous research on Mis Island (Hurst, 2013; Soler, 2012; Vollner, 2016) and at Gabati (Judd, 2012). Anthropological standards recommend categorizing each individual as young adult, middle adult, or old adult when possible, and used the category "unknown age adult" if epiphyseal fusion is complete but no other age markers can be assessed (Buikstra and Ubelaker, 1994). The age ranges for each of these categories are listed in Table 5.2.

The most commonly used methods for adult age estimation from the skeleton assess the age-progressive morphology of the pubic symphysis (Brooks and Suchey, 1990; Katz and Suchey, 1986), the fourth sternal rib end (Işcan *et al.*, 1985, 1984), and the auricular surface (Lovejoy *et al.,* 1985; Osborne *et al., 2*004). The Suchey-Brooks method is a sex-specific phase method appropriate for application to all ancestries. Analysts assign the unknown pubic symphysis to one of six phases, using a series of casts and/or written descriptions. The Işcan and Loth method for age estimation from the fourth sternal rib end is also a sex-specific phase method. Descriptions, photographs, and/or casts are used to assign the rib to a numbered phase. Other typical ribs (ribs 3-8) may be substituted if the fourth sternal rib end is not observable (Dudar, 1993). Although developed on a sample of white Americans, the Işcan and Loth method may be applied to other ancestries (Işcan *et al.,* 1987). Finally, the auricular surface of the ilium is often well preserved in bioarchaeological contexts. The phase method used for age estimation from the auricular surface is not sex specific (Lovejoy *et al.,* 1985). Improved statistical treatment of this method has resulted in corrected age ranges based on the Lovejoy *et al.*'s (1985) descriptions and photographs (Osborne *et al.*, 2004). The 95% confidence intervals for each of the methods that could be applied to each skeleton were considered in selecting an age category for the individual.

Table 5.2. Adult age groups with associated summary age ranges.

Age group	Age range
Young adult	20–34
Middle adult	35–49
Old adult	≥50
Unknown age adult	≥20

Soler (2012) estimated age at death for all adults from Mis Island cemeteries 3-J-10 and 3-J-11 and placed each one into one of the standard age groups. The same age groups were used by Judd in the Gabati osteobiographies (2012). No reliable age estimates were available for the adults from Mis Island cemetery 3-J-18 at the time of data collection. Therefore estimates were made using the methods described above at the time of nonmetric data collection. The monograph of the Kulubnarti cemeteries does not use adult age groups (Adams *et al.,* 1999). Rather, the whole collection was seriated by the primary researchers and each individual was given a point estimate for age at death (e.g., 37 years). For this study, the narrow ages at death provided in the updated Kulubnarti inventory (Van Gerven, personal communication, 2016) were placed into the standard age groups by the author.

THE SKELETAL SAMPLES

A total of six cemeteries from three archaeological sites are included in the present research (N = 480). Three cemeteries were excavated from the fourth cataract site of Mis Island, two are from the *Batn el Hajar* region at Kulubnarti, and one is from upriver of the fifth cataract at Gabati. Most of the sample (n = 289) is represented by adults from the medieval (550–1500 CE) Mis Island cemeteries 3-J-10 (n=74; Ginns, 2010c), 3-J-11 (n=143; Ginns, 2010b), and 3-J-18 (n=72; Ginns, 2010a). The two medieval cemeteries from Kulubnarti (n = 151) are designated 21-R-2 (n = 97) and 21-S-46 (n = 54; Adams *et al.,* 1999). Finally, the Post-Meroitic (350–550 CE) and Medieval Periods (550–1500 CE) are also represented at Gabati (n = 32), a fifth cataract site (Judd, 2012). For each cemetery sample, the author collected nonmetric traits from complete and fragmentary adult crania. Age and sex estimates were collected from existing records where possible, otherwise the author made the age and sex estimation. Table 5.3 describes the total sample by cemetery and sex.

Table 5.3. Total skeletal sample by cemetery and sex.

Cemetery	Use (years CE)	Female	Male	Unknown	Total
Mis Island 3-J-10	1100–1500	36	37	1	74
Mis Island 3-J-11	300–1400	68	64	11	143
Mis Island 3-J-18	1100–1500	39	30	3	72
Mis Island subtotal		*143*	*131*	*15*	*289*
Kulubnarti 21-R-2 (mainland)	300–800	57	40	0	97
Kulubnarti 21-S-46 (island)	300–1500	33	21	0	54
Kulubnarti subtotal		*90*	*61*	*0*	*151*
Gabati subtotal	*450–1100*	*18*	*14*	*0*	*32*
TOTAL		**255**	**210**	**15**	**480**

Table 5.4. Mis Island skeletal sample by cemetery, age, and sex.

	Female	Male	Unknown	Total
Young adult	5	11	0	16
Middle adult	15	23	1	39
Old adult	11	2	0	13
Unknown Age Adult	5	1	0	6
Total 3-J-10	*36*	*37*	*1*	*74*
Young adult	22	20	4	46
Middle adult	26	31	1	58
Old adult	19	12	0	31
Unknown Age Adult	1	1	5	7
Total 3-J-11	*68*	*64*	*10*	*142*
Young adult	20	7	3	30
Middle adult	10	17	0	27
Old adult	7	4	0	11
Unknown Age Adult	1	2	1	4
Total 3-J-18	*38*	*30*	*4*	*72*
Young adult	**48**	**38**	**7**	**93**
Middle adult	**51**	**71**	**2**	**124**
Old adult	**37**	**18**	**0**	**55**
Unknown Age Adult	**7**	**4**	**6**	**17**
Total Mis Island	**143**	**131**	**15**	**289**

Mis Island

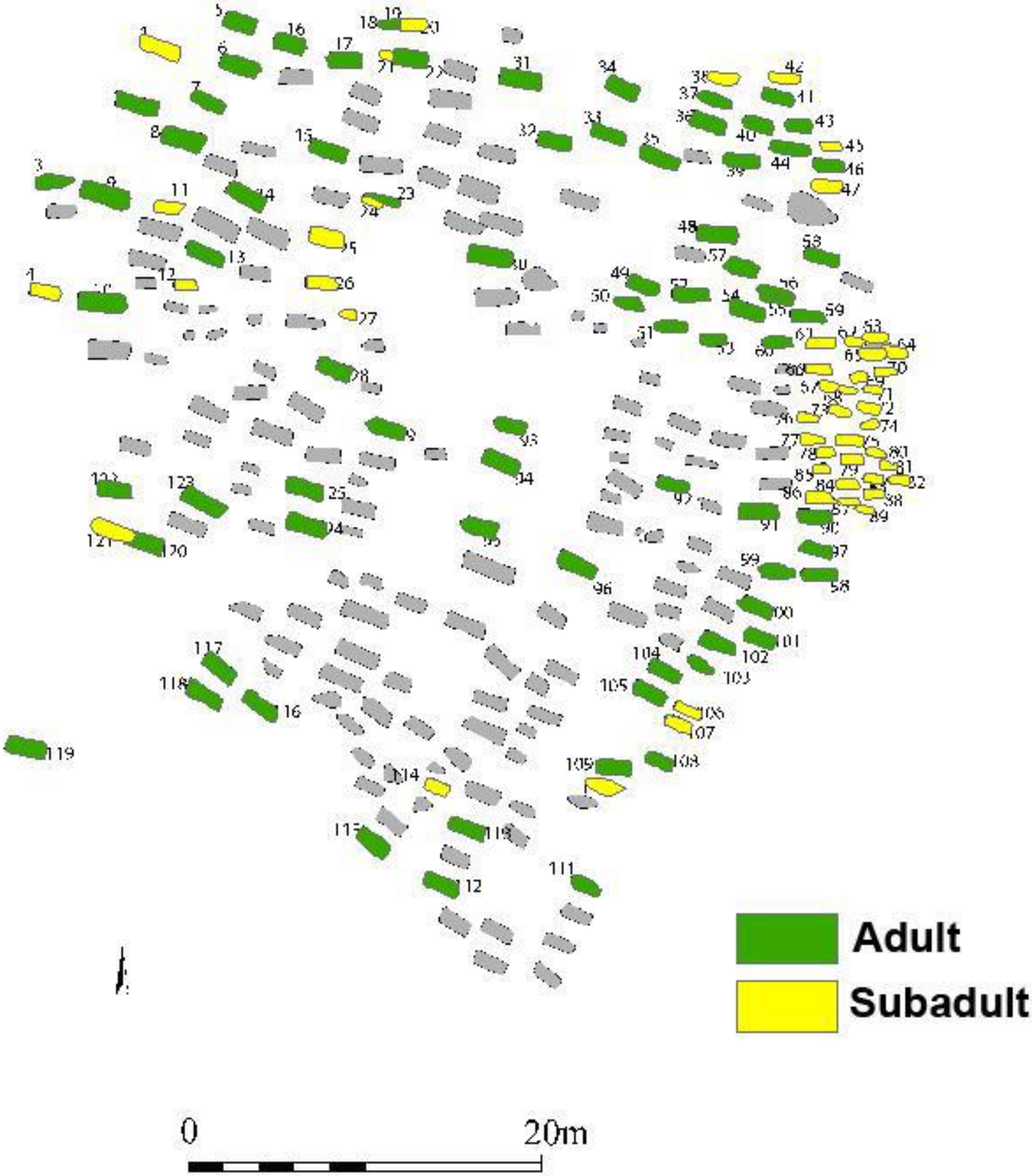
The Mis Island skeletal sample (n = 297) comes from the three large medieval cemeteries 3-J-10, 3-J-11, and 3-J-18 (Table 5.4). No skeletal material was recovered from the five medieval graves at the hilltop site 3-J-20 (Ginns, 2010e), so that site is not included in the present analysis. Most of the human remains excavated from cemeteries 3-J-10 and 3-J-11 are currently on long-term loan to the Department of Anthropology at Michigan State University from the British Museum, except for extremely fragile remains and those with significant portions of naturally mummified soft tissue.

Cemetery 3-J-10

Cemetery 3-J-10 was bounded by natural features of the landscape and was composed of 262 “box-grave” monuments associated with Nubian Christian burials and one continuous phase of use in the Late Medieval Period (1170–1500 CE; Figure 5.1). Graves were narrow sub-rectangular cuts oriented east to west, and grave coverings were “rectangular shaped, formed of outer faces of moderate sized sub-rectangular stones arranged [one or] two to four courses in height with a central infilling of smaller stones and gravel” (Ginns, 2010c, p. I). These correspond to MDASP grave types FF03c and FF03a, respectively (Borcowski and Welsby, 2012). The cemetery was bounded by natural outcroppings on the northern and western edges, and by an unexcavated Muslim cemetery to the east (Ginns, 2010c).

About half of the extant graves were chosen for excavation by following a sampling strategy where archaeologists attempted to achieve “roughly equal density from across the entire site,” (Ginns, 2010c, p. I) resulting in 126 sets of human skeletal remains. Of the 80 adults and adolescents (Hurst, 2013), all individuals with available crania and fused long bone epiphyses were used for this study (n = 74). Mortuary analysis found no difference in the burial treatment or location of adult males and females (Soler, 2012), but younger subadults demonstrated different spatial and mortuary treatment compared to adults, visible in the cluster of subadult burials in the eastern portion of the cemetery (Hurst, 2013).

Figure 5.1. Plan of Mis Island cemetery 3-J-10 showing adult and subadult burials (Soler, 2012).



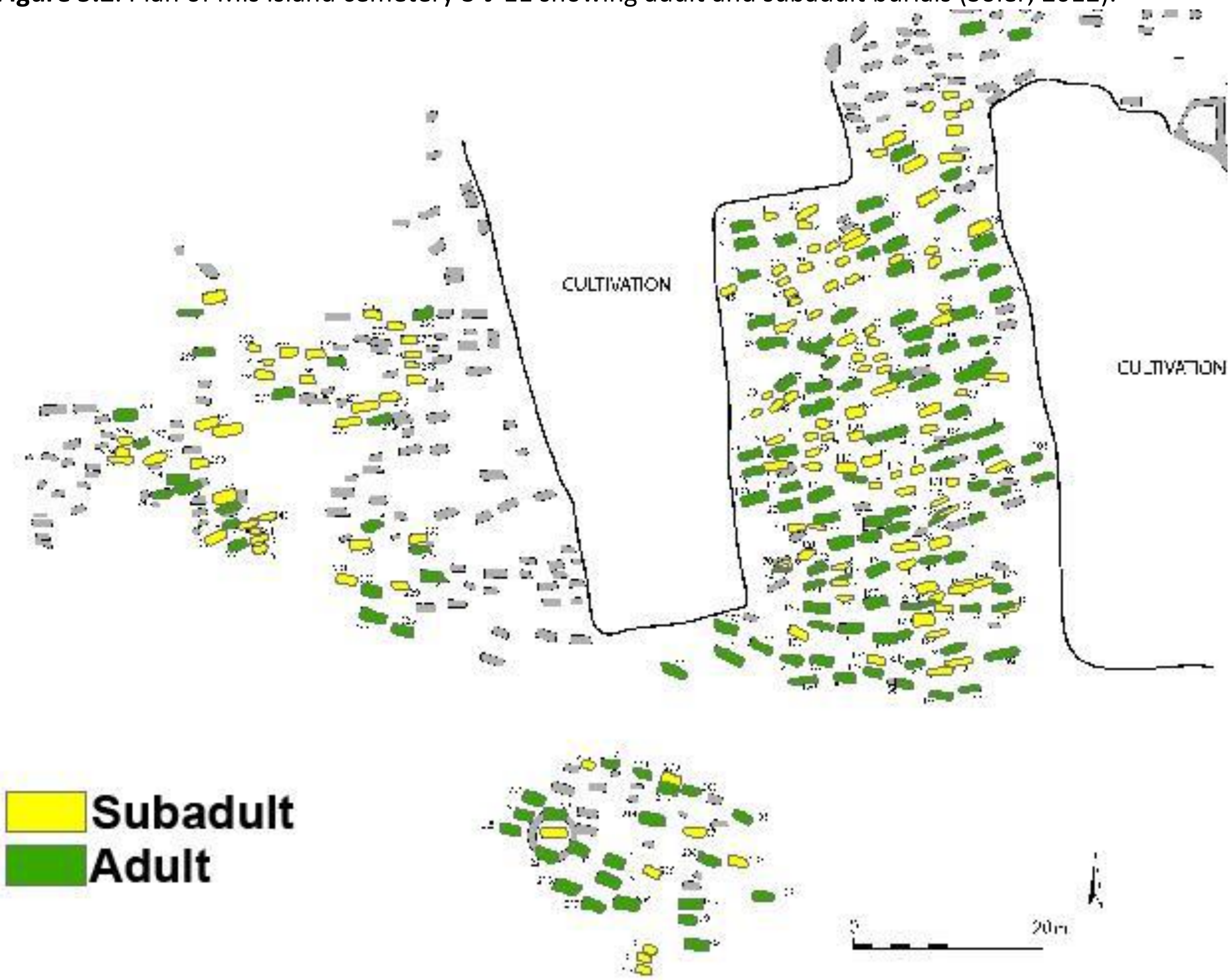
Cemetery 3-J-11

Cemetery 3-J-11 was the largest of the three Mis Island cemeteries, even though recent agricultural activities had damaged multiple areas (Figure 5.2). Cemetery 3-J-11 was used from the Meroitic Period (300 BCE–350 CE) and through the Late Medieval Period (1170–1500 CE), transitioning finally into a Muslim cemetery which was used until modern times (Ginns, 2010b). Like at cemetery 3-J-10, graves were aligned east to west and used a simple stone superstructure as a marker. This cemetery was closer to the riverbank and was less geographically bounded than cemetery 3-J-10. Over five hundred graves were recognized in cemetery 3-J-11, and about half of observed graves were excavated in “approximately equal density” from across the cemetery, resulting in 259 complete and 29 partial individuals. The latter are the result of later graves cutting into existing burials. Of the 164 adults and adolescents (Hurst, 2013), all individuals with available crania and fused long bone epiphyses were used for this study (n = 142). Similar to cemetery 3-J-10, mortuary analysis found no different treatment of the sexes (Soler, 2012). However, subadults were distributed through the cemetery, unlike at cemetery 3-J-10, leading Soler (2012) and Hurst (2013) to suggest the presence of kin-based burial clusters in cemetery 3-J-11. No biodistance analysis has attempted to confirm this.

Cemetery 3-J-18

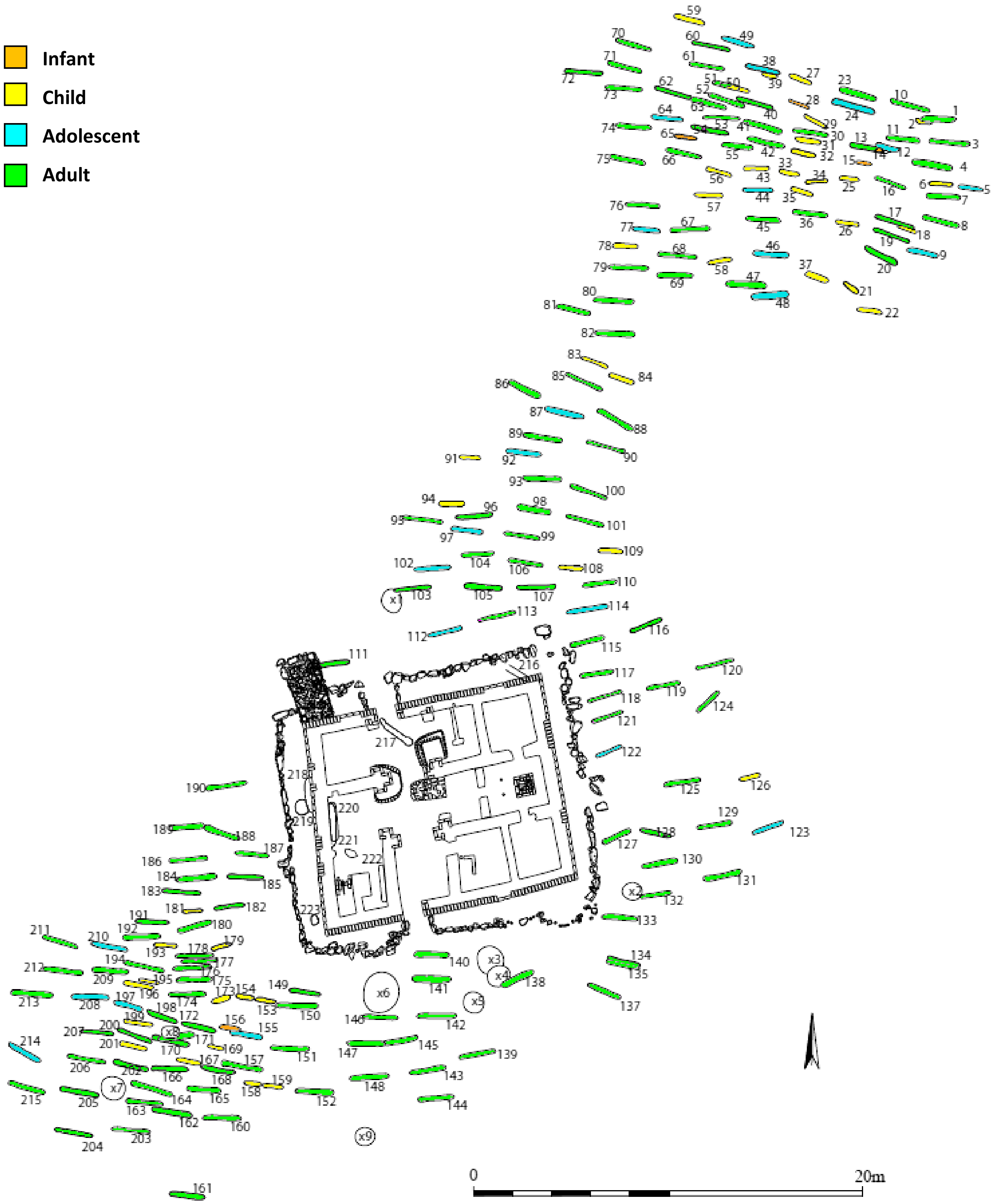
Cemetery 3-J-18 was associated with a church found on the east side of Mis Island (Figure 5.3). The church was built on top of a handful of pre-existing graves and the cemetery was bounded by natural rock outcrops. The overall square shape of the church and its construction of mudbricks covered in plaster are consistent with other late medieval Nubian ecclesiastical architecture. The church was likely a single story building with stairs leading to the roof (Ginns, 2010d). This area was used for burials from the period preceding church construction around 1100 CE until the end of the Medieval Period (1170–1500 CE).

Figure 5.2. Plan of Mis Island cemetery 3-J-11 showing adult and subadult burials (Soler, 2012).



Nearly all of the graves at this site were excavated, resulting in 217 complete and 5 incomplete sets of human skeletal remains (Ginns, 2010a). No reports have yet been published analyzing the demography or health of this Mis Island cemetery, although the preliminary site report presents some raw data (Ginns, 2010a). Grave types included those described for 3-J-10 and 3-J-11 (MDASP types FF03c and FF03a) but other grave coverings were also used, including FF02-type coverings consisting of a stone or mudbrick pavement (Borcowski and Welsby, 2012). Graves in 3-J-18 were aligned east to west with single extended supine inhumations and no grave goods. Data was not collected on all excavated adults in the cemetery 3-J-18 sample (n = 72 of about 108). There were two main reasons for this.

Figure 5.3. Plan of Mis Island cemetery 3-J-18 showing adult and subadult burials. Modified from Ginns, 2010a, p. V.



First, extensive mummified tissue was present on some individuals, preventing osteological data collection. Second, data collection for this research was under a time constraint, limiting the sample size. Thus, data collection conducted at the British Museum followed an opportunistic sampling strategy aimed at even representation of skeleton numbers and therefore cemetery area.

Kulubnarti

The two medieval cemeteries included in this dissertation are designated by their location and their site number: 21-R-2 (n = 97), located on the mainland left bank immediately south of Kulubnarti Island, and 21-S-46 (n = 54), located near the west coast of the island (Table 5.5).

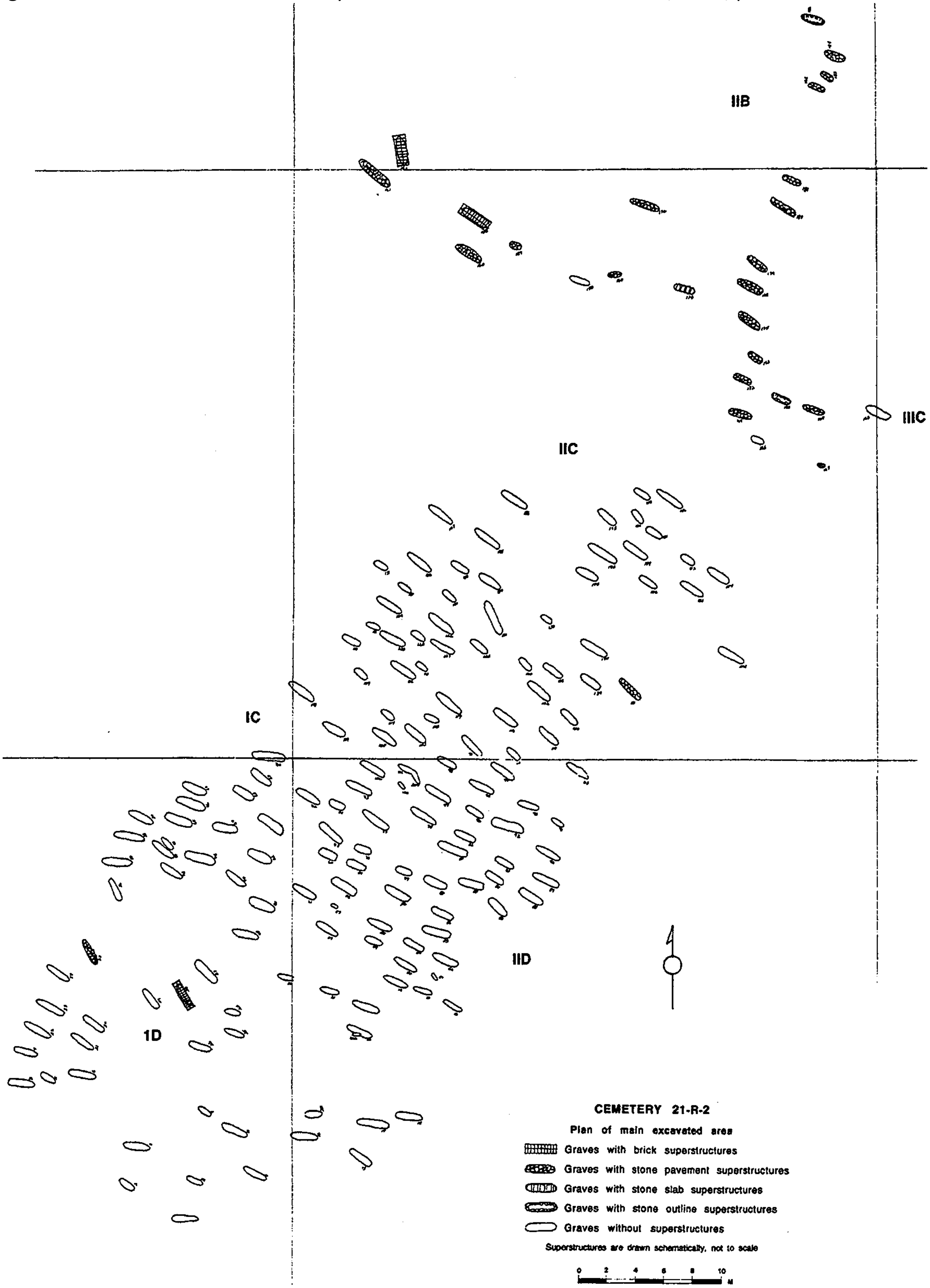
Table 5.5. Kulubnarti skeletal sample by cemetery, age, and sex.

	Female	Male	Unknown	Total
Young adult	12	5	0	17
Middle adult	13	16	0	29
Old adult	8	0	0	0
Unknown Age Adult	0	0	0	0
Total 21-S-46	*33*	*21*	*0*	*54*
Young adult	21	17	0	38
Middle adult	28	22	0	50
Old adult	8	1	0	9
Unknown Age Adult	0	0	0	0
Total 21-R-2	*57*	*40*	*0*	*97*
Young adult	**33**	**22**	**0**	**55**
Middle adult	**41**	**38**	**0**	**79**
Old adult	**16**	**1**	**0**	**17**
Unknown Age Adult	**0**	**0**	**0**	**0**
Total Kulubnarti	**90**	**61**	**0**	**151**

Cemetery 21-R-2

The larger of the two Kulubnarti cemeteries, 21-R-2, was situated on the left bank of the Nile just south of the island itself and is sometimes referred to as the “mainland” cemetery. It is situated on a gentle slope with no natural boundaries (Figure 5.4). Over 500 graves were identified, but excavations

Figure 5.4. Plan of Kulubnarti cemetery 21-R-2. Modified from Adams *et al.,* 1999, p. 27.



in 1979 focused on a region in the northwest portion of the cemetery and resulted in a total of 188 sets of excavated human remains. Of the 106 adults recovered from cemetery 21-R-2, all available individuals with at least partially skeletonized crania were used in the present study (n = 97). A few individuals had excellent preservation of the soft tissues of the head, obstructing view of the underlying bone and preventing data collection.

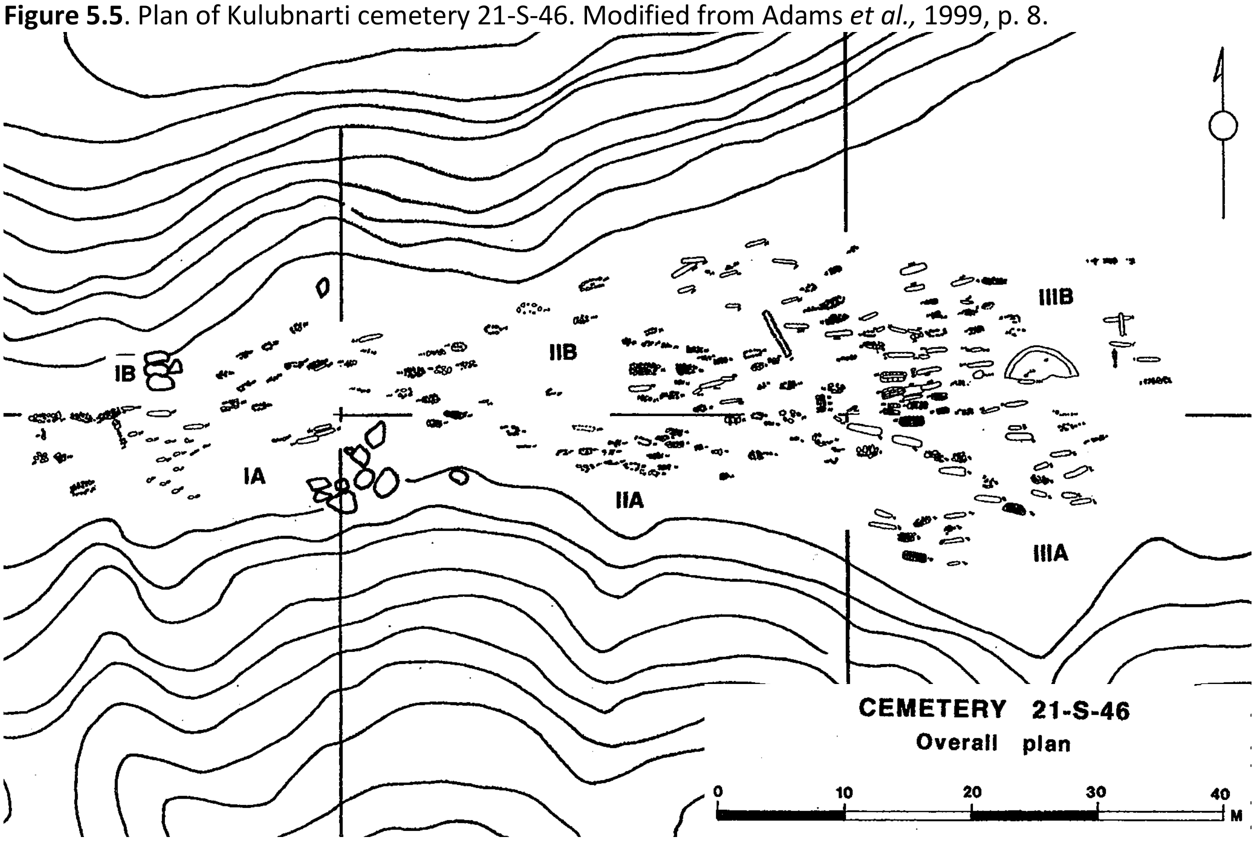
Overall grave style in the mainland cemetery is like that found in island cemetery. Single, extended, supine inhumations demonstrating an absence of grave goods and oriented west-east characterize cemetery 21-R-2 and make dating the cemetery within the Medieval Period (550–1500 CE) difficult (Adams *et al.,* 1999). Many of the simple subrectangular grave cuts are not associated with any superstructure. Superstructures, when present, are in the form of stone or mudbrick pavements or stone outlines (Adams *et al.,* 1999). Cemetery 21-R-2 is associated with a late medieval settlement on the nearby southern tip of Kulubnarti Island and a Classic Medieval church. Use of both the mainland cemetery 21-R-2 and the island cemetery 21-S-46 began in the Early Medieval Period (550–835 CE; Adams, 2011). However, use of the mainland cemetery 21-R-2 continued through the Late Medieval Period (1170–1500 CE) and into modern times (1500–2000 CE; Adams *et al.,* 1999). Demographic and paleopathological analysis demonstrate a relatively healthy population with two thirds of the population living beyond the age of ten.

Cemetery 21-S-46

The “island” cemetery 21-S-46 consisted mostly of typical Christian-style west-east oriented unlined simple graves with the cemetery stretching west to east and bounded on the north and south borders by natural rock formations (Figure 5.5). The graves at Kulubnarti are designated “slot graves” by Adams *et al.* (1999). They resemble Mis Island “box graves” in that both grave cuts are simple subrectangular shafts with no side niche or other structural embellishment. Grave coverings in cemetery

21-S-46 are described as stone pavements and stone outlines (Adams *et al.,* 1999), which broadly correlate with the MDASP FF03 grave types seen most often in the Mis Island cemeteries (Borcowski and Welsby, 2012). Excavations completed in 1979 resulted in the discovery of 218 sets of human remains (Adams *et al.,* 1999). Of the 60 adults, all available individuals with crania were used for this study (n = 54). A few individuals retained extensive mummified tissue, obstructing view of the underlying bony structures and preventing data collection.

Figure 5.5. Plan of Kulubnarti cemetery 21-S-46. Modified from Adams *et al.,* 1999, p. 8.



A handful of graves appear to be in the Post-Meroitic style of tumulus, but otherwise, archaeological dating of the Christian graves within the Medieval Period was extremely difficult due to the similarity of the graves and the absence of grave goods or association with a settlement or church (Adams *et al.,* 1999). However, as mentioned above, carbon dating results put the mean age of this cemetery around the mid-eighth century (Van Gerven, personal communication). Archaeological interpretation, supported by the same carbon dates, suggests that cemetery use ceased after the Early Medieval Period (550–835 CE) after a few centuries of use (Adams *et al.,* 1999). Where grave goods are present, they are usually items of personal adornment, often with a Christian-style cross associated, often with juvenile remains (Adams *et al.,* 1999). Demographic and paleopathological analysis reveal a population under significant physiological stress in which only one third of the population lived beyond the age of ten. The conclusion is that the island population buried at cemetery 21-S-46 experienced higher levels of stress than the mainland population (Adams *et al.,* 1999).

Gabati

A total of 114 graves were excavated from all periods at Gabati, with 50 of these from the Post-Meroitic (350–550 CE) and Medieval (550–1500 CE) Periods (Figure 5.6). All adults with crania (n = 32) were used for data collection for the present research (Table 5.4). Of demographic note, no old adults (age ≥ 50 years) were identified in the Post-Meroitic or Medieval burials (Table 5.6), although a few were identified from the Meroitic Period burials (Judd, 2012). Overall, health and disease, including childhood stresses, are observed to be lower at Gabati than in contemporary Lower Nubian samples, yet the life expectancy at birth is lower at Gabati (Judd, 2012).

The Gabati burials used in this study are those identified as Post-Meroitic and Medieval in the site report (Judd, 2012). Post-Meroitic burials were included primarily because of the overlapping definitions of the Medieval Period and the Christian Period. Christianity spread through Nubia as early as the sixth century CE in Lower Nubia, but did not reach Upper Nubia and more rural communities until the seventh or eighth centuries CE. In addition, following religious conversion, Christian funerary practices were not fully adopted in all communities, including at Gabati (Judd, 2012). It seems likely that use period of Post-Meroitic burial styles at Gabati overlaps significantly in time with early Christian burials found further downriver at Mis Island and Kulubnarti.

Figure 5.6. Plan of the cemetery at Gabati, showing Post-Meroitic and medieval graves shaded in (Judd, 2012, p. 70).

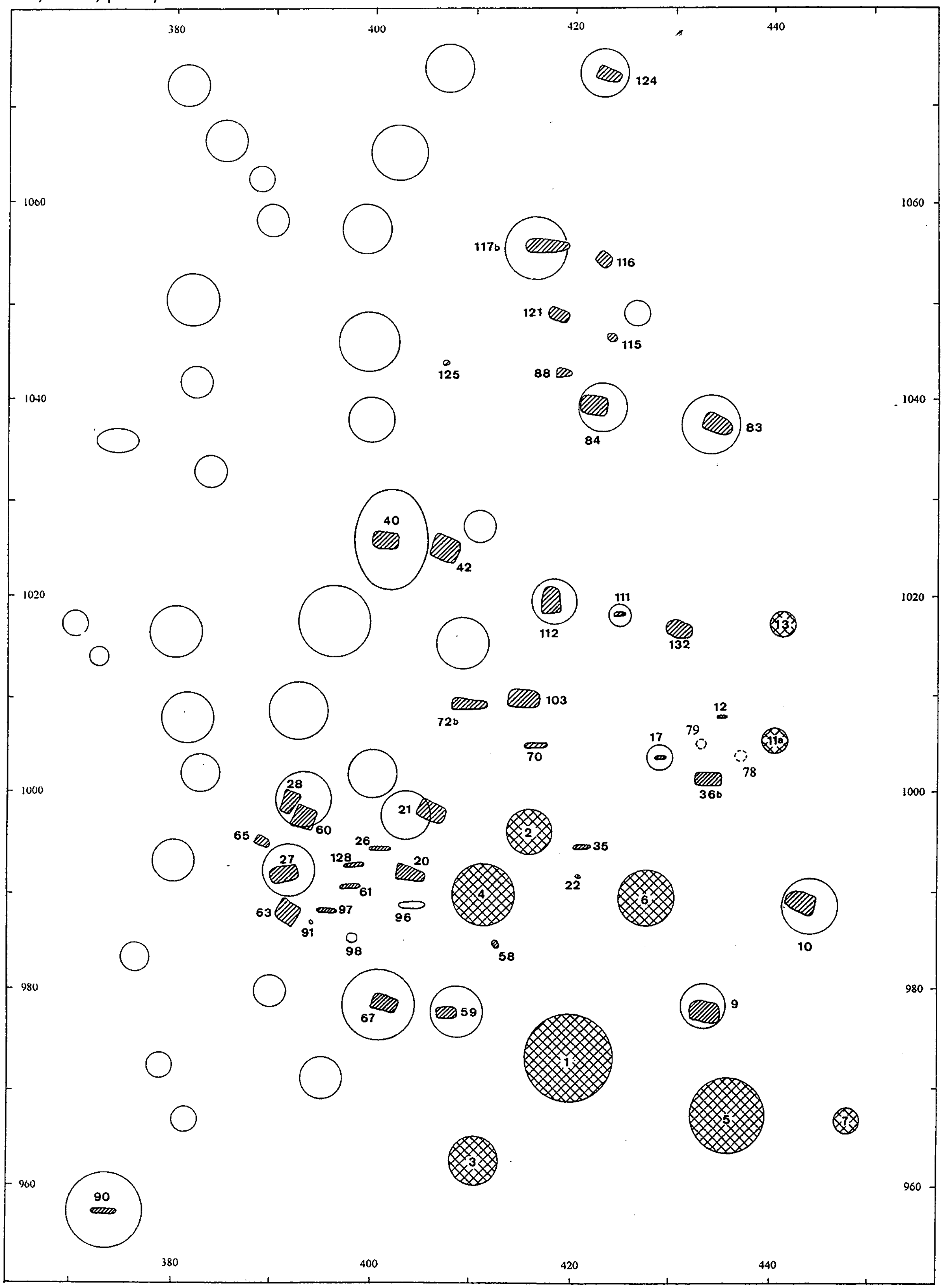


Table 5.6. Gabati skeletal sample by age and sex.

	Female	Male	Unknown	Total
Young adult	11	9	0	20
Middle adult	7	5	0	12
Old adult	0	0	0	0
Unknown age adult	0	0	0	0
Total Gabati	**18**	**14**	**0**	**32**

The Post-Meroitic burials are most commonly characterized by a right-side flexed body position, sometimes with a bed included in the chamber (bed burials having been common in Nubia since at least the third millennium BCE), and a variety of grave goods (Edwards, 1998). Some Early Medieval (550–835 CE) graves include traits normally found in Post-Meroitic contexts, including: flexed side body positions, Post-Meroitic-style circular grave cuts, presence of grave goods, and the use of a circular cairn superstructure (Judd, 2012). Overall, the medieval burials at Gabati are inconsistently "Christian" in form, leading researchers to describe this group as undiagnostic medieval, but not necessarily Christian burials (Judd, 2012). The skeletal subsamples are not large enough to permit statistical comparison between Christian- and alternate-style medieval burials.

Comparative data

Results from Vollner's doctoral dissertation (2016) were used for comparison with analogous results produced by cranial nonmetric traits in this study. Vollner's Mis Island craniometric data sample is comprised of adults from cemeteries 3-J-10 and 3-J-11, and her Kulubnarti data includes about 60% of the crania used in the present study. Both Vollner and I collected data on all adult crania from Gabati. Relevant results from Vollner include the biased Mahalanobis D^2 distance matrix derived from her three-site analysis (Table 6.5, 2016, p. 107) and the ratios of male-to-female variance at each site (Table 6.14 2016, p. 119).

For regional context, Ossenberg's global cranial nonmetric trait data was used (2013, http://library.queensu.ca/data/cntd). Only African samples were selected. Groups from the same country with the same tribal or sub-tribal affiliation and with an adult sample size of 29 or more were included. The Ossenberg samples chosen were the Ashanti (Ghana, n = 32), Calabar (Nigeria, n = 29), Kerma (Sudan, n = 77), Khoisan (South Africa, n = 37), and Pare (Tanzania, n = 33). Ossenberg's data comprises 38 nonmetric traits of the skull and first cervical vertebra (atlas), with bilateral observations reported for all bilateral traits. Eleven of Ossenberg's traits overlap sufficiently in description and threshold to justify integration with my data set. These traits are designated by a double asterisk in Table 5.1. For bilateral traits, the side used from Ossenberg's dataset was randomly chosen, following the protocols used for the original data in this study (Konigsberg, 1990).

STATISTICAL METHODS

The statistical methods used in the present study are detailed in this section. Descriptive and exploratory statistics are presented first, including reports on intraobserver error, trait intercorrelation, and correlations between traits, age, and sex. Then the analytical methods used to investigate each of the stated research questions are described. R statistical software was used for most statistical procedures and creation of figures (R Core Team, 2017), except where otherwise indicated.

Intraobserver error

To assess the rate of intraobserver error, forty-eight individuals were re-scored after an interval of at least eight weeks. Both left and right sides were observed, following the protocol for this study, and the side used for analysis was randomly determined for bilateral traits (Konigsberg, 1990). Then, the two sets of observations were tested for agreement using Cohen's kappa (1960). Cohen's kappa measures the agreement between two observers, correcting for agreement that would occur by chance alone. Cohen's kappa (κ) is calculated as:

$$\kappa = \frac{\mathrm{P(o)} - P(e)}{1 - P(e)}$$

where P(o) denotes the observed percentage of agreement, and P(e) denotes the probability of expected agreement due to chance (Cohen, 1960; Hefner, 2009). If observations are in perfect agreement, the expected kappa value is 1, whereas if observations are randomly assigned, the expected kappa value is 0. The results of a two-rater analysis are entered into a 2 x 2 table as shown in Table 5.7.

Table 5.7. Example of the results of a two-rater analysis.

		Rater B		
		yes	no	Totals
Rater A	yes	a	b	a + b
	no	c	d	c + d
	Totals	a + c	b + d	(a + b + c + d) = N

Prevalence refers to the proportion of positive (a) and negative (d) observation agreements, with the assumption in interpreting kappa statistics being that these are roughly equal. Prevalence problems may occur when very unequal frequencies of conditions are present, as in the present study (Byrt *et al.,* 1993). Bias refers to the differing proportions by which two different observers will tend to observe yes and no. Prevalence problems cause Cohen's kappa to be unrepresentatively low, and calculating and reporting a prevalence- and bias-adjusted kappa (pabak) is recommended in such cases (Byrt *et al.,* 1993; Hallgren, 2012).

The bias index (BI) and prevalence index (PI) may be calculated as:

$$\mathrm{BI\ (bias\ index)} = \frac{\mathrm{b-c}}{\mathrm{N}}$$

$$\mathrm{PI\ (prevalence\ index)} = \frac{\mathrm{a-d}}{\mathrm{N}}$$

The PI is 0 when a and d are equal, 1 when a = N and d = 0, and -1 when a = 0 and d = N. Prevalence indices further from 0 will result in a lower Cohen's kappa, even in samples with the same overall number of agreements. The PI and BI are used in the calculation of pabak using the following equation:

$$\kappa = \frac{2\mathrm{P(o)} - 1 - \mathrm{PI}^2 + \mathrm{BI}^2}{1 - \mathrm{PI}^2 + \mathrm{BI}^2}$$

where P(o) denotes the observed percentage of agreement, PI denotes the prevalence index, and BI denotes the bias index (Byrt *et al.,* 1993).

Cohen's kappa values were calculated using the kappa2 function with weight = "squared" and percent agreements were calculated using the agree function in the "irr" package for R (Gamer *et al., 2*012). Pabak and PI values were calculated using the epi.kappa function in the "epiR" package for R (Stevenson, 2016).

Research Questions 1a, 2a, and 2b: Biological relationships among samples

Research Question 1a involves a three-site analysis of Mis Island, Kulubnarti, and Gabati; Research Question 2a involves a six-cemetery analysis across the three sites; and Research Question 2b involves an eleven-sample analysis adding five comparative African samples to the six medieval Nubian cemeteries used elsewhere in this dissertation. The statistical methods described in this section were used to answer all three of these research questions.

Fisher's exact tests were used to examine the relationship between each trait and cemetery or site. (Fisher's exact tests were not run for Research Question 2b.) Fisher's exact test is a test of statistical significance between categorical variables. It is used in place of Pearson's chi-squared test when any cell in the contingency table has a count of less than five. For many of the traits used in the current study, their rarity makes Fisher's exact test the most appropriate statistic to examine the significance of the association between trait presence and cemetery/site. Fisher's exact tests were run for each trait against the three total sites, three Mis Island cemeteries, and two Kulubnarti cemeteries using the "fisher.test" function in R (R Core Team, 2017).

The biodistance among groups is calculated in this dissertation using Konigsberg's modification of the Mahalanobis distance statistic or D^2 (1936). Mahalanobis D^2 is a multivariate statistic first applied as a quantitative analysis of biodistance using craniometrics (Irish, 2010). It was modified for use with dichotomous nonmetric trait data by the inclusion of a tetrachoric correlation matrix (Konigsberg, 1990). Nonmetric Mahalanobis D^2 between populations i and j is calculated as (Konigsberg, 1990):

$$D^2{}_{ij} = (Z_{ik} - Z_{jk})' T^{-1} (Z_{ik} - Z_{jk})$$

where Z_{ik} = threshold value (presence) for a trait frequency of p_{ik} for trait k in sample i; z_{jk} = threshold value for a trait frequency of p_{jk} for trait k in sample j; $'$ indicates transposition; T^{-1} = inverse of pooled tetrachoric correlation matrix between the k traits (Irish, 2016). The distance matrix produced by pairwise calculation of D^2 shows numbers approaching 0 for pairs that are very closely related and larger numbers for increasing dissimilarity. The distance values are dependent on the number of traits used in calculations, meaning that distance values are not comparable between studies (Relethford, 2016). However, subsequent calculations are affected, and F_{ST} may be compared among studies. The effect of small sample size on D^2 values should be corrected for, using the bias correction formula suggested by Rightmire (1969):

$$bias - corrected\ D^2{}_{ij} = D^2{}_{ij} - \frac{t(n_i + n_j)}{n_i * n_j}$$

where t is the number of traits and n_i and n_j are the sample size of the populations being compared. D^2 values were tested for significance using an F-test as described by Konigsberg *et al.* (1993, p. 42):

$$F = \left(\frac{n_i + n_j - t - 1}{n_i + n_j - 2}\right) * \left(\frac{n_i * n_j}{n_i + n_j}\right) * D^2$$

where the degrees of freedom are "t" and "$n_i + n_j - t - 1$." F tests were calculated in Excel 2016 and p values were found using an online calculator (https://graphpad.com/quickcalcs/PValue1.cfm).

As Relethford points out, Mahalanobis D^2 "is a model-free distance, because its derivation is based on statistical concerns, not any specific model of population genetics" (2016, p. 25). Additional inferences about the genetic relationship among populations may be derived by using a Mahalanobis D^2 matrix to produce a genetic relationship matrix (R matrix) and calculate Wright's fixation index (F_{ST}) for each subsample (Konigsberg, 2006; Wright, 1951). R-matrix theory was developed in the field of population genetics, but has been extended for use with quantitative (Relethford, 1994; Relethford and Blangero, 1990; Relethford and Harpending, 1994) and nonmetric traits (Konigsberg, 2006). The R matrix is a scaled variance-covariance matrix produced by first using the D^2 matrix to calculate a C- or codivergence-matrix (Konigsberg, 2006). The C-matrix measures the variance around the mean of all samples (Konigsberg, 2006) and is calculated as:

$$C = -0.5(I - 1w')D^2(I - 1w')'$$

where I = g x g identity matrix, g = number of groups; 1 = g x 1 column vector of 1s; D^2 = $a \cdot g$ x g matrix of squared distances based on t traits; w = g x 1 column vector of relative population sizes (if known); and ′ indicates transposition (Irish, 2016). In this case, as with many bioarchaeological scenarios, population sizes are not known so the groups are weighted equally with $w_i = 1/g$ (Relethford, 2016, 1994).

F_{ST} is the computed from the C-matrix diagonal values and provides a measure of among-sample variation (Relethford, 2016). Actually, it is a measure of the average inbreeding (*F*) of a subpopulation (*S*) relative to the total population (*T*) (Pink *et al.,* 2016). Calculation of F_{ST} relies on heritability, but because heritability is population specific, it is rarely known for cranial nonmetric traits of past populations. Thus in bioarchaeological contexts, the conservative value of minimum F_{ST} is calculated by assuming $h^2 = 1$ (Irish, 2016). A value closer to 0 indicates high within-group heterogeneity, less inbreeding, and more gene flow, while a value closer to 1 indicates low within-group heterogeneity, more inbreeding, and less gene flow (Hartl and Clark, 2007). Minimum F_{ST} may be calculated from the diagonal of the C-matrix as (Relethford, 2016, p. 27):

$$minimum\ F_{\mathrm{ST}} = \frac{\sum w_i c_{ii}}{2t + \sum w_i c_{ii}}$$

Finally, the R matrix is computed following Relethford and Blangero (1990):

$$R = \frac{\mathrm{C}(1 - F_{\mathrm{ST}})}{2t}$$

The R matrix, defined above as a scaled variance-covariance matrix, is more intuitively described as "a matrix of average kinship coefficients between populations (off the diagonal) and within populations (on the diagonal)" (Konigsberg, 2006, p. 279). Off-diagonal values (r_{ij}) are positive when the subsamples being compared are more similar than average, and negative when they are less similar than average (Irish, 2016). On-diagonal values (r_{ii}) are measures of within-group heterogeneity; the mean of these is F_{ST}.

Previous biodistance studies have calculated an estimated F_{ST} from the R matrix using an average heritability inferred from other studies of craniometrics (Vollner, 2016) and dental nonmetric traits (Irish, 2016), but this approach is less common in studies of cranial nonmetric traits. Therefore, following Godde (2009b), this study relies only on the conservative estimate of minimum F_{ST} ($h^2 = 1$). More realistic (lower) heritabilities would increase the actual F_{ST} (Irish, 2016), but minimum F_{ST} still provides a valuable tool for comparing variability among subsamples.

Group differences are visualized through principal coordinates analysis (PCoA, also known as multidimensional scaling or MDS; Gower, 1966). The principal coordinates of each R matrix were derived by the "tdistR" package, and the first two and three principal coordinates of the R matrix (scaled by the square root of the associated eigenvalues) were plotted for each level of analysis (Konigsberg, 2017).

Dendrograms were created for visualization of the relationships among samples in Research Questions 2a and 2b. Ward's clustering method was applied to R matrix values using the "hclust" function in R (R Core Team, 2017). Dendrograms were created using the as.phylo function from the "ape" package for R (Paradis *et al.,* 2004) with additional features of the figure enhanced using the "dendextend" package for R (Galili, 2015).

The tdistR code for R (available for download from Lyle Konigsberg's website at https://anthro.illinois.edu/directory/profile/lylek) was used to analyze the nonmetric cranial data by site and by cemetery. The run.D2 function produced by-cemetery and by-site D^2 and R-matrices, and the plot2D and plot3D functions produced scaled plots of the first two and three principal coordinates of each R matrix.

Research Question 1b: Comparison of biodistance results

To compare Vollner's three-site analysis with the one performed in this dissertation, Vollner's Mahalanobis D^2 distance matrix was used (2016, p. 107, Table 6.5). Her subsequent analyses used an estimated average heritability of $h^2 = 0.55$ for craniometric traits, whereas this study used $h^2 = 1$. To make the craniometric R matrix more directly comparable to my cranial nonmetric R matrix, Konigsberg's tdistR code was applied to Vollner's D^2 matrix, producing a three-site craniometric R matrix with $h^2 = 1$.

The methods of Herrera *et al.* (2014) were used to compared the distance matrices resulting from the analysis of multiple types phenotypic data. Because each analysis uses different units, Herrera *et al.* (2014) first perform a Procrustes analysis on the principal coordinates. A Procrustes analysis is a linear transformation that scales, reflects, and rotates elements of a matrix to find the best fit with a second matrix, compensating for some differences in the scale of the different datasets (Herrera *et al.,* 2014). Both sets of data are then plotted on the first three principle coordinates (PCs) for visual assessment. To assess the correlation between the two distance matrices, two-way Mantel tests (Mantel, 1967) were used. The Procrustes analysis minimizes the sum of squares deviations (m^2), and the significance of m^2 was tested using the PROTEST function in the "vegan" package (Oksanen *et al.,* 2017), because PROTEST is a more powerful method of examining the correlation between the two matrices (Herrera *et al.,* 2014).

R code for the Herrera *et al.* (2014) methods is available online at https://sites.google.com/site/drgodde/r-scripts/herrera-et-al-2014. This R code was used to perform the Procrustes analyses and

PROTEST using the “vegan” package (Oksanen *et al.,* 2017) and to plot the data using the “scatterplot3D” package (Ligges and Machler, 2003).

Research Question 3: Postmarital residence

The theoretical underpinnings of the methods used in this study to quantify sex-specific variance have roots in bioarchaeological research (Konigsberg, 1988). As reviewed in Chapter Two, within-site phenotypic variability is greater in the sex with higher mobility, which is related to postmarital residence and gendered aspects of social structure. For this study, a bootstrap method recently modified from a genetic approach (Konigsberg and Frankenberg, 2016) was used to quantify diversity using cranial nonmetric trait data. All male and female individuals from each subsample were grouped by sex for this analysis. (See Table 5.3 for known-sex sample sizes at each site.)

One of the most recent approaches to the analysis of sex-specific variance using cranial nonmetric traits focuses on a bootstrap method, allowing for the calculation of confidence intervals and therefore hypothesis testing (Konigsberg and Frankenberg, 2016). The new application used by Konigsberg and Frankenberg borrowed from genetic analysis (Felsenstein, 1985; Hasegawa and Kishino, 1989) to reanalyze cranial nonmetric data collected by Konigsberg (1987). The genetic analysis method uses bootstrap sampling across nucleotides samples with replacement across nucleotide sites to quantify variability (Konigsberg and Frankenberg, 2016). When Konigsberg and Frankenberg (2016) applied this approach to cranial nonmetric traits, they substituted presence and absence codes in their nonmetric dataset for two of the nucleotide codes used in the genetic model. They used: “a” (usually for adenine) to signify absence, “c” (usually for cytosine) to indicate presence/complete, and “?” to indicate unobservable instances. Thus, data in the present study was recoded in the same manner.

Because variation in practices among cemeteries might obscure results at the site level, the sex-specific variance was calculated for each cemetery as well as at the site level at Mis Island, Kulubnarti, and Gabati. For each subsample, all possible pairs of individuals within each sex were compared, and the observed mean number of pairwise differences between was calculated. The smallest sex-specific sample is females at Gabati, where n = 14 and 91 possible pairs were compared. The largest sex-specific sample is females at Mis Island, where n = 68 and 2,346 possible pairs were compared. To provide a confidence interval, following the recommendations of Konigsberg and Frankenberg (2016), calculating mean pairwise differences from 10,000 bootstrap samples with replacement for each subsample. These calculations were done using the dist.dna function from the "ape" package (Paradis *et al.,* 2004) for R.

Finally, I calculated a bootstrap confidence interval on the ratio of mean pairwise differences between the female and male subsamples in each cemetery and at each site (Konigsberg and Frankenberg, 2016). A ratio between the sexes of 1.0 represents the null hypothesis, where male and female variances are the same. A ratio greater than 1.0 indicates higher female variance and therefore greater female mobility, while a ratio less than 1.0 indicates less female variance and therefore greater male mobility. For visual appreciation of the results, the bootstrap ratio between the sexes in each cemetery and at each site were plotted as empirical cumulative density plots using the "ecdf" function in R (R Core Team, 2017).

Research Question 4: Spatial analysis

Spatial analysis in this study will focus on the three Mis Island cemeteries. The term "kin cluster" will be used to indicate a group of relatives identified by phenotypic similarity using cranial nonmetric traits, and the term "burial cluster" will indicate a spatial grouping of burials. Two methods will be used. The first will analyze each of the three Mis Island cemeteries as a uniformly distributed cemetery, since few mortuary or spatial differences are observed. The second method will test Soler's (2012) identification of burial clusters in cemetery 3-J-11, treating this cemetery as spatially structured. Individuals with unknown grave locations were excluded from all spatial analysis methods.

Uniformly distributed cemeteries

For uniformly distributed cemeteries, the first step in identifying kin-based groups is to determine whether spatial distances and phenotypic distances between individuals are correlated (Stojanowski and Schillaci, 2006). Spatial distance matrices for each cemetery were created by pairwise calculation of Euclidean distances between the x and y coordinates of individuals in each cemetery. Spatial (Euclidean) distance matrices were created in each cemetery using the "dist" function in R (R Core Team, 2017).

Phenotypic distance matrices for each cemetery were calculated using Gower dissimilarity coefficients, by pairwise calculation of Gower's general coefficient of dissimilarity (1971). The formula for Gower's general coefficient of similarity is given by Shennan (1997, p. 232) as:

$$S = \frac{\sum_{k=1}^{p} S_{ijk}}{\sum_{k=1}^{p} w_{ijk}}$$

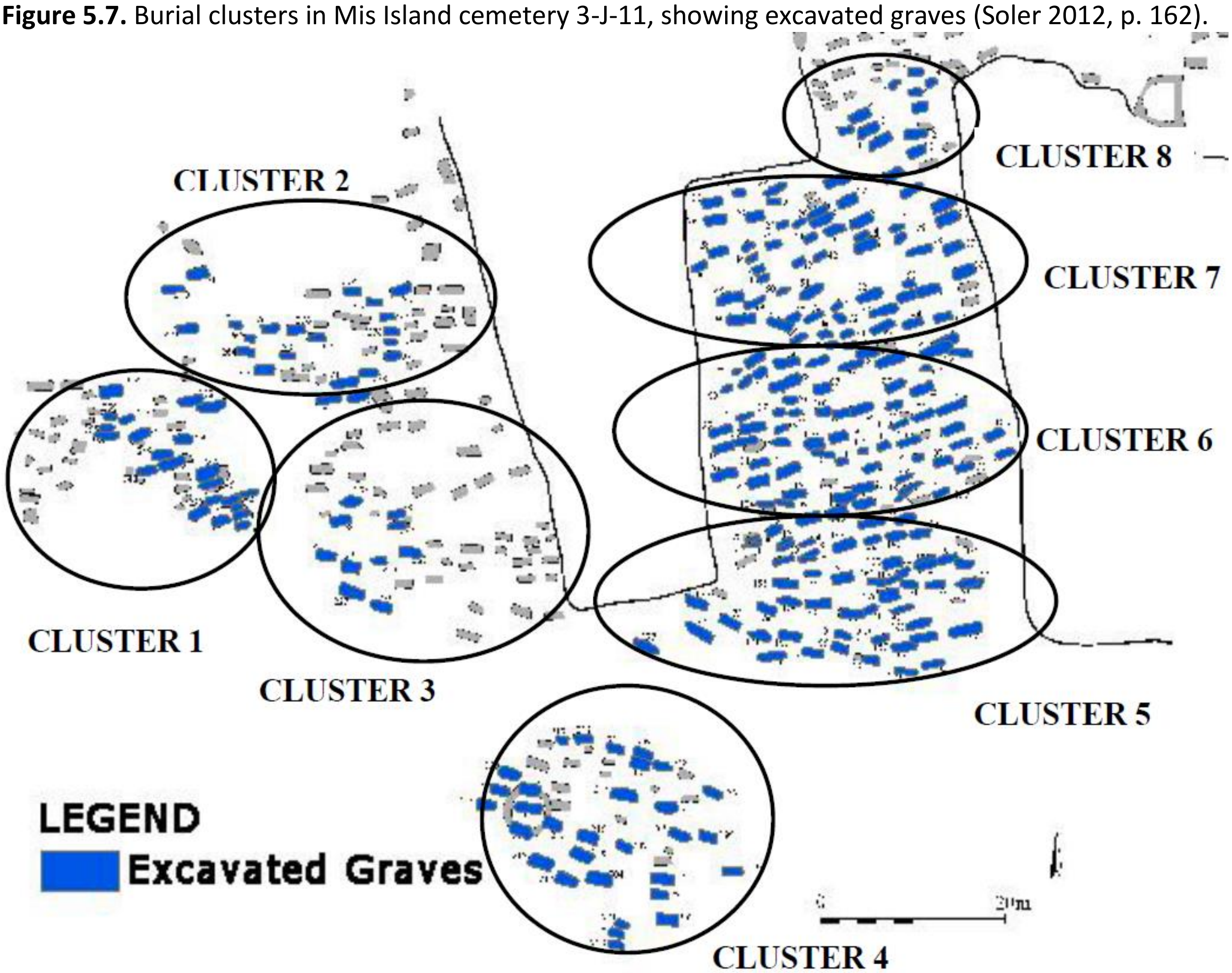
where *i* and *j* are two individuals being compared over a set of *p* variables. The similarity for each variable is evaluated as s_{ijk} before all similarity values are summed. Gower's similarity and dissimilarity coefficients are both derived using the same formula, but with different values accorded to different types of matches and mismatches for each case. For the calculation of dissimilarity from presence/absence variables, the dissimilarity (s_{ijk}) is coded as 1 (mismatch) or 0 (match), and the weight is always 1. The sum of all dissimilarity values is standardized by the sum of the weights (w_{ijk}) associated with each variable (Shennan, 1997). Gower dissimilarity coefficient matrices were created using the daisy function with method = "gower" in the "cluster" package for R (Maechler *et al.,* 2017).

The Mantel test is commonly used in biodistance analyses to compare phenotypic distance and geographic distance (Smouse and Long, 1992; Stojanowski and Schillaci, 2006). The Mantel test is a non-parametric statistical test used to compare two matrices (Manly, 2007; Ward, 1963). The Mantel test computes significance by permutation of the rows and columns of one of the input matrices. As with the

Spearman's correlation on which the Mantel test is based, a rho (*r*) of 0 indicates no correlation and an *r* of 1 indicates strong correlation. The phenotypic and spatial distance matrices for each of the three Mis Island cemeteries were tested for correlation via Mantel test using the mantel function with method = "spearman" in the "vegan" package for R (Oksanen *et al.,* 2017).

Cemetery 3-J-11 was analyzed again as a spatially structured cemetery. Testing of Soler's proposed clusters (Figure 5.7) follows the methods of Howell and Kintigh (1996). Each cranial nonmetric trait was observed as present in at least one individual in the cemetery, so all 30 cranial nonmetric traits were used. One hundred and thirty-eight individuals were used for the spatial analysis of Mis Island cemetery 3-J-11.

Figure 5.7. Burial clusters in Mis Island cemetery 3-J-11, showing excavated graves (Soler 2012, p. 162).



Spatially structured cemetery

First, simple binomial probabilities were calculated among burial clusters to explore distribution of traits among subsamples. The total frequency of each trait in 3-J-11 was used as the probability of occurrence. The likelihood of each trait's frequency within a subsample was then tested against the total frequency. If traits are non-randomly distributed among clusters (burials are organized according to biological affinity), some traits in each cluster will be present in a frequency that differs from the overall probability of occurrence, indicated by a low probability.

Next, a phenotypic distance matrix was created using Gower dissimilarity coefficients as described above for the uniformly distributed cemetery analyses. Ward's clustering method (Ward, 1963) was used to cluster individuals based on the Gower phenotypic distance matrix. The eight-cluster solution was used because it created the most balanced cluster sizes. The eight kin clusters were assigned letters A–H. Ward's clustering method was applied to the phenotypic distance matrix using the "hclust" function in R (R Core Team, 2017).

The distribution of kin clusters (A–H) in each burial cluster (1–8) was explored using simple binomial probabilities, as described above for trait distributions. In addition, Simpson's Index of Diversity (1 – *D*) provides a better understanding of the degree to which burial clusters are dominated by a small number of kin clusters. Howell and Kintigh (1996) refer to this as Simpson's *C*. The equation for Simpson's Index of Diversity is:

$$C = 1 - \sum {p_i}^2$$

where *p* is the proportion of individuals of kin cluster *i* in the burial cluster. The greater the value, the more concentrated the kin clusters are, while low values indicate random distribution of kin clusters among burial clusters. Low values approach 1/*k* where *k* is the number of kin clusters, so that in this study, the lowest possible value of *C* is 1/8 or 0.125. Simpson's Index of Diversity (*C*) was derived using the diversity function in the "vegan" package for R (Oksanen *et al.,* 2017). To characterize the overall

Index of Diversity in cemetery 3-J-11, *C'* was calculated as the weighted average of *C* in each burial cluster.

Finally, to provide a probability that given *C* values would occur by chance, a Monte Carlo simulation was performed wherein the contingency table of kin clusters and burial clusters was randomly sorted, keeping row totals constant. This simulation was performed 10,000 times and the proportion of randomly generated *C* greater than observed *C* values in each burial cluster provided the probability of random occurrence. Two-way random tables with given marginals (totals) were produced using the "r2dtable" function in R (R Core Team, 2017).

CHAPTER SIX: RESULTS

The results of the statistical analyses performed for this dissertation are presented in the sections below. Descriptive statistics and results of intraobserver error tests are presented before the results specific to each research question. In each section specific to a research question, the statistical results and a brief explanation of their meaning are presented. Limitations of this study are also noted in the sections on individual research questions.

FREQUENCY

Table 6.1 presents frequencies of each trait by cemetery, site, and total sample. Traits with 0% or 100% frequency in a sample do not provide distinguishing information among groups and should be removed from a data set. In this study, two traits (divided parietal bones [DPB] and divided temporal squama [DTS]) were not observed in the total sample (frequency 0.0%) and were therefore removed from all further analyses.

INTRAOBSERVER ERROR

The results of intraobserver error tests are presented in Table 6.2, including traditional Cohen's κ, PABAK, and percent agreement. Thirteen of the 35 traits tested for intraobserver error contained had no positive observations in the error subsample. Usually, Cohen's κ is a better measure of agreement than percent agreement observed because Cohen's κ takes agreement by chance into account. However, because calculation of Cohen's κ fails in instances with no positive observations, percent agreement is also presented in Table 6.2.

According to Landis and Koch's table of significance values (1977), a kappa ≤ 0.40 indicates poor to fair agreement, 0.41–0.60 indicates moderate agreement, 0.61–0.80 indicates substantial agreement, and 0.81–1.00 indicates almost perfect agreement. Six of the 35 traits tested display Cohen's κ ≤ 0.40:

foramen spinosum incomplete (FSP), hypoglossal canal bridging (HCB), marginal tubercle (MAR), sagittal ossicles (SGO), squamous ossicles (SQO), and supraorbital osseous structures (SOS). However, the PI for each of these traits is far from zero (-0.8333 or 0.6047–0.9487), and the pabak values for all six traits indicate moderate to substantial agreement. All pabak values represent moderate agreement or better, and no traits were removed from further analysis based on intraobserver error.

Table 6.1. Nonmetric trait frequencies for each of the cemeteries and sites.

Trait	Mis Island				Kulubnarti			Gabati	TOTAL
	3-J-10	**3-J-11**	**3-J-18**	***Site Total***	**21-R-2**	**21-S-46**	***Site total***		
AAM	12/68 (0.176)	21/129 (0.163)	13/72 (0.181)	*46/269 (0.171)*	29/86 (0.337)	15/44 (0.341)	*44/130 (0.338)*	0/32 (0.000)	**90/431 (0.209)**
ASO	2/32 (0.063)	6/87 (0.069)	6/64 (0.094)	*14/183 (0.077)*	12/93 (0.129)	5/44 (0.114)	*17/137 (0.124)*	2/26 (0.077)	**33/346 (0.095)**
AUT	1/73 (0.014)	1/137 (0.007)	0/72 (0.000)	*2/282 (0.007)*	2/93 (0.022)	1/48 (0.021)	*3/141 (0.021)*	1/32 (0.031)	**6/455 (0.013)**
COO	1/35 (0.029)	6/86 (0.070)	0/57 (0.000)	*7/178 (0.039)*	1/87 (0.011)	0/44 (0.000)	*1/131 (0.008)*	0/23 (0.000)	**8/332 (0.024)**
DIF	6/56 (0.107)	10/108 (0.093)	7/70 (0.100)	*23/234 (0.098)*	8/93 (0.086)	2/46 (0.043)	*10/139 (0.072)*	6/32 (0.188)	**39/405 (0.096)**
DMF	5/74 (0.068)	7/131 (0.053)	2/71 (0.028)	*14/276 (0.051)*	3/94 (0.032)	5/48 (0.104)	*8/142 (0.056)*	0/32 (0.000)	**22/450 (0.049)**
DOC	1/57 (0.018)	3/118 (0.025)	4/71 (0.056)	*8/246 (0.033)*	3/90 (0.033)	6/51 (0.118)	*9/141 (0.064)*	2/32 (0.063)	**19/419 (0.045)**
DPB*	0/60 (0.000)	0/119 (0.000)	0/58 (0.000)	*0/237 (0.000)*	0/91 (0.000)	0/47 (0.000)	*0/138 (0.000)*	0/31 (0.000)	**0/406 (0.000)**
DTS*	0/62 (0.000)	0/117 (0.000)	0/69 (0.000)	*0/248 (0.000)*	0/92 (0.000)	0/44 (0.000)	*0/136 (0.000)*	0/32 (0.000)	**0/416 (0.000)**
EPI	9/29 (0.310)	18/83 (0.217)	10/63 (0.159)	*37/175 (0.211)*	21/85 (0.247)	7/42 (0.167)	*28/127 (0.220)*	4/25 (0.160)	**69/327 (0.211)**
FOV	2/59 (0.034)	2/121 (0.017)	1/70 (0.014)	*5/250 (0.020)*	0/87 (0.000)	1/49 (0.020)	*1/136 (0.007)*	1/31 (0.032)	**7/417 (0.017)**
FSP	12/51 (0.235)	22/117 (0.188)	5/65 (0.077)	*39/233 (0.167)*	13/87 (0.149)	4/46 (0.087)	*17/133 (0.128)*	4/30 (0.133)	**60/396 (0.152)**
FVS	20/54 (0.370)	66/116 (0.569)	28/65 (0.431)	*114/235 (0.485)*	40/83 (0.482)	21/46 (0.457)	*61/129 (0.473)*	19/31 (0.613)	**194/395 (0.491)**
HCB	9/67 (0.134)	17/124 (0.137)	10/68 (0.147)	*36/259 (0.139)*	10/83 (0.120)	4/47 (0.085)	*14/130 (0.108)*	6/32 (0.188)	**56/421 (0.133)**
LDO	13/33 (0.394)	35/85 (0.412)	17/60 (0.283)	*65/178 (0.365)*	41/88 (0.466)	15/44 (0.341)	*56/132 (0.424)*	6/25 (0.240)	**127/335 (0.379)**
LPF	28/42 (0.667)	67/101 (0.663)	29/59 (0.492)	*124/202 (0.614)*	46/81 (0.568)	31/42 (0.738)	*77/123 (0.626)*	20/29 (0.690)	**221/354 (0.624)**

**0% total frequency*

Table 6.1 (cont'd). Nonmetric trait frequencies for each of the cemeteries and sites.

Trait	Mis Island				Kulubnarti			Gabati	TOTAL
	3-J-10	**3-J-11**	**3-J-18**	***Site Total***	**21-R-2**	**21-S-46**	***Site total***		
MAR	16/70 (0.229)	23/130 (0.177)	16/72 (0.222)	*55/272 (0.202)*	30/97 (0.309)	11/52 (0.212)	*41/149 (0.275)*	13/30 (0.433)	**109/451 (0.242)**
MET	0/65 (0.000)	3/127 (0.024)	3/66 (0.045)	*6/258 (0.023)*	3/89 (0.034)	1/49 (0.020)	*4/138 (0.029)*	0/32 (0.000)	**10/428 (0.023)**
MFS	0/62 (0.000)	0/122 (0.000)	0/64 (0.000)	*0/248 (0.000)*	1/87 (0.011)	1/47 (0.021)	*2/134 (0.015)*	0/31 (0.000)	**2/413 (0.005)**
MHB	7/71 (0.099)	13/129 (0.101)	4/68 (0.059)	*24/268 (0.090)*	6/87 (0.069)	2/49 (0.041)	*8/136 (0.059)*	3/32 (0.094)	**35/436 (0.080)**
MNT	2/74 (0.027)	10/131 (0.076)	4/70 (0.057)	*16/275 (0.058)*	16/72 (0.222)	11/43 (0.256)	*27/115 (0.235)*	5/31 (0.161)	**48/421 (0.114)**
MXT	0/64 (0.000)	2/123 (0.016)	0/70 (0.000)	*2/257 (0.008)*	0/70 (0.000)	0/40 (0.000)	*0/110 (0.000)*	0/31 (0.000)	**2/398 (0.005)**
OMW	2/32 (0.063)	9/87 (0.103)	4/64 (0.063)	*15/183 (0.082)*	4/89 (0.045)	1/45 (0.022)	*5/134 (0.037)*	2/25 (0.080)	**22/342 (0.064)**
PAB	1/52 (0.019)	2/109 (0.018)	0/65 (0.000)	*3/226 (0.013)*	2/88 (0.023)	1/50 (0.020)	*3/138 (0.022)*	0/29 (0.000)	**6/393 (0.015)**
PAF	39/66 (0.591)	65/124 (0.524)	29/63 (0.460)	*133/253 (0.526)*	44/87 (0.506)	28/49 (0.571)	*72/136 (0.529)*	21/32 (0.656)	**226/421 (0.537)**
PEF	0/30 (0.000)	5/80 (0.063)	2/64 (0.031)	*7/174 (0.040)*	2/92 (0.022)	2/48 (0.042)	*4/140 (0.029)*	1/24 (0.042)	**12/338 (0.036)**
PLT	8/63 (0.127)	20/120 (0.167)	9/70 (0.129)	*37/253 (0.146)*	20/79 (0.253)	6/44 (0.136)	*26/123 (0.211)*	1/32 (0.031)	**64/408 (0.157)**
PNB	5/34 (0.147)	18/90 (0.200)	3/64 (0.047)	*26/188 (0.138)*	22/93 (0.237)	6/46 (0.130)	*28/139 (0.201)*	2/26 (0.077)	**56/353 (0.159)**
PSB	0/52 (0.000)	1/109 (0.009)	0/65 (0.000)	*1/226 (0.004)*	1/88 (0.011)	0/50 (0.000)	*1/138 (0.007)*	0/29 (0.000)	**2/393 (0.005)**
SGO	2/31 (0.065)	5/79 (0.063)	0/50 (0.000)	*7/160 (0.044)*	6/72 (0.083)	0/37 (0.000)	*6/109 (0.055)*	0/23 (0.000)	**13/292 (0.045)**
SNS	45/66 (0.682)	79/126 (0.627)	38/64 (0.594)	*162/256 (0.633)*	44/89 (0.494)	33/50 (0.660)	*77/139 (0.554)*	23/31 (0.742)	**262/426 (0.615)**
SOS	64/67 (0.955)	119/132 (0.902)	58/69 (0.841)	*241/268 (0.899)*	84/97 (0.866)	47/52 (0.904)	*131/149 (0.879)*	31/32 (0.969)	**403/449 (0.898)**
SQO	2/33 (0.061)	12/86 (0.140)	1/65 (0.015)	*15/184 (0.082)*	2/93 (0.022)	0/44 (0.000)	*2/137 (0.015)*	1/26 (0.038)	**18/347 (0.052)**
STP	2/66 (0.030)	0/123 (0.000)	4/67 (0.060)	*6/256 (0.023)*	4/95 (0.042)	2/50 (0.040)	*6/145 (0.041)*	5/32 (0.156)	**17/433 (0.039)**
TBS	4/62 (0.065)	14/124 (0.113)	4/70 (0.057)	*22/256 (0.086)*	12/90 (0.133)	10/50 (0.200)	*22/140 (0.157)*	1/31 (0.032)	**45/427 (0.105)**
TZS	1/67 (0.015)	2/124 (0.016)	1/70 (0.014)	*4/261 (0.015)*	5/94 (0.053)	0/49 (0.000)	*5/143 (0.035)*	0/29 (0.000)	**9/433 (0.021)**
ZYG	6/58 (0.103)	11/110 (0.100)	8/71 (0.113)	*25/239 (0.105)*	11/96 (0.115)	2/48 (0.042)	*13/144 (0.090)*	4/25 (0.160)	**42/408 (0.103)**

**0% total frequency*

Table 6.2. Results of intraobserver error tests: Cohen's kappa (κ) (1960), prevalence index (PI), prevalence and bias adjusted kappa (PABAK) (Byrt *et al.,* 1993), and total percent agreement observed.

Trait	κ	PI	pabak	Agreement (%)
AAM	0.7345	0.7234	0.8723	93.6
ASO	0.4621	0.7895	0.7895	89.5
AUT*	---	---	---	97.9
COO*	---	---	---	94.7
DIF	0.6004	0.6667	0.7778	88.9
DMF	1.0000	0.9574	1.0000	100.0
DOC*	---	---	---	100.0
EPI	0.5943	0.4737	0.6842	84.2
FOV*	---	---	---	100.0
FSP	**0.3666	0.6047	0.5814	79.1
FVS	0.6080	-0.2727	0.6364	81.8
HCB	**0.1667	0.6889	0.5556	77.8
LDO	0.7136	0.0571	0.7143	85.7
LPF	0.4118	-0.4000	0.5000	75.0
MAR	**0.3967	0.6522	0.6522	82.6
MET*	---	---	---	100.0
MFS*	---	---	---	100.0
MHB	0.7444	0.5652	0.8261	91.3
MNT	0.7895	0.8958	0.9583	97.9
MXT*	---	---	---	97.8
OMW	0.9073	0.6579	0.9474	97.4
PAB*	---	---	---	97.6
PAF	0.4621	-0.0625	0.4583	72.9
PEF*	---	---	---	97.0
PLT	0.5831	0.4468	0.6596	83.0
PNB*	---	---	---	87.2
PSB*	---	---	---	97.6
SGO	**0.0000	0.9487	0.8974	94.9
SNS	0.7209	-0.3333	0.7500	87.5
SOS	**0.1864	-0.8333	0.7500	87.5
SQO	**-0.0460	0.8205	0.6410	82.1
STP*	---	---	---	100.0
TBS	0.6417	0.6304	0.7826	89.1
TZS*	---	---	---	100.0
ZYG	0.6306	0.7805	0.8537	92.7

**no observations of presence in sample used for intraobserver error*
***less than moderate agreement according to Landis and Koch (1977)*

TRAIT SELECTION

None of the statistics used in the present study require removal of traits with very high or very low frequencies (< 5% or > 95%), including Mahalanobis D^2 (Ishida and Dodo, 1997; Konigsberg, 1990). In fact, rare traits are quite useful in some intra-cemetery analyses because they may indicate clusters of related individuals (Stojanowski, 2005). Of fourteen traits with low frequency in this sample, I consider five to be problematic: auditory torus (AUT, 1.3%), maxillary torus (MXT, 0.5%), metopic fissure (MFS, 0.5%), posterior ethmoidal foramen absent (PEF, 3.6%), and symmetrical thinness of parietal bones (STP, 3.9%). Each of these traits was only observed a handful of times across hundreds of skulls. A combination of my unfamiliarity with these particular traits and a dearth of photographs of minor expression in reference material suggest that these few observations are not reliable. Furthermore, none of these five could be tested for intraobserver error (Table 6.2) because no positive observations were made in the intraobserver sample.

Nonmetric Mahalanobis D^2 corrects for some correlation among traits, so none need to be removed from the dataset based on the results of the tetrachoric correlations (Irish, 2010). Konigsberg recommends removal of traits that are highly age- or sex-dependent (1990). In this dataset, there was one moderately sex-dependent trait and no age-dependent traits. Since the female to male ratio is roughly consistent (1:1–2:1) in all cemeteries, the sexes and age groups were pooled in this study, following Ishida and Dodo (1997). Removal of the five unreliable traits listed above in addition to the two traits removed due to 0% frequency resulted in a final list of 30 cranial nonmetric traits.

RESEARCH QUESTION 1A

When cemeteries from the same site are pooled, what are the biological relationships among Mis Island, Kulubnarti, and Gabati as revealed by biodistance analysis of nonmetric traits of the skull?

The results presented in this section relate to the biodistance analysis of Mis Island, Kulubnarti, and Gabati using cranial nonmetric traits. The results of the Fisher's exact test for the three-site analysis are presented in Table 6.3 sorted by p-value. Six traits have a p-value < 0.05, indicating that trait presence is significantly associated with site. These are: aperture in the floor of the acoustic meatus (AAM), mandibular torus (MNT), marginal tubercle (MAT), squamous ossicles (SQO), palatine torus (PLT), and trace biasterionic suture (TBS). The statistically significant differences between the frequencies of these traits in the three-site analysis suggests nonrandom distribution of traits.

Table 6.4 presents the biased and the bias-corrected Mahalanobis D^2 values for the three-site analysis using 30 cranial nonmetric traits. The Mis Island-Kulubnarti distance is the lowest of the Mahalanobis D^2 values, indicating a closer relationship between these two sites than the between either one and Gabati. An F-test showed that all biased and bias-corrected D^2 values were significant at the $p < 0.0001$ level.

Table 6.5 presents the minimum F_{ST}, bias-corrected minimum F_{ST}, and 95% confidence intervals (CI) for each of the three sites. The overall minimum F_{ST} ($h^2 = 1$) for the three-site analysis was 0.194791 (SE = 0.007445) when using the biased D^2 values, and the bias-corrected minimum F_{ST} was 0.191803 (SE = 0.007438). The F_{ST} for each site represents the variation present in that subsample compared to the total sample. The closer the value is to 0, the more heterogeneous the subsample is, and the closer the value is to 1, the less heterogeneous the subsample is. All F_{ST} values are significantly different from 0 at the 0.05 level, indicating significant among-group variation.

Table 6.3. Results of Fisher's exact tests for each trait in the three-site analysis.

Trait	*p*-value
AAM	0.0000
MNT	0.0000
MAR	0.0113
SQO	0.0240
PLT	0.0279
TBS	0.0396
SNS	0.1029
DIF	0.1500
PNB	0.1659
LDO	0.1995
OMW	0.2119
DOC	0.2454
COO	0.2641
SOS	0.3440
ASO	0.3567
FVS	0.3641
TZS	0.3650
FOV	0.3698
PAF	0.3835
HCB	0.4073
ZYG	0.4920
MHB	0.4963
DMF	0.5262
FSP	0.5874
SGO	0.6781
LPF	0.7538
PAB	0.7968
EPI	0.8531
MET	0.8834
PSB	1.0000

Table 6.4. Mahalanobis D^2 values for the three-site analysis: biased values are above the diagonal, and bias-corrected values are below the diagonal.

	Mis Island	**Kulubnarti**	**Gabati**
Mis Island	---	1.7820	60.3373
Kulubnarti	1.4799	---	68.5140
Gabati	59.2963	67.3778	---

Table 6.5. Minimum F_{ST}, bias-corrected F_{ST}, and associated 95% confidence intervals (CI) for the three-site analysis, sorted from lowest to highest F_{ST} value.

Cemetery	Minimum F_{ST}	95% CI	Bias-corrected F_{ST}	95% CI
Mis Island	0.08309	0.0745–0.0917	0.08108	0.0726–0.0896
Kulubnarti	0.11967	0.1061–0.1332	0.11737	0.1039–0.1308
Gabati	0.38161	0.3297–0.4336	0.37696	0.3252–0.4287

Table 6.6 presents the R matrix values among the three sites. R matrix values are weighted such that positive values indicate a closer than average relationship, while negative values indicate a more distant relationship than average. The R value between Mis Island and Kulubnarti is the only positive relationship, indicating a closer than average genetic distance between these two sites.

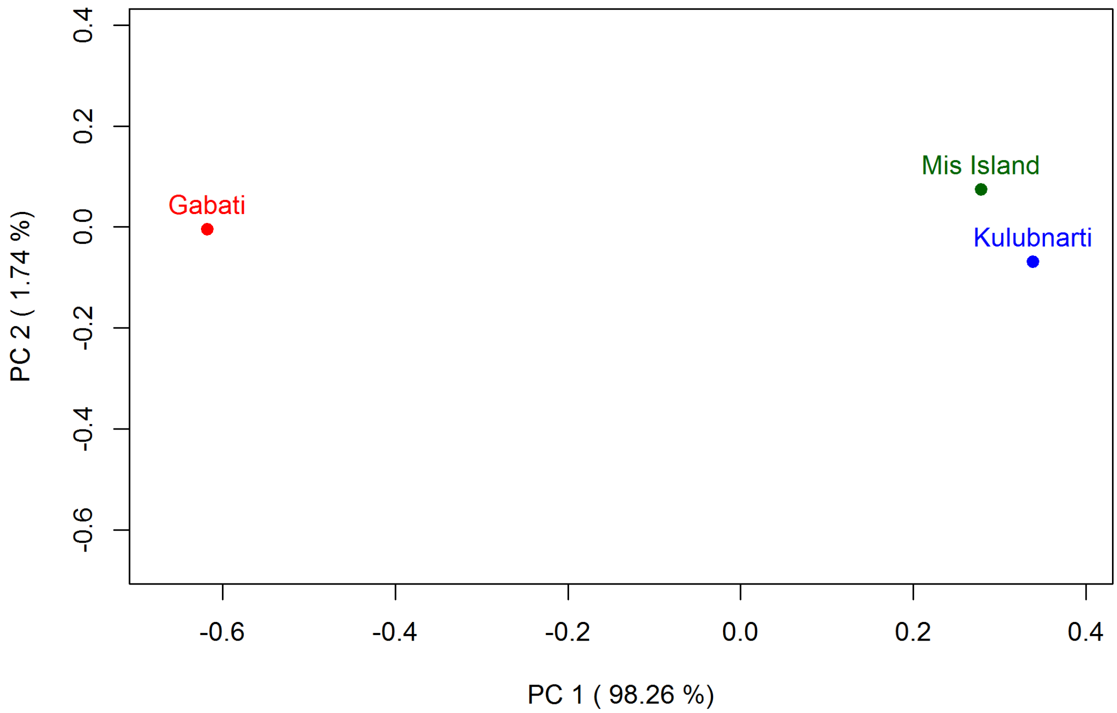
Table 6.6. R matrix values for the three-site analysis.

	Mis Island	Kulubnarti
Kulubnarti	0.0893	---
Gabati	-0.1703	-0.2066

Figure 6.1 is a plot showing Mis Island, Kulubnarti, and Gabati on the first two principal coordinates (scaled by the square root of the associated eigenvalues) of the R matrix of sites. The first principal coordinate (PC) accounts for 98.26% of the differences among sites. It separates Mis Island and Kulubnarti from Gabati. The second PC accounts for 1.74% and separates Kulubnarti from the other two sites. Because the first two PCs account for 100% of the variability among sites, a plot of the third PC is not presented.

These results support the stated expectation that Mis Island and Kulubnarti share a closer-than-average biological relationship, while Gabati is biologically distant to both sites. The Mahalanobis D^2 distances revealed a relatively close relationship between Mis Island and Kulubnarti, with Mis Island being slightly closer than Kulubnarti to Gabati. The R matrix values further indicate a closer than average relationship between Mis Island and Kulubnarti and a more distant than average relationship between Gabati and each of the other two sites.

Figure 6.1. Two-dimensional plot of the three-site analysis using cranial nonmetric data.



The Mahalanobis distances suggest an extreme relationship where Mis Island and Kulubnarti are very close, with Gabati being an extreme outlier. However, the sample sizes in the three-site analysis are uneven, with the Mis Island sample being nine times the size of the Gabati sample and the Kulubnarti sample being five times the size of the Gabati sample. This adds a source of bias to the biodistance analyses, which do not correct for uneven sample sizes. However, when biodistance analyses are carried out with a smaller random selection of Mis Island and Kulubnarti individuals (each site n = 64), the overall pattern of relationships matched the pattern found when the complete samples were used. Therefore, even though uneven sample sizes exaggerate Gabati's true distance from the other two sites, the patterns of relationships presented by the Mahalanobis and R matrix values support the stated expectation.

The levels of genetic diversity at each site are represented by minimum F_{ST} values. The results suggest that Mis Island was the most heterogeneous subpopulation, while Gabati was the most homogenous. As in the previous case, the Gabati minimum F_{ST} value (0.381610) appears artificially elevated and potentially unreliable because of the presence of uneven sample sizes (Pink *et al., 2*016). The bias correction used on the Mahalanobis distances accounts for overall small sample size, but it does not correct for uneven sample sizes. Yet, again, when the R matrix is reproduced using a random sample of 64 individuals from each of Mis Island and Kulubnarti, so that these samples are only twice the size of Gabati, the minimum F_{ST} values are all lower and more in line with the values expected for subpopulations within a species (Mis Island 0.042995, Kulubnarti 0.059686, Gabati 0.070371; Hartl and Clark, 2007). These adjusted minimum F_{ST} values show the same pattern as the unadjusted results, where Mis Island is the most heterogeneous subpopulation and Gabati is the most homogenous subpopulation.

RESEARCH QUESTION 1B

Do the results of biological distance analyses using cranial nonmetric traits and craniometrics correlate when cemeteries from the same site are pooled?

The results presented in this section relate to the Procrustes analysis performed using cranial nonmetric and metric data from Mis Island (excluding nonmetric data from cemetery 3-J-18), Kulubnarti, and Gabati. Table 6.7 presents the R matrix based on a three-site analysis of nonmetric traits of the skull excluding Mis Island cemetery 3-J-18 and using 64 randomly chosen individuals from each of Mis Island and Kulubnarti, to correct for uneven sample sizes. As explained in Chapter Five, it was necessary to produce an R matrix with h^2 = 1 based on Vollner's D^2 matrix, since she used h^2 = 0.55 for her R matrix. Table 6.8 presents the R matrix and minimum F_{ST} values produced from craniometric Mahalanobis D^2 values.

Table 6.7. R matrix produced from nonmetric data excluding cemetery 3-J-18. Genetic distances (r_{ij}) are below the diagonal and minimum F_{ST} values (r_{ii}) are on the diagonal.

	Mis Island	Kulubnarti	Gabati
Mis Island	0.03928		
Kulubnarti	-0.02083	0.07807	
Gabati	-0.01845	-0.05724	0.07569

Table 6.8. R matrix produced from craniometric Mahalanobis D^2 values. Genetic distances (r_{ij}) are below the diagonal and minimum F_{ST} values (r_{ii}) are on the diagonal.

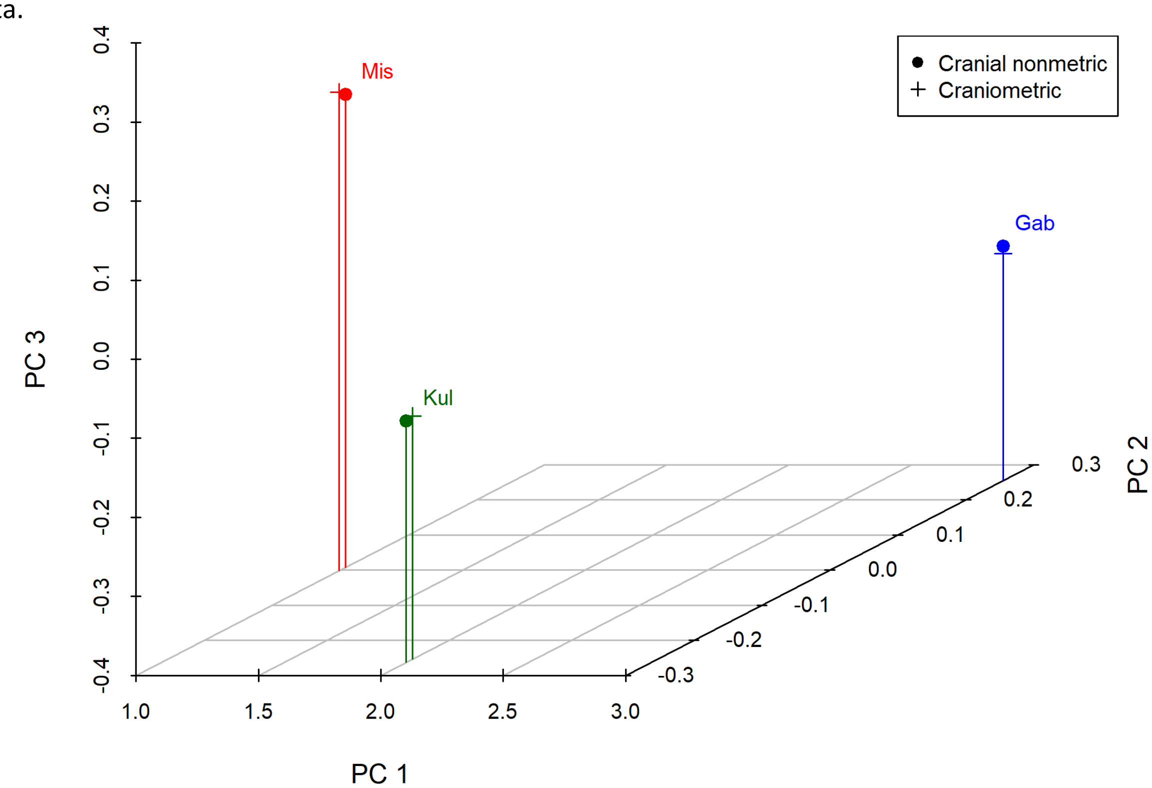
	Mis Island	Kulubnarti	Gabati
Mis Island	0.04199		
Kulubnarti	-0.01859	0.07263	
Gabati	0.02340	-0.05404	0.07744

The Mantel test was used to test the null hypothesis that the cranial nonmetric and craniometric datasets are not correlated. The resulting Mantel *r* value was 0.9838, with a two-tailed *p* value of 0.33. The *p* value was calculated based on 5 permutations of the R matrices used as input data, whereas 999 permutations are recommended by Herrera *et al.* (2014). This difference will be considered in Chapter Seven. The PROTEST analysis produced a correlation value of 0.9992 and a *p* value of 0.33, also using 5 permutations. Figure 6.2 presents the two datasets plotted in three dimensions. The first principal coordinate separates the three sites, the second differentiates the two types of data (metric and nonmetric), and the third shows Mis Island separated from Kulubnarti and Gabati.

These results fail to support the hypothesis that distance matrices produced by craniometric and cranial nonmetric data would be significantly correlated when cemeteries from the same sites were pooled. This is more likely an artifact of the method than a true result. Because only three sites were used in each analysis, the Mantel test that compared the two sets of genetic distances was unable to calculate a meaningful level of significance.

The Mantel test ($r = 0.9838$) and the PROTEST ($r = 0.9992$) showed very high correlation values. The three-dimensional plot of the craniometric and cranial nonmetric data (Figure 6.2) shows that the two distance matrices are very closely related, with no visible difference between the datasets on the first principle coordinate and only small differences visible in the second principal component. Although the high correlation values and the three-dimensional plot suggest a strong relationship between the results of craniometric and cranial nonmetric biodistance analyses, the *p* values did not approach significance. The insignificant *p* values are likely related to the fact that each data set only consisted of three sites. Calculation of Mantel and PROTEST significance values uses permutation of the rows and columns of a matrix, with the maximum possible permutations being n!–1. The number of permutations used in calculating the *p* value in this test was limited to 5 because the comparison was between two 3 x 3 matrices (3!–1 = 5). The recommended number of permutations in the code provided by Herrera *et al.* (2014) is 999. Thus, the five permutations used in this analysis were insufficient for the derivation of a meaningful significance value.

Figure 6.2. Three-dimensional plot of Procrustes analysis using cranial metric and cranial nonmetric data.



In addition to the Mantel test and PROTEST, which compared the between-sites distances (r_{ij}) from both sets of phenotypic data, the within-site measures of biological variation (r_{ii} / F_{ST} values) for each dataset may also be compared. For the both cranial nonmetric and craniometric analyses, Mis Island has the lowest F_{ST} value of the three sites, indicating a higher level of heterogeneity in that population. Both analyses show Kulubnarti and Gabati display less heterogeneity than Mis Island, although cranial nonmetric data shows Kulubnarti as the most homogenous site, while craniometrics data suggests instead that Gabati is the most homogenous. Ninety-five percent confidence intervals for the minimum F_{ST} values based on craniometrics data could not be calculated because the data was derived from Vollner's Mahalanobis D^2 matrix rather than from raw data. However, the standard deviations were calculated for the cranial nonmetric F_{ST} values. These showed overlapping 95% confidence intervals for Kulubnarti and Gabati, with Mis Island having a significantly different level of biological variation than the other two sites. Although the standard deviations for the craniometrics F_{ST} values are unknown, they display much the same pattern as the cranial nonmetric F_{ST} values.

Few firm conclusions can be drawn from the quantitative comparison performed here on the three-site cranial nonmetric and metric distance matrices due to the low number of groups being compared. However, dividing the dataset by cemetery instead of by site would result in five sub-samples for each type of data (the five cemeteries used by Vollner) and the 119 possible permutations of the data matrices would provide more meaningful p values. Since Vollner (2016) did not publish her raw data, it is not possible to perform that iteration of the Mantel test at this time.

RESEARCH QUESTION 2A

What are the biological relationships among the six cemeteries at Mis Island, Kulubnarti, and Gabati as revealed by biodistance analysis of nonmetric traits of the skull?

The results in this section relate to the biodistance analysis of the six Nubian cemeteries using cranial nonmetric traits. The results of the Fisher's exact test for significance at Mis Island and at Kulubnarti are presented in Table 6.9. For the three Mis Island cemeteries, four traits have a *p*-value < 0.05, indicating that the presence of these traits is significantly correlated with cemetery membership at Mis Island. These are: squamous ossicles (SQO), parietal notch bone (PNB), foramen of Vesalius (FVS), and foramen spinosum incomplete (FSP). These results suggest nonrandom distribution of traits across the three Mis Island cemeteries. At Kulubnarti, none of the traits has a *p*-value < 0.05. The lowest values, which approach significance (p < 0.10) are divided occipital condyle (DOC), supranasal suture (SNS), lesser palatine foramen multiple (LPF), and sagittal ossicles (SGO). In contrast to the Mis Island findings, these results suggest random distribution of traits across the two cemeteries at Kulubnarti.

Table 6.10 presents the biased Mahalanobis D^2 values and the bias-corrected D^2 values for the six-cemetery analysis using 30 cranial nonmetric traits. Surprisingly, the closest biological distance is between Mis Island cemetery 3-J-11 and Kulubnarti cemetery 21-R-2 (bias-corrected D^2 = 2.4029). The greatest distance is between Kulubnarti cemetery 21-S-46 and Gabati (bias-corrected D^2 = 26.6178). An F-test showed that all biased and bias-corrected D^2 values were significant at the $p < 0.0001$ level.

Table 6.11 presents the minimum F_{ST}, bias-corrected minimum F_{ST} and 95% confidence intervals (CI) for each of the six cemeteries. The overall minimum F_{ST} for the six-cemetery analysis was 0.061540 (SE = 0.003641) when using the biased D^2 values, and the overall minimum F_{ST} was 0.055897 (SE = 0.003518) when using the bias-corrected D^2 values. The lowest value, indicating significant gene flow into the site and increasing within-group heterogeneity (Pink *et al.,* 2016), is found for Kulubnarti cemetery 21-R-2. The highest value is found at the other Kulubnarti cemetery, 21-S-46. All F_{ST} values are significantly different from 0 at the 0.05 level, indicating significant among-group variation.

Table 6.9. Results of Fisher's exact tests for each trait against the three Mis Island and two Kulubnarti cemeteries.

	***p*-value**	
Trait	**Mis Island**	**Kulubnarti**
AAM	0.9336	1.0000
ASO	0.8734	1.0000
COO	0.1022	1.0000
DIF	0.9598	0.4965
DMF	0.5665	0.1198
DOC	0.4612	0.0715
EPI	0.2513	0.3675
FOV	0.7155	0.3603
FSP	0.0422	0.4161
FVS	0.0314	0.8547
HCB	0.9727	0.7694
LDO	0.2607	0.1944
LPF	0.0782	0.0782
MAR	0.5959	0.2498
MET	0.2335	1.0000
MHB	0.5979	0.7107
MNT	0.3776	0.8205
OMW	0.7187	0.6632
PAB	0.6044	1.0000
PAF	0.3438	0.4800
PLT	0.7199	0.1682
PNB	0.0181	0.1798
PSB	1.0000	1.0000
SGO	0.1550	0.0938
SNS	0.5850	0.0756
SOS	0.0950	0.6038
SQO	0.0147	1.0000
TBS	0.3836	0.3368
TZS	1.0000	0.1652
ZYG	0.9626	0.2200

Table 6.10. Mahalanobis D^2 values for the six-cemetery analysis: biased values are above the diagonal, and bias-corrected values are below the diagonal.

	10(Mis)	11(Mis)	18(Mis)	R(Kul)	S(Kul)	Gab(Gab)
10(Mis)	---	3.2157	5.9529	3.9743	16.6102	12.6331
11(Mis)	2.6006	---	4.4166	2.4029	14.4343	10.7504
18(Mis)	5.1309	3.7902	---	3.8453	10.5723	9.0572
R(Kul)	3.2596	1.8838	3.1194	---	6.7801	10.3809
S(Kul)	15.6493	13.6690	9.8070	5.9153	---	26.6178
Gab(Gab)	11.2902	9.6031	7.9100	9.1341	25.1247	---

Table 6.11. Minimum F_{ST}, bias-corrected minimum F_{ST}, and associated 95% confidence intervals (CI) for the six-cemetery analysis.

Cemetery	Minimum F_{ST}	95% CI	Bias-corrected minimum F_{ST}	95% CI
Kulubnarti 21-R-2	0.00984	0.0047–0.0150	0.00524	0.0014–0.0090
Mis Island 3-J-18	0.02669	0.0168–0.0365	0.02214	0.0131–0.0311
Mis Island 3-J-11	0.03027	0.0222–0.0384	0.02683	0.0192–0.0345
Mis Island 3-J-10	0.04895	0.0342–0.0637	0.04358	0.0296–0.0575
Gabati	0.11948	0.0881–0.1509	0.10948	0.0794–0.1396
Kulubnarti 21-S-46	0.13401	0.1077–0.1603	0.12811	0.1023–0.1539

Table 6.12 presents the R matrix values for the six-cemetery analysis. Positive R matrix values, indicating a closer than average relationship, are noted between cemeteries 3-J-10 and 3-J-11, 3-J-11 and 21-R-2, 3-J-18 and Gabati, and 21-R-2 and 21-S-46. The within-site pairs of closely related cemeteries are not surprising, but close between-site relationships are unexpected.

Table 6.12. R matrix values for the six-cemetery analysis.

	10(Mis)	11(Mis)	18(Mis)	R(Kul)	S(Kul)
11(Mis)	0.0145	---			
18(Mis)	-0.0087	-0.0061	---		
R(Kul)	-0.0017	0.0013	-0.0118	---	
S(Kul)	-0.0384	-0.0307	-0.0023	0.0189	---
Gab(Gab)	-0.0146	-0.0092	0.0022	-0.0165	-0.0814

Figure 6.3 shows the six cemeteries plotted on the first two principal coordinates (scaled by the square root of the associated eigenvalues) of the R matrix of cemeteries. The first PC clusters all three

Mis Island cemeteries with Kulubnarti cemetery 21-R-2, with Gabati and Kulubnarti 21-S-46 as opposing outliers. The second PC clusters Mis Island cemeteries 3-J-10 and 3-J-11, Mis Island 3-J-18 and Kulubnarti 21-R-2, with Kulubnarti 21-S-46 and Gabati each isolated. The first three principal coordinates (PCs) account for 58.43%, 25.81%, and 8.84% of the differences among the six cemeteries, respectively. Figure 6.4 is a 3-dimensional plot of sites on the first three PCs. Mis Island cemetery 3-J-18 is the outlier along the third PC, with all other cemeteries clustering.

Figure 6.3. Two-dimensional plot of the six-cemetery analysis using cranial nonmetric data.

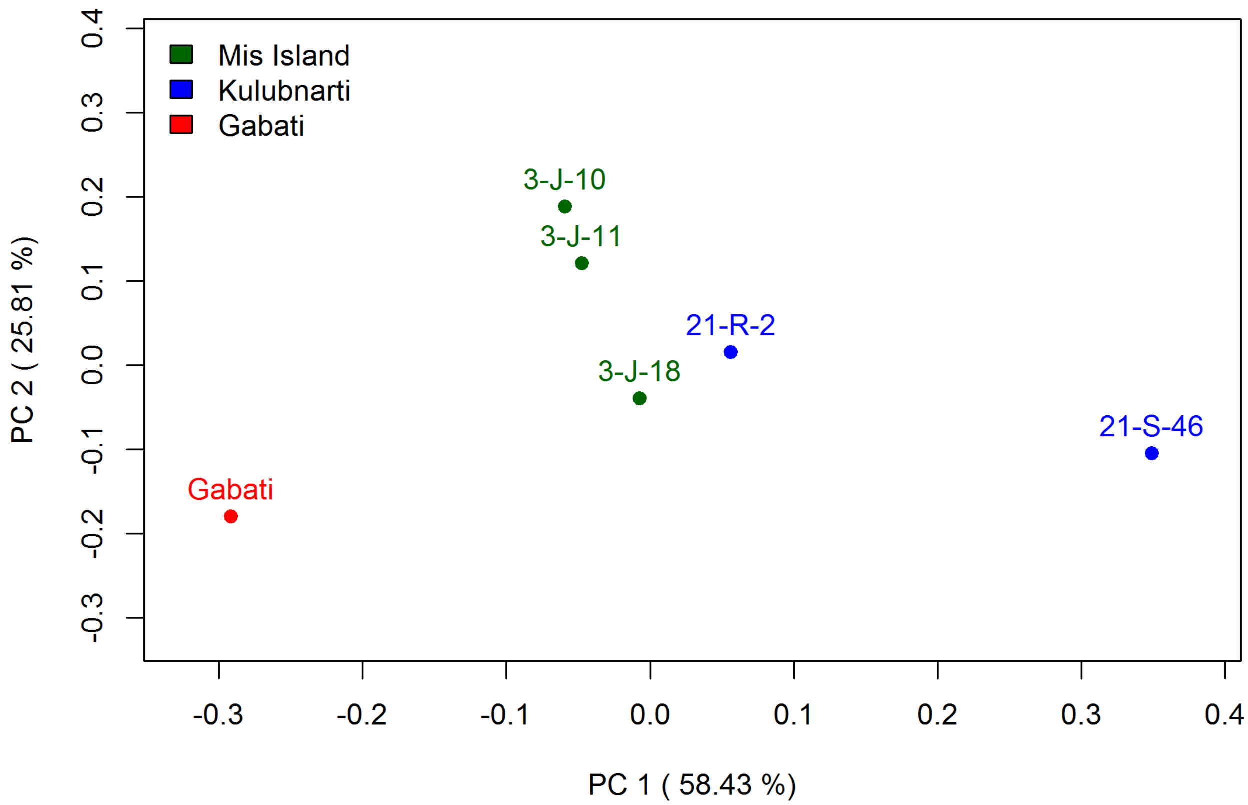


Figure 6.5 is a dendrogram (Ward's method) showing how the six cemeteries used in this analysis clustered according to R matrix values. Somewhat surprisingly, Kulubnarti cemetery 21-S-46 is the outlier, with Gabati clustering more tightly with Mis Island cemeteries and the other Kulubnarti cemetery. Mis Island cemeteries 3-J-10 and 3-J-11 form the mostly closely related node, with Mis Island cemetery 3-J-18 and Kulubnarti cemetery 21-R-2 also closely linked.

Figure 6.4. Three-dimensional plot of the six-cemetery analysis using cranial nonmetric data.

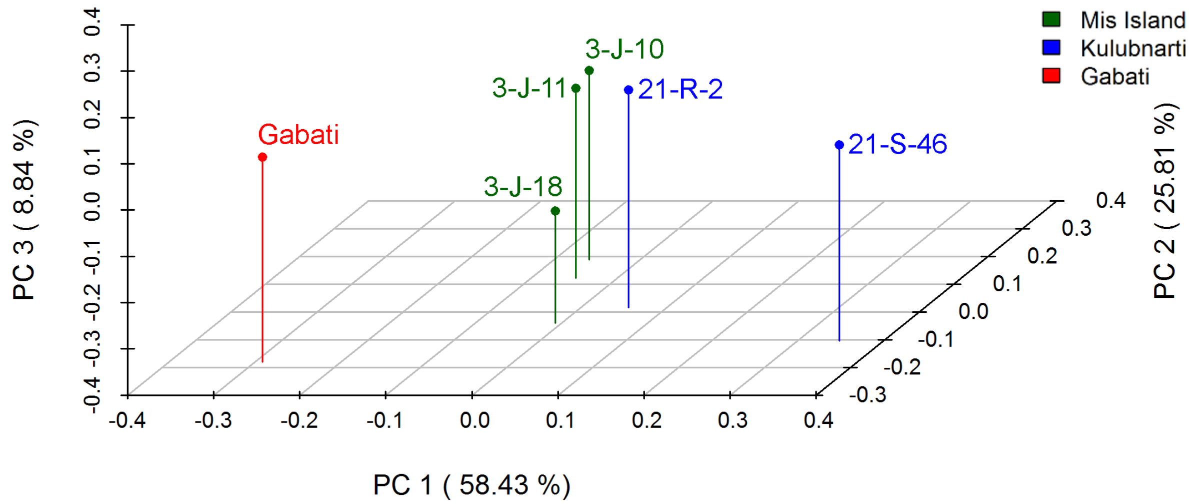
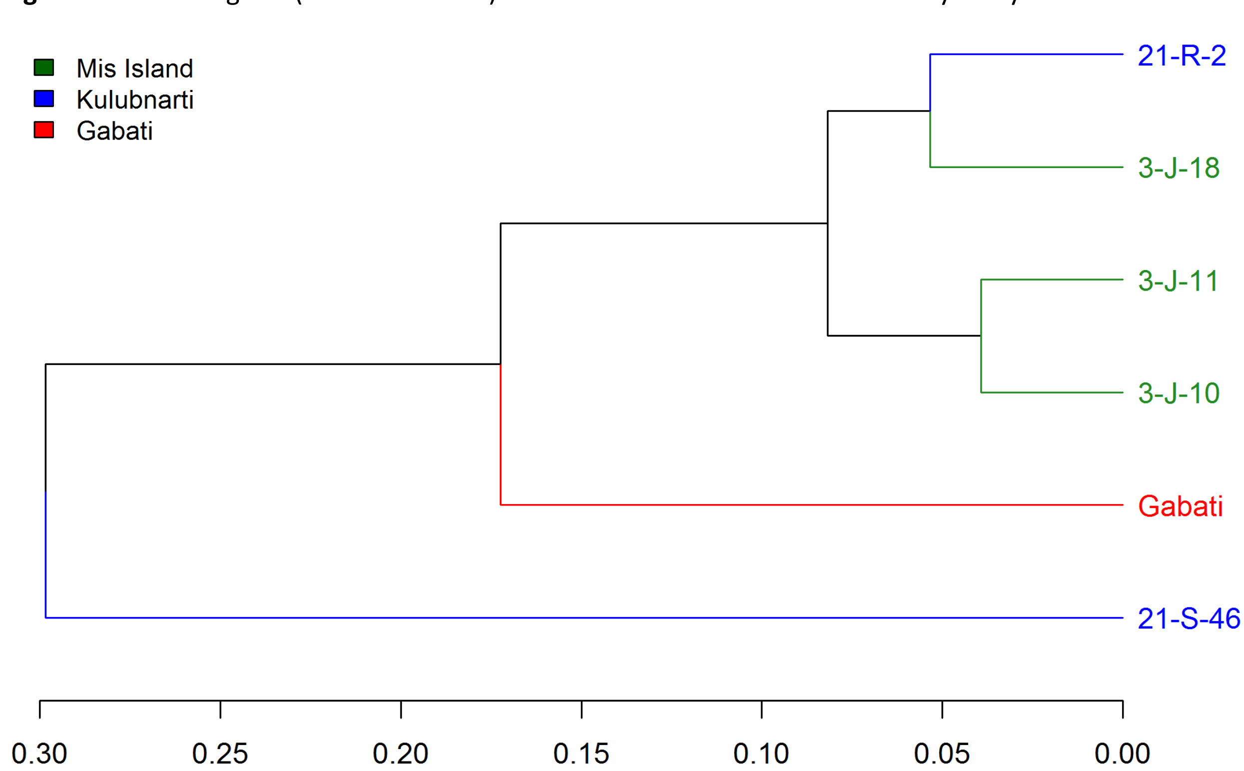


Figure 6.5. Dendrogram (Ward's method) of the R matrix from the six-cemetery analysis.



These results reject the null hypothesis that no significant differences would be detected among the three Mis Island cemeteries using cranial nonmetric traits. In fact, four traits demonstrated significant association with cemetery membership at Mis Island, suggesting nonrandom distribution of traits (and genes) among the three cemeteries. Further support that significant differences are present among the three Mis Island cemeteries comes from the Mahalanobis D^2 values, which were all significant at the $p < 0.0001$ level. These results contradict Vollner's (2016) findings that no significant differences were present between Mis Island cemeteries 3-J-10 and 3-J-11.

In contrast, mixed results are seen in the analysis of the two Kulubnarti cemeteries. The univariate analysis of cranial nonmetric traits failed to reject the null hypothesis that no significant difference would be detected. No traits were significantly associated with cemetery membership, suggesting random distribution of traits (and genes) between the cemeteries. However, the Mahalanobis D^2 value between Kulubnarti cemeteries 21-R-2 and 21-S-46 was significant at the $p < 0.0001$ level. This contradicts the univariate cranial nonmetric results and Vollner's results, suggesting differences are present between the two Kulubnarti cemeteries.

Vollner (2016) tested for significant differences between cemeteries at the same site using a multivariate analysis of variance (MANOVA). Using the MANOVA, she found no significant differences between Mis Island cemeteries 3-J-10 and 3-J-11 or between Kulubnarti cemeteries 21-R-2 and 21-S-46. There is no analogous test that could analyze the present study's presence/absence data. However, the six-cemetery analysis used here reveals information about intra-site relationships. In addition, this analysis provides regional context for each site. By considering each pair of same-site cemeteries in isolation, then grouping them for a regional view, Vollner (2016) missed the opportunity to use each multi-cemetery site as an outgroup for the other.

The bias-corrected minimum F_{ST} values show a range of biological variation present in individual cemeteries (0.005–0.128 bias-corrected F_{ST}). Mis Island cemetery 3-J-10 was significantly more homogenous than the other two Mis Island cemeteries. In comparison to Mis Island cemetery 3-J-11, cemetery 3-J-10 is smaller, slightly more physiologically stressed, and represents only the Late Medieval Period (1170–1500 CE). No paleopathological data is available for Mis Island cemetery 3-J-18, which was significantly more heterogeneous than cemetery 3-J-10. Both cemeteries were exclusively used in the Late Medieval Period, but cemetery 3-J-18 surrounds the church, whereas cemetery 3-J-10 is 300 meters to the northeast.

The Kulubnarti cemeteries have significantly different F_{ST} values, where the 95% confidence intervals do not overlap. The mainland cemetery 21-R-2 was more "well off" according to archaeological and bioarchaeological analyses and more biologically heterogeneous according to biodistance analysis. The island cemetery 21-S-46, on the other hand, was more impoverished according to archaeological and bioarchaeological evidence and more homogenous according to biodistance analysis. The architecture of the settlements associated with cemetery 21-S-46 was unprofessionally constructed and in many cases had haphazard-seeming wall placement (Adams, 2011). Ceramics found in these settlements were lower quality utilitarian wares compared to those associated with the mainland cemetery 21-R-2 (Adams and Adams, 1998). And delayed growth and early death were more common in the sample from cemetery 21-S-46 (Adams *et al.*, 1999).

Finally, the results failed to support the expectation that in the six-cemetery analysis, cemeteries would show greater affinity within sites than between sites. If this expectation were supported, the R matrix would show closer than average relationships among cemeteries at the same site and more distant than average distances among cemeteries at different sites. In fact, closer than average relationships were found between a pair of Mis Island cemeteries, the two Kulubnarti cemeteries, as well as a Mis Island cemetery and a Kulubnarti cemetery and a Mis Island cemetery and the Gabati cemetery. In addition, the dendrogram would have clustered cemeteries from the same site, with sites forming nodes higher up. (The pattern of relationships shown by the dendrogram in Figure 6.5 is the same regardless of which clustering method is used.) Instead, Kulubnarti cemetery 21-R-2 clustered with the three Mis Island cemeteries, leaving other Kulubnarti cemetery 21-S-46 as an outlier.

By combining the results of the within-cemetery variation analysis (bias-corrected minimum F_{ST}) with the relationships found among cemeteries (R matrix), a closer-than-average relationship is observed between Kulubnarti cemetery 21-R-2 and Mis Island cemetery 3-J-18, two heterogeneous cemeteries located at different sites. Perhaps these individuals were more well-connected, exchanging mates across greater distances, increasing both the biological variability within each group and perhaps increasing access to trade networks. The more homogenous samples from Kulubnarti cemetery 21-S-46 and Gabati may represent groups of biologically isolated, materially impoverished locals. However, it has also been suggested (Van Gerven, personal communication) that the impoverished Kulubnarti group represents a community of impoverished migrating workers, while the healthier local population was better able to leverage longstanding relationships with nearby villages and therefore gain greater access to trade and high-quality construction. Isotopic studies would help clarify whether one group had experienced childhood and development in a region with a different chemical signature to that found at Kulubnarti and Mis Island.

RESEARCH QUESTION 2B

How closely are the six medieval Nubian cemeteries related, when regional comparative data is included in cranial nonmetric trait biodistance analyses?

The results presented in this selection relate to the biodistance analysis of the six Nubian and five comparative African samples using cranial nonmetric traits. Table 6.13 presents the minimum F_{ST} and 95% confidence intervals (CI) for each of the eleven samples. The overall minimum F_{ST} for the 11-sample analysis was 0.087074 (SE = 0.005294). All F_{ST} values are significantly different from 0 at the 0.05 level, indicating significant among-group variation.

Table 6.14 presents the Mahalanobis D^2 values and R matrix values for the eleven-sample analysis using 8 cranial nonmetric traits. An F-test showed that all D^2 values were significant at the

$p < 0.0001$ level. Positive R matrix values, which indicate a closer than average relationship between cemeteries are present when the Nubian samples are compared to each other, such as the three Mis Island cemeteries with the Kulubnarti or Gabati cemeteries, as well as when the Ossenberg samples are compared, so among the Khoisan, Kerma, Pare, Ashanti, and Calabar. Negative values, indicating a more distant relationship than average, are seen in distance between Gabati and Kulubnarti 21-S-46 and all comparisons between a Nubian sample and an Ossenberg sample.

Table 6.13. Minimum F_{ST}, bias-corrected F_{ST}, and associated 95% confidence intervals (CI) for the 11-sample analysis, sorted from lowest to highest F_{ST} value.

Cemetery	Minimum F_{ST}	95% CI
Mis Island 3-J-10	0.04957	0.02529–0.07385
Kulubnarti 21-R-2	0.05441	0.03431–0.07450
Mis Island 3-J-11	0.05926	0.04063–0.07790
Kerma (Sudan)	0.06743	0.04296–0.09189
Pare (Tanzania)	0.07660	0.03398–0.11921
Kulubnarti 21-S-46	0.08241	0.04842–0.11640
Calabar (Nigeria)	0.08537	0.03740–0.13334
Khoisan (South Africa)	0.08979	0.04758–0.13200
Mis Island 3-J-18	0.11366	0.08010–0.14722
Gabati	0.11955	0.06764–0.17146
Ashanti (Ghana)	0.15979	0.10094–0.21863

Figure 6.6 shows a two-dimensional plot of the 11-sample analysis. The first principal coordinate (PC) divides data from the present study from Ossenberg's African data. The second PC divides each set of data by region. The relative distance between same-site cemeteries at Mis Island and Kulubnarti is surprising, considering the distances between Ossenberg groups represent different countries. The first and second principal coordinates explain 61.7 and 13.37% of the differences among groups, respectively.

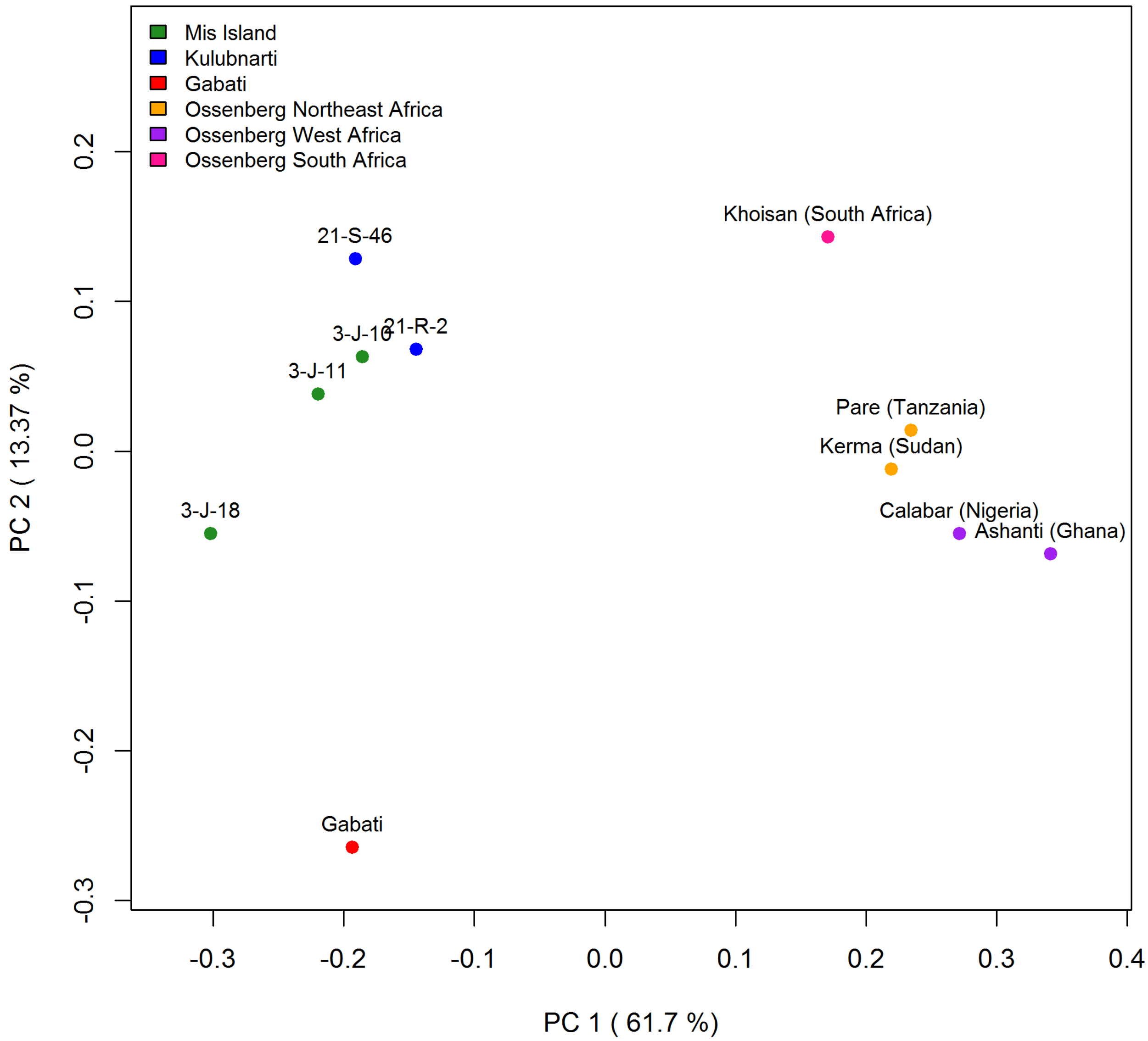
Figure 6.7 is a dendrogram (Ward's method) showing how the 11 samples used in this analysis clustered according to R matrix values. As in the two-dimensional plot, the primary separation is between data collected for this study and Ossenberg data. Within the Nubian samples, Gabati is still an

Table 6.14. Distances among 11 sites using 11 cranial nonmetric traits: the upper values are the biased Mahalanobis D^2 values and the lower values are the R matrix values.

	3-J-10	3-J-11	3-J-18	21-R-2	21-S-46	Gabati	Khoisan	Kerma	Pare	Ashanti	Calabar
3-J-10	---	0.3419	1.9345	1.3806	1.3426	2.7619	4.0094	4.5577	5.2116	8.5036	6.1777
3-J-11	0.0473	---	1.4368	1.2468	1.6396	2.5392	4.8318	4.9484	5.7043	9.4413	6.6613
3-J-18	0.0415	0.0566	---	2.1868	1.8066	2.6111	8.2663	7.9227	7.6063	11.1985	8.2402
21-R-2	0.0233	0.0310	0.0387	---	1.6939	4.0236	4.8619	4.2941	5.1108	7.7282	4.9777
21-S-46	0.0381	0.0368	0.0605	0.0333	---	5.2773	5.8944	6.3062	6.2734	7.9840	6.7098
Gabati	0.0273	0.0367	0.0624	0.0035	-0.0085	---	7.4851	6.3882	7.0952	9.4503	7.1403
Khoisan	-0.0135	-0.0257	-0.0698	-0.0288	-0.0362	-0.0506	---	2.2545	1.7955	4.5333	2.9511
Kerma	-0.0361	-0.0393	-0.0738	-0.0282	-0.0559	-0.0391	0.0318	---	0.9744	2.4717	0.8372
Pare	-0.0450	-0.0504	-0.0627	-0.0405	-0.0507	-0.0491	0.0459	0.0518	---	2.8627	0.7521
Ashanti	-0.0718	-0.0864	-0.0956	-0.0533	-0.0446	-0.0564	0.0307	0.0623	0.0588	---	1.2646
Calabar	-0.0607	-0.0659	-0.0715	-0.0334	-0.0553	-0.0457	0.0263	0.0590	0.0654	0.0963	---

outlier, while Mis Island and Kulubnarti cemeteries cluster differently than in the six-cemetery analysis. However, Mis Island cemeteries 3-J-10 and 3-J-11 are still closely related. These differences are likely attributable to the reduction of the dataset from 30 traits used in the six-cemetery analysis to 8 traits used in the 11-sample analysis.

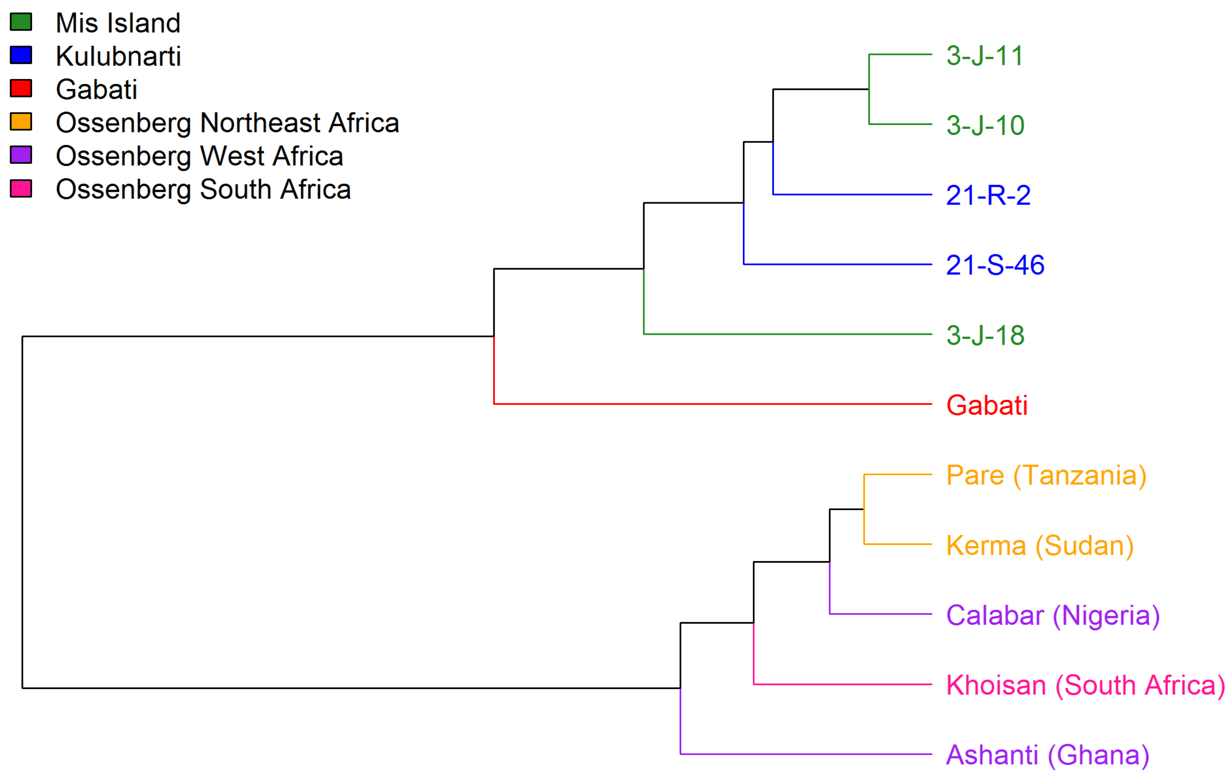
Figure 6.6. Two-dimensional plot of 11-sample analysis using cranial nonmetric traits.



These results do not support the expectation that the eleven African samples would cluster geographically, with the Nubian samples being close to each other compared to other African samples.

Instead, the samples clustered according to researcher. The results do not reflect a link between genetic affinity and geographic proximity or suggest a likely version of African population history regarding how Nubian samples relate to other African samples.

Figure 6.7. Dendrogram (Ward's method) of the R matrix from the 11-sample analysis.



The relationships among Mis Island, Kulubnarti, and Gabati as shown by the eleven-sample analysis were different from the six-cemetery analysis. Whereas Mis Island cemetery 3-J-18 was close to Kulubnarti cemetery 21-R-2 in the six-cemetery analysis, 3-J-18 is an outlier in the eleven-sample scatterplot. Mis Island cemeteries show a closer relationship to each other than in the case of the Kulubnarti cemeteries, and Kulubnarti cemetery 21-R-2 still appears closer to Mis Island than to the second Kulubnarti cemetery.

The editing of the trait list for use in the eleven-sample analysis was based on the documentation provided by Ossenberg (2013) for use with her web-published dataset. Only a few trait definitions that are used in this study (Table 5.1) were based on Ossenberg's original definitions (ossicles at asterion, pterygo-alar bridge, and pterygo-spinous bridge; 1969). Although many of the same trait names appear in both datasets, only those with nearly identical definitions and thresholds for presence were included in this analysis. Therefore, the dataset was reduced from 30 nonmetric traits of the skull to only 8. This extreme editing reduced the amount of underlying genetic data that the dataset represents, resulting in a different pattern of relationships even within the six medieval Upper Nubian cemeteries.

Another potential source of error within this analysis is the introduction of multiple observers. All other analyses in this study use data collected by a single analyst with good concordance between observations taken weeks to months apart, as shown by the tests for intraobserver error. Other studies have had success using data collected by multiple observers (e.g., Hanihara, 2008; Hanihara *et al.*, 2003). However, the observers in these studies were trained by the same team and collected their data using identical trait definitions and thresholds for presence.

The choice of Ossenberg comparative samples may also contribute some error to the results. Ossenberg's dataset is vast, consisting of thousands of individuals, with groups ranging across millennia and continents. Her samples were derived from a variety of museum and university collections, with varying amounts of background information known for the individuals in each sample. She includes five levels of group membership in her database, ranging from continental to tribal, with as few as two or three individuals in some tribal samples. I did my best to choose appropriately scaled samples (intra-country or single-tribe) with comparable sample sizes to my Nubian cemeteries ($n \geq 28$), since the archaeological samples for Mis Island, Kulubnarti, and Gabati have broad temporal and very narrow geographic coverage.

RESEARCH QUESTION 3

Is there cranial nonmetric trait evidence of virilocal or uxorilocal postmarital residence practices at Mis Island, Kulubnarti, or Gabati?

The results presented in this section relate to the analysis of sex-specific variance in each of the six cemeteries and the three sites using cranial nonmetric traits. Following trait selection, thirty nonmetric traits were available for analysis, all of which were used in the following calculations. Each step of the sex-specific variance analysis is demonstrated here using the Mis Island data as an example. For all other subsamples, only the final female-to-male ratio plots are presented. At Mis Island, the observed mean number of pairwise differences was 6.0443 for females and 5.9489 for males (Figure 6.8). The 2.5, 50.0, and 97.5 percentile values for female average pairwise differences from the bootstrap samples were 5.5201, 5.9618, and 6.4120 and for males they were 5.4354, 5.9698, and 6.5041. Figure 6.9 presents these sex-specific data from Mis Island as an empirical cumulative density plot for better visual appreciation of the confidence interval.

Figure 6.8. Histogram of 10,000 bootstrap samples across cranial nonmetric traits for mean number of pairwise differences within females and within males for the Mis Island sample. The dashed vertical lines are the observed values for each sex.

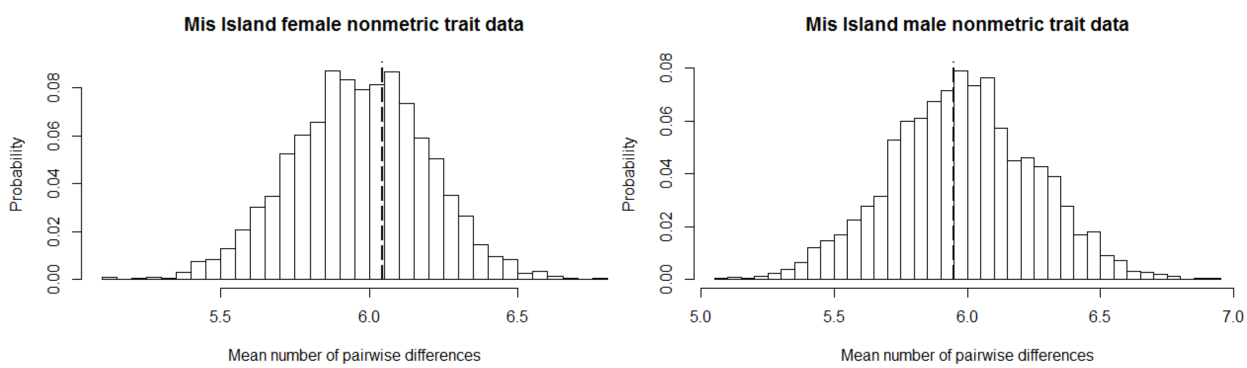


Figure 6.9. Empirical cumulative density representation of the 10,000 bootstrap samples for Mis Island females and males. The 2.5th, 50th, and 97.5th percentile values and the actual observed value are marked.

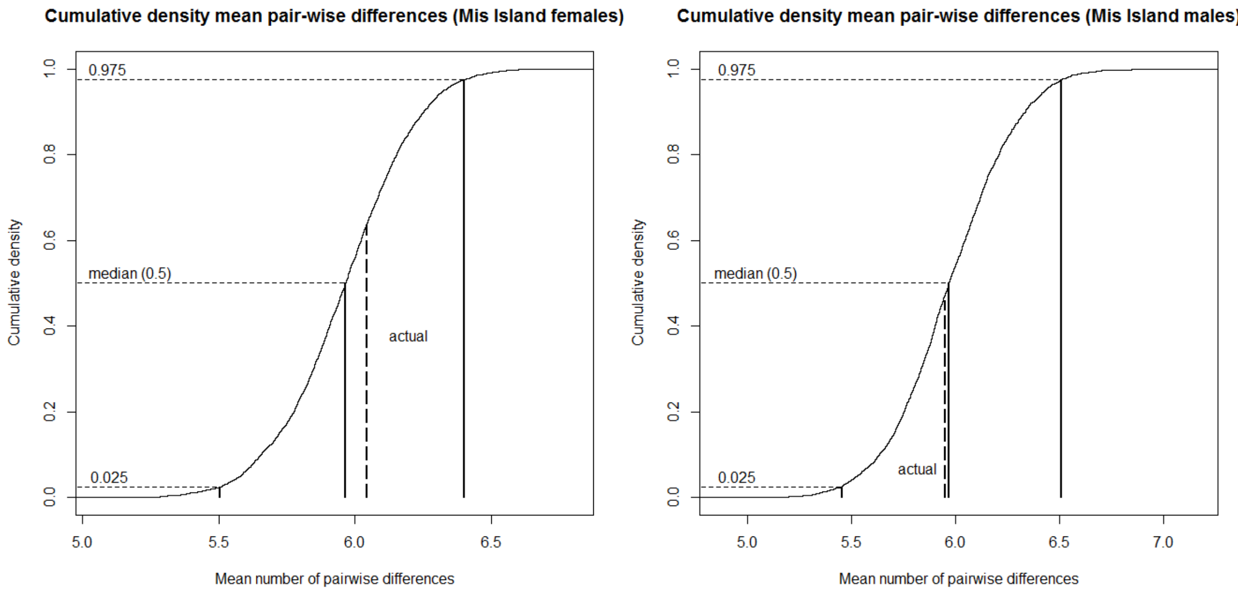


Table 6.15 presents the mean number of pairwise differences among individuals of each sex at each cemetery and site and 95% confidence intervals (CI) for each value. Across the three sites, females at Gabati show the fewest within-sex differences (average mean number of pairwise differences between females 5.2808), and Kulubnarti shows the most within-sex differences (6.4223). Males follow the same pattern, with Gabati males showing the fewest within-sex differences (5.7956) and Kulubnarti males showing the most within-sex differences (6.4559). When the sites are divided into cemeteries and the same values are compared across sites, Gabati females still show the fewest within-sex differences, but Mis Island and Kulubnarti cemeteries show overlapping ranges for female within-sex differences. For example, the value of Mis Island cemetery 3-J-11 females (6.6299) falls between the Kulubnarti cemeteries and is closer to the Kulubnarti average than it is to the other two Mis Island female values. For males in the six-cemetery analysis, Mis Island 3-J-18 males show the fewest within-sex differences (5.3013), whereas Gabati males fall in the middle of the pack. The two cemeteries with

males showing the most within-sex differences are Kulubnarti cemetery 21-R-2 (6.8190) and Mis Island cemetery 3-J-10 (6.3317).

Table 6.15. Mean number of pairwise differences among individuals of each sex and 95% confidence interval (CI) at each of the cemeteries and sites.

Site	Female	95% CI	Male	95% CI
Mis Island 3-J-10	5.3415	4.1749–6.1565	6.3317	5.1673–7.0990
Mis Island 3-J-11	6.6299	5.8280–7.0951	5.9309	5.1340–6.8000
Mis Island 3-J-18	5.5305	4.6248–6.0827	5.3013	4.2931–5.8820
Mis Island total				
	6.0443	*5.5201–6.4147*	*5.9489*	*5.4354–6.5041*
Kulubnarti 21-R-2	6.6983	5.8885–7.2339	6.8190	5.7327–7.5389
Kulubnarti 21-S-46	6.0243	5.0470–6.6088	5.5044	4.0627–6.3046
Kulubnarti	*6.4223*	*5.8111–6.8632*	*6.4559*	*5.6580–7.0421*
Gabati	*5.2808*	*4.0376–5.9469*	*5.7956*	*4.0054–6.5638*

Table 6.16 presents the actual female-to-male ratio of mean pairwise differences for each subsample and the associated 95% confidence interval (CI). The Gabati sample presented the fewest mean pairwise differences among females in any cemetery or site, but the Gabati males were neither the most nor least variable among cemeteries and sites. The Kulubnarti males and females exhibited the greatest mean pairwise differences for both sexes, but individual cemetery values at Mis Island and Kulubnarti are mixed.

Table 6.16. Female-to-male ratio of mean pairwise differences within each sex and 95% confidence intervals (CI) in each of the cemeteries and sites.

Cemetery	Female-male ratio	95% CI
Mis Island 3-J-10	0.8449	0.6525–1.0748
Mis Island 3-J-11	1.0738	0.8933–1.2891
Mis Island 3-J-18	1.0496	0.8514–1.3057
Mis Island total	*0.9991*	*0.8969–1.1195*
Kulubnarti 21-R-2	0.9884	0.8376–1.1804
Kulubnarti 21-S-46	1.1127	0.8768–1.4658
Kulubnarti	*0.9997*	*0.8741–1.1529*
Gabati	*0.9228*	*0.6936–1.3120*

Figures 6.10–6.12 show the bootstrap analysis for each site, with the bootstrap analyses for individual cemeteries presented alongside the site total site plot. The observed ratio of mean female-to-male differences is 0.9991 at Mis Island, 0.9997 at Kulubnarti, and 0.9228 at Gabati. These are all close to the null hypothesis value of 1.0 and indicate equivalent variation in the sexes. However, the individual cemeteries at Mis Island and Kulubnarti show varying trends around the null hypothesis, a pattern that is not visible at the site level when cemeteries are grouped. The observed ratio at cemetery 3-J-10 is 0.8449, indicating a trend of more male variability. The other two Mis Island cemeteries have values greater than 1.0, indicating a trend of more female variability. The only cemetery whose female-male ratio of mean pairwise differences approaches significance is Mis Island cemetery 3-J-10, the small Late Medieval cemetery at that site. In cemetery 3-J-10, females had lower variance than males, suggesting that females were more closely related and males were more mobile. Kulubnarti shows a similar pattern, with cemetery 21-R-2 suggesting slightly more male variability and the ratio at cemetery 21-S-46 suggesting slightly more female variability. None of these deviations from the null hypothesis is statistically significant, since all confidence intervals include the null hypothesis value of 1.0.

These results support the expectation that no significant differences would be found between the variances of the sexes as determined by mean pairwise differences in cranial nonmetric trait expression at Mis Island, Kulubnarti, or Gabati. Differences between the variability found in each sex are not statistically significant at any of the three sites. In addition, at the cemetery level, none of the six cemeteries have significantly different mean pairwise differences between male and female samples. However, it is interesting to note that trends at individual cemeteries differ from the overall trend at each site.

Figure 6.10. Empirical cumulative density plot of the 10,000 bootstrap samples for the total Mis Island sample and each of three Mis Island cemeteries.

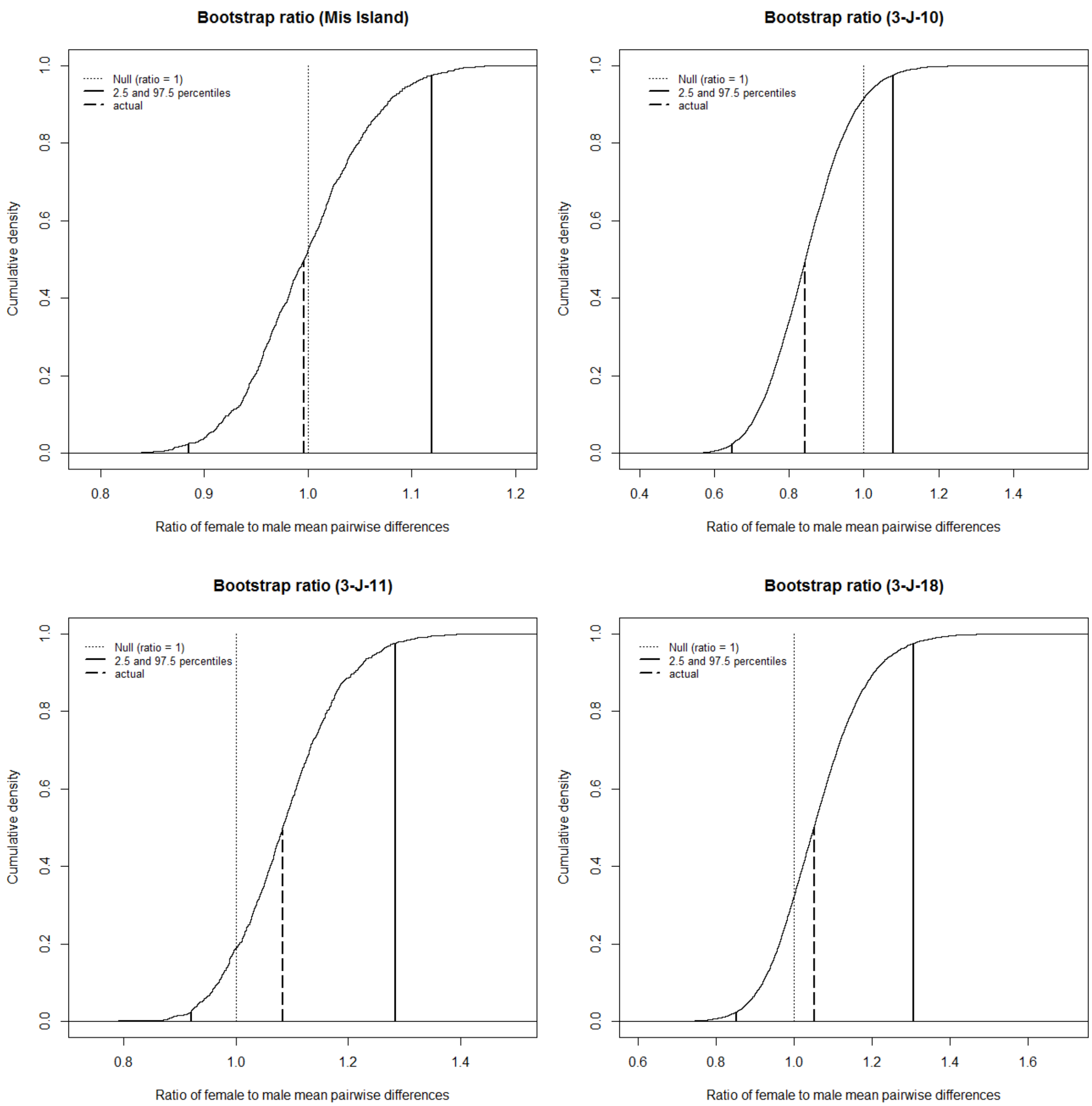


Figure 6.11. Empirical cumulative density plot of the 10,000 bootstrap samples for the total Kulubnarti sample and each of two Kulubnarti cemeteries.

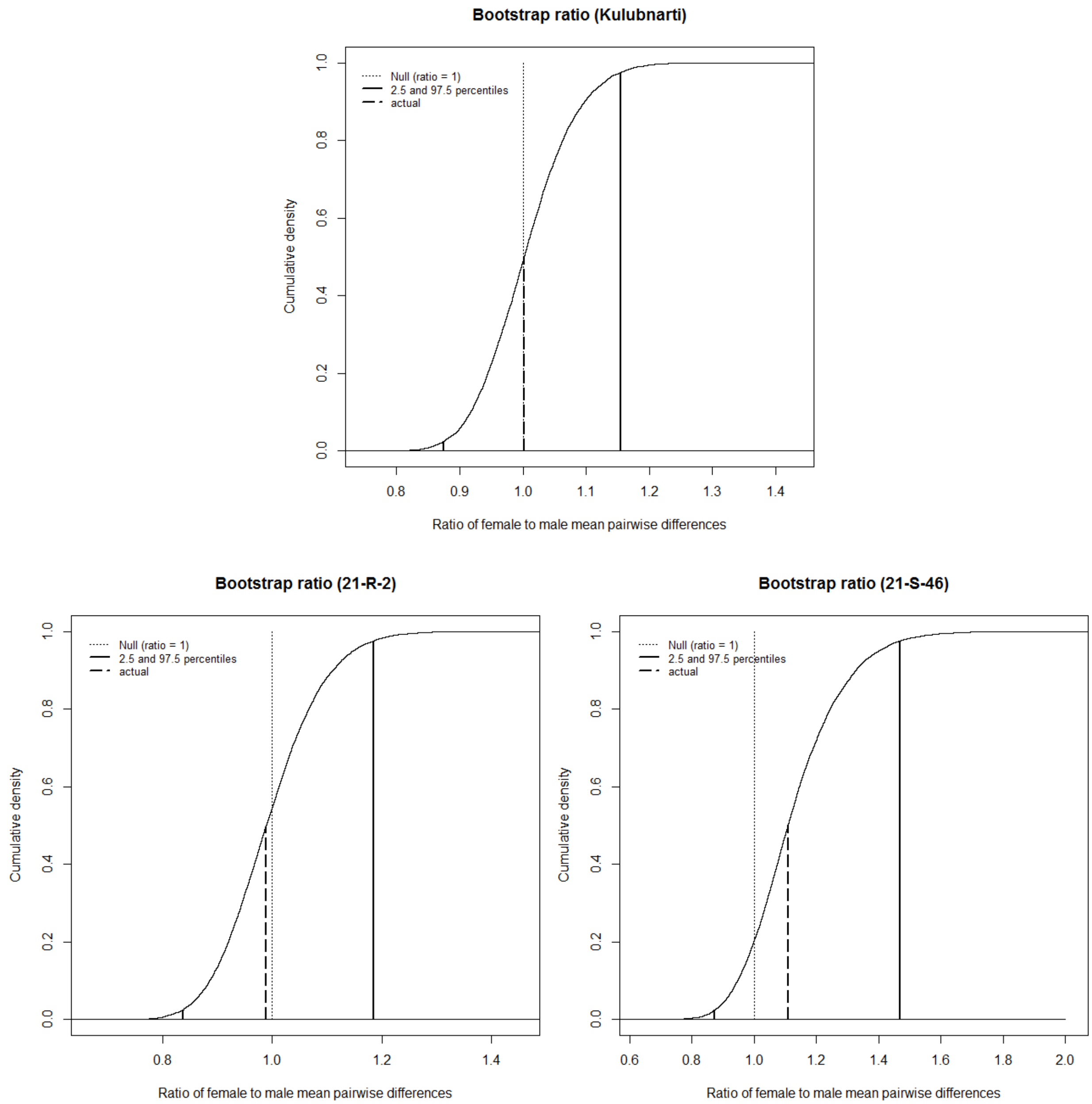
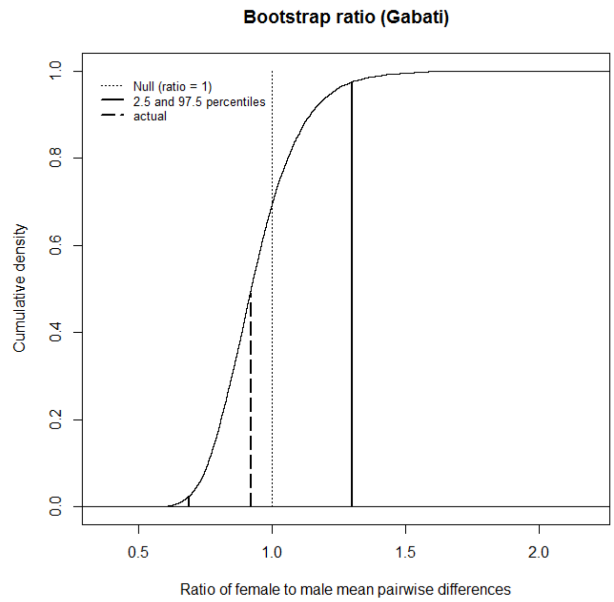


Figure 6.12. Empirical cumulative density plot of the 10,000 bootstrap samples for the Gabati sample.



Both sexes from Mis Island cemetery 3-J-18 showed relatively low variance in comparison with each of the six other cemeteries. This contradicts the F_{ST} results, which found a high level of heterogeneity in the 3-J-18 sample. The evangelical role of males in the medieval church suggests the possibility of traveling religious, the presence of whom would increase the heterogeneity of males buried near the church, which the F_{ST} results support. However, males in 3-J-18 are the most homogenous of all subsamples in the sex-specific variance analysis, suggesting the alternate possibility that burial around the church was reserved for locals. Future research involving strontium or oxygen isotopes might clarify whether first-generation migrants to Mis Island are present in the cemetery surrounding the church.

Quantitative comparison of the results using nonmetrics and craniometrics was not possible due to the nature of the data and the statistical procedures used. The level of sex-specific variance at each site mirrored Vollner's results, where Kulubnarti single-sex samples were the most variable, and Gabati single-sex samples were the least variable (2016, p. 118). Vollner (2016) found insignificant differences between sex-specific variability at all three sites, as did this research. (Vollner's Mis Island sample did not include cemetery 3-J-18.) In the present research, each site showed females having slightly less variance than males, with trends at each cemetery being a mix of greater female variance and greater male variance. Vollner (2016) found that males were more variable at Kulubnarti and Mis Island, while females were more variable at Gabati, although the results were not statistically significant. The same statistically results were found in the present research.

RESEARCH QUESTION 4A

Assuming uniform distribution of burials, can kin-based groups be detected in any of the Mis Island cemeteries using cranial nonmetric traits?

The results in this section relate to the analysis of each of the three Mis Island cemeteries as a uniformly spatially distributed cemetery. The results of the Mantel tests between the Gower phenotypic dissimilarity matrices and the spatial distance matrices at each Mis Island cemetery are presented in Table 6.17. All *r* values are very low, indicating none or little correlation between phenotypic distance and spatial distance in each of the three Mis Island cemeteries. The *r* value for cemetery 3-J-18 is low (0.05956) but significant (p = 0.045), but a significant very low correlation carries little interpretive value.

Table 6.17. Results of Mantel tests on Mis Island cemeteries, assuming uniform spatial distribution of burials with significance based on 999 permutations.

Cemetery	Mantel statistic (*r*)	Significance (*p*)
3-J-10	0.01771	0.350
3-J-11	0.04636	0.140
3-J-18	0.05956	0.045*

These results support the expectation that burials at Mis Island cemetery 3-J-10 would not be spatially organized according to biologically defined kin groups. This finding provides further support for Soler's (2012) interpretation of the spatial distribution of mortuary and demographic data in this cemetery. She found random distributions of body position, grave covering, sex, and disease. The only spatial distinction she identified is differences the placement of adults versus subadults. Infants and children were buried in the eastern edge of the cemetery, and some adolescents were treated as adults and buried throughout the cemetery. Infants and children were thus placed according to age cohort, and not spaced out among the adults, as would be expected if family plots were used within the cemetery area. Based on these findings, Soler (2012) concluded that the importance of community and church membership outweighed biological affinity when a burial location was chosen for an individual.

The results of the uniform-distribution spatial analysis did not support the expectation that burials at Mis Island cemetery 3-J-11 would be spatially organized according to biologically defined kin groups. No significant correlation was found between spatial and phenotypic distance matrices. The expectation was based on the demographic distribution of individuals in the cemetery, as identified by Soler (2012). This test, however, assumed uniform spatial distribution of burials, which may not be present in cemetery 3-J-11. Research Question 4B more appropriately tests the spatial organization of this cemetery, because it may be spatially structured.

The results support the expectation that burials at Mis Island cemetery 3-J-18 would not be spatially organized according to biologically defined kin groups. No significant correlation is found between spatial and phenotypic distance matrices. The bedrock outcroppings around cemetery 3-J-18 impose spatial limits on the cemetery, causing its unusual elongated shape. No formal demographic or spatial analysis has been conducted on this cemetery, but a simple visual assessment of the three cemetery plans with age cohorts of adults and subadults indicated (Figures 5.2–5.4) shows that the spatial distribution of adults and subadults in Mis Island cemetery 3-J-18 more closely resembles the pattern found in cemetery 3-J-11, where kin groups are a possible organizing factor in burial placement. In the section on future research below, I discuss the possibility of pursuing other avenues of kin group identification in this cemetery.

RESEARCH QUESTION 4B

Assuming the presence of spatially structured burial groups, are individuals in Mis Island cemetery 3-J-11 buried according to kin-based groups as determined by cranial nonmetric traits?

The results presented in this section relate to the analysis of cemetery 3-J-11 as a spatially structured cemetery. Table 6.18 presents the distribution of cranial nonmetric traits in the Soler's burial clusters in cemetery 3-J-11. Following the liberal probability values used by Howell and Kintigh (1996), a < 0.15 probability of a trait occurring within a burial cluster at its observed frequency is noted. Some nonrandom distribution of trait presence is evident, since each burial cluster has at least one trait with a p value < 0.15. Burial clusters 4, 6, and 7 each have eight traits with a $p < 0.15$.

Figure 6.13 presents a simplified map of cemetery 3-J-11, where point shape and color indicate burial clusters 1–8 and letter labels indicate kin clusters A–H. Some nonrandom distribution of kin clusters is evident. This is also reflected in the binomial probabilities of kin cluster frequency in each burial cluster (Table 6.17).

Table 6.18 presents the frequency of each cranial nonmetric trait in Soler's burial clusters 1-8. Following the liberal probability values used by Howell and Kintigh (1996), a < 0.15 probability of a trait occurring within a burial cluster at its observed frequency is noted. For example, AAM has an overall frequency in the cemetery of 20/124 (16.13%), while in burial cluster 5 it has a frequency of 0/24 (0%). The 0% frequency in burial cluster 5 is highly unlikely to occur by chance based on the expected (overall) frequency in the cemetery ($p = 0.01$). Low p values suggest nonrandom distribution of traits within burial clusters.

Figure 6.13. Map of cemetery 3-J-11 with numbers 1–8 and point color/shape indicating burial clusters and labels A–H indicating kin clusters.

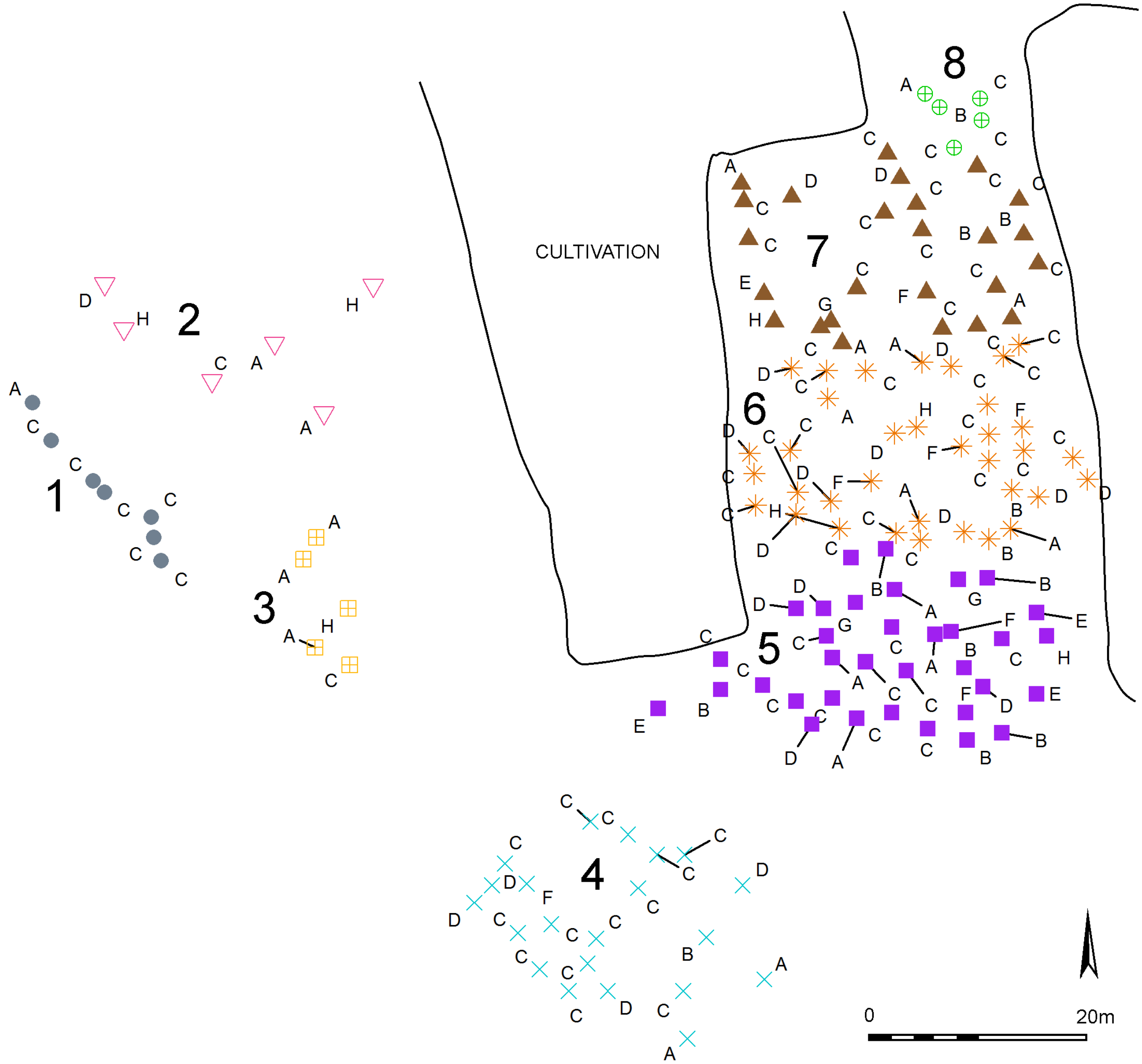


Table 6.19 presents the frequency of each kin cluster (A-H) in each burial cluster (1-8), with frequencies with a probability of $p < 0.15$ noted. Low p values suggest nonrandom distribution of kin clusters within burial clusters. Table 6.19 also presents Simpson's C values for each burial cluster, with higher values indicating dominance by one or a few kin clusters. The probability of each C value occurring by chance is presented, with two burial clusters showing a probability of $p < 0.15$. Burial cluster 5, which shows low probabilities of occurrence of the frequencies of kin groups B, C, E, and G,

has the highest *C* value of the burial clusters at $C = 0.8010$ ($p = 0.0166$). Burial cluster 2, which shows low probabilities of occurrence of the frequencies of kin groups C and H has the third-highest *C* value of the burial clusters at $C = 0.7222$ ($p = 0.1249$). The overall value of Simpson's *C* for the site is $C' = 0.6697$.

These results do not support the expectation that burials at Mis Island cemetery 3-J-11 would be spatially organized according to biologically defined kin groups. Overall spatial organization is not significantly dominated by kin clusters, although individual traits and kin clusters show some nonrandom patterning. Soler (2012) concluded that the burial clusters in cemetery 3-J-11 represented kin groups, and that the emphasis on kin group membership in the Early Medieval Period (550–835 CE) was a holdover from pre-Christian (indigenous) cultural emphasis on the family or kin group as the unit of social organization. She argued that kin membership declined in importance in medieval Christian communities as more emphasis was placed on community and church membership. The mortuary and demographic analyses support these conclusions. Further, the differences between the placement patterns of age cohorts in cemeteries 3-J-10 and 3-J-11 suggest that there must have been some reason for the use of multiple contemporaneous cemeteries and for the placement of individuals within each cemetery.

Previous bioarchaeological research demonstrates that phenotypic data such as cranial nonmetric traits can successfully identify biological kin groups even with small cell sizes (Howell and Kintigh, 1996; Stojanowski and Schillaci, 2006). Thus, although only four of Soler's (2012, Table 22) burial clusters in cemetery 3-J-11 contain more than 10 adults, the literature supports the idea that biodistance analyses can accurately identify kin groups in this sample.

There are a few reasons why this test might return insignificant results. If there are not biologically-based burial groups present in the cemetery, the analysis may be accurately detecting that. However, if there are biologically-based burial groups present, this analysis may still return negative results. First, formation processes of the cemetery might obscure the pattern. Agricultural activity did cut into the cemetery area from the north and the east, which altered the sample composition in unknown ways. Also, the sampling strategy used during excavation attempted to randomly sample throughout the cemetery (Ginns, 2010b), but the density of excavated graves appears uneven across the site (Figure 5.9). In addition, the statistical procedures used in this analysis are designed to quantify the relationship between pre-defined spatial clusters and biological clusters. If burial groups are present but not represented by the spatial clusters defined by Soler (2012), this test would not suggest alternative boundaries, but only return negative results. In the section on Future Research below, I discuss a possible method for detecting other kin groups in Mis Island cemetery 3-J-11.

Finally, the flexible relationship between biological affinity and social kin may be causing the negative test results in this analysis (assuming undetected kin group presence). Certainly, there is little risk of overemphasizing the value of biological data, since neither test of spatial distribution of biological kin clusters yielded positive results. Instead, the relationship between social kin and biological affinity offers an explanation for negative results in a cemetery whose mortuary composition otherwise suggests family-based burial placement. Nothing is currently known about social organization in Post-Meroitic or early medieval Nubia. If a strong emphasis was placed on adoptive children, godparents, or any definition of kin other than a strict biological definition, the analysis used here would be more likely to fail.

Table 6.18. Cranial nonmetric trait distributions in 3-J-11 by burial cluster, with binomial probability noted if $p < 0.15$.

Trait	1 (n = 7)	2 (n = 6)	3 (n = 5)	4 (n = 21)	5 (n = 34)	6 (n = 35)	7 (n = 25)	8 (n = 5)	Total (N = 138)
AAM	1/7	4/6 (p = 0.01)	1/4	5/21 (p = 0.13)	0/24 (p = 0.01)	6/33	2/24 (p = 0.15)	1/5	20/124 (16.13%)
ASO	1/5	0/5	0/2	0/16	1/16	4/20 (p = 0.04)	0/16	0/4	6/84 (7.14%)
COO	0/5	0/5	0/2	1/17	2/16	2/19	1/15	0/4	6/83 (7.23%)
DIF	0/5	0/6	1/3	1/19	3/21	1/24	3/20	0/5	9/103 (8.74%)
DMF	1/7	1/5	0/5	1/21	1/28	1/30	2/24	0/5	7/125 (5.60%)
DOC	1/6 (p = 0.14)	0/6	0/4	0/19	1/23	1/28	0/21	0/5	3/112 (2.68%)
EPI	0/5	2/4	0/1	3/16	3/15	4/18	5/17	0/3	17/79 (21.52%)
FOV	0/7	0/6	0/3	0/19	0/27	1/30	1/19	0/5	2/116 (1.72%)
FSP	2/7	1/6	0/4	4/20	3/27	2/27 (p = 0.10)	5/18 (p = 0.10)	2/4 (p = 0.12)	19/113 (16.81%)
FVS	3/7	1/6 (p = 0.05)	2/2	12/19	14/27 (p = 0.13)	15/27 (p = 0.15)	12/18 (p = 0.14)	5/5 (p = 0.06)	64/111 (57.66%)
HCB	2/7	1/6	1/5	1/21	3/23	2/30 (p = 0.14)	5/21 (p = 0.09)	1/5	16/118 (13.56%)
LDO	1/5	3/5	1/2	7/17	9/16 (p = 0.09)	6/18	4/14 (p = 0.15)	2/4	33/81 (40.74%)
LPF	4/5	2/5	3/4	16/19 (p = 0.05)	14/21	15/21	8/17 (p = 0.05)	2/5	64/97 (65.98%)
MAR	2/7	1/6	2/4 (p = 0.14)	2/21 (p = 0.15)	6/29	4/29	5/23	1/5	23/124 (18.55%)
MET	0/6	0/6	1/5 (p = 0.11)	0/21	1/24	0/32	0/22	1/5 (p = 0.11)	3/121 (2.48%)

Table 6.18 (cont'd). Cranial nonmetric trait distributions in 3-J-11 by burial cluster, with binomial probability noted if $p < 0.15$.

Trait	1 (n = 7)	2 (n = 6)	3 (n = 5)	4 (n = 21)	5 (n = 34)	6 (n = 35)	7 (n = 25)	8 (n = 5)	Total (N = 138)
MHB	1/7	1/6	0/5	4/21 ($p = 0.09$)	2/26	2/30	2/23	0/5	12/123 (9.76%)
MNT	2/7 ($p = 0.09$)	0/5	2/5 ($p = 0.05$)	3/21	0/27 ($p = 0.10$)	3/31	0/24 ($p = 0.14$)	0/5	10/125 (8.00%)
OMW	0/5	0/5	1/2	0/16	2/16	2/20	3/16	1/4	9/84 (10.71%)
PAB	1/7 ($p = 0.12$)	0/6	0/3	0/19	0/24	1/24	0/17	0/4	2/104 (1.92%)
PAF	3/7	3/6	3/4	9/19	19/27 ($p = 0.03$)	13/30 ($p = 0.08$)	9/20 ($p = 0.13$)	4/5	63/118 (53.39%)
PLT	1/5	1/5	0/3	6/21 ($p = 0.08$)	3/27	4/28	4/20	0/5	19/114 (16.67%)
PNB	0/5	0/5	0/2	3/17	4/16	6/21 ($p = 0.10$)	3/16	0/4	16/86 (18.60%)
PSB	1/7 ($p = 0.06$)	0/6	0/3	0/19	0/24	0/23	0/17	0/5	1/104 (0.96%)
SGO	0/5	0/5	0/1	1/19	2/12 ($p = 0.14$)	1/16	1/14	0/4	5/76 (6.58%)
SNS	3/7	4/6	0/5 ($p = 0.01$)	14/19 ($p = 0.13$)	16/24	21/32 ($p = 0.14$)	15/23	4/5	77/121 (63.64%)
SOS	7/7	4/6 ($p = 0.09$)	4/5	19/21	25/26	31/34	19/22	5/5	114/126 (90.48%)
SQO	0/5	0/5	0/2	0/16 ($p = 0.10$)	4/16 ($p = 0.10$)	4/19 ($p = 0.14$)	3/16	0/3	11/82 (13.41%)
TBS	0/7	1/6	1/5	4/21 ($p = 0.12$)	2/25	4/28	1/22	0/5	13/119 (10.92%)
TZS	0/6	0/5	0/3	1/21	0/27	1/28	0/24	0/5	2/119 (1.68%)
ZYG	0/4	0/5	1/4	3/20	2/22	3/25	1/20	0/5	10/105 (9.52%)

Table 6.19. Distribution of individuals in cemetery 3-J-11 by burial cluster and kin cluster (Ward's method), with binomial probability noted if $p < 0.15$.

Burial cluster	Kin cluster								Total	Simpson's *C*	Estimated probability
	A	B	C	D	E	F	G	H			
1	1	0	6 ($p = 0.04$)	0	0	0	0	0	7	0.2449	0.9577
2	2	0	1 ($p = 0.12$)	1	0	0	0	2 ($p = 0.03$)	6	0.7222	0.1249
3	3 ($p = 0.02$)	0	1	0	0	0	0	1	5	0.5600	0.5036
4	2	1	13 ($p = 0.07$)	4	0	1	0	0	21	0.5669	0.9434
5	4	6 ($p = 0.05$)	12 ($p = 0.05$)	4	3 ($p = 0.06$)	2	2 ($p = 0.13$)	1	34	0.8010	0.0166
6	4	2	15 ($p = 0.12$)	9 ($p = 0.03$)	0	3	0	2	35	0.7233	0.4147
7	3	2	14 ($p = 0.11$)	2	1	1	1	1	25	0.6528	0.7632
8	1	1	3	0	0	0	0	0	5	0.5600	0.5108
TOTAL	**20**	**12**	**65**	**20**	**4**	**7**	**3**	**7**	**138**	***C'* = 0.6697**	**0.9339**

CHAPTER SEVEN: DISCUSSION AND CONCLUSIONS

The purpose of this study was twofold: 1) to conduct biodistance analyses within and between medieval Upper Nubian sites and cemeteries using cranial nonmetric traits; and 2) to provide statistical analyses comparing previous craniometric analyses to new cranial nonmetric analyses. The two aspects of this dissertation contribute to the growing body of medieval Nubian literature and to the methodological understanding of the scales at which various biodistance analyses are useful. The statistical results of each analysis and a brief explanation of their significance were presented in Chapter Six. This chapter consists of three thematic discussion sections focusing on each of the main goals of the study and the role of biodistance in anthropological inquiry. Finally, possibilities for future research are detailed and concluding thoughts are presented.

SOCIAL ORGANIZATION IN MEDIEVAL UPPER NUBIA

This section and the next one provide broader discussion related to each of the overall goals of the present research. The first goal was to explore biodistance in three medieval Upper Nubian populations via cranial nonmetric traits. The cranial nonmetric biodistance analyses revealed the relationships among Mis Island, Kulubnarti, and Gabati in a three-site analysis, as well as the relationships among all six cemeteries within and between sites. A regional comparison using a freely available global dataset provided by Nancy Ossenberg (2013, http://library.queensu.ca/data/cntd) failed to provide meaningful regional context, likely due to differing data collection methods. Measures of sex-specific variance contributed to the investigation of social organization in medieval Nubia, and finally the spatial organization of the three Mis Island cemeteries found that burials were placed within cemeteries without reference to kin group membership.

Textual sources suggest that diplomatic relations between Arab Egypt and Alwa were significantly different from the relations between Arab Egyptian and Makuria (Spaulding, 1995). The medieval *Baqt* treaty, created in the mid-seventh century CE, set the terms for centuries of prosperous relations between Egypt and Makuria. Its terms notably excluded the kingdom of Alwa; the *Baqt* identified Makuria as a kingdom contiguous with but separate from the more southerly kingdom of Alwa (Welsby, 2014). Although Alwa is only peripheral in the terms of the *Baqt* treaty, the Upper Nubian kingdom is mentioned in other Arabic sources that suggest that Alwa was more powerful and prosperous than Makuria in the Medieval Period (550–1500 CE; Vantini, 1975). Thus, the historical record indicates the existence of two competing Middle Nile kingdoms, each with diplomatic ties to the Mediterranean. But what effect, if any, would state-level politics have had on the relationships among rural communities?

Archaeological evidence, rather than historical evidence, is more likely to indicate how rural communities were integrated into the regional economy via trade networks. And although material evidence from Mis Island is scanty, the economic status of Mis Island is likely similar to that of Kulubnarti, in part because of their geographic similarities. Riverine travel was critical to trade in ancient and medieval Nubia (Welsby 2002e). However, both Mis Island and Kulubnarti are located along relatively impassable stretches of the Nile: Mis Island along the fourth cataract and Kulubnarti along the rocky *Batn el Hajar*. Adams and Adams (1998) note that riverine trade was uncommon along the rapids found along the *Batn el Hajar*, with goods being portaged overland along this stretch of the Nile. Furthermore, even when goods passed nearby in the Medieval Period, the royal monopoly on foreign trade would have reduced Kulubnarti's access to foreign wares and luxury items. Ceramic evidence from Kulubnarti provides support for this scenario, since ceramics recovered from that site were almost exclusively utilitarian, with luxury or exotic items not represented (Adams and Adams, 1998). Further upriver, the community at Mis Island may have been similarly excluded from regional trade networks. However, the presence of late medieval churches in the fourth cataract region suggests at least some contact between local communities and the greater hierarchy of the Byzantine church (Zurawski, 2014).

A medieval church was excavated on Mis Island; the draft site report notes that its architectural style "displayed characteristics in common with Later Nubian ecclesiastical architecture" (Ginns, 2010d).

Meanwhile at Gabati in medieval Alwa, the grave goods found in some Post-Meroitic graves suggest strong links with the capital at Soba as well as Egypt and the Red Sea Hills (Edwards, 1998). Excavations at Soba itself also reveal tentative connections with Egypt via fragments of glass and amphorae (Welsby *et al.*, 1998). Welsby *et al.* (1998) further noted the presence of late medieval glazed ceramics that may have been imported from sites on the Red Sea coast, similar to the finds at Gabati. Welsby *et al.* (1998) caution that foreign items found in Alwa may have been transferred through Makuria. Edwards (1998) laments the dearth of archaeological evidence from the medieval kingdom of Alwa, especially settlement archaeology, and is hesitant to draw any conclusions about regional patterns based on the existing evidence. If the proportion of material wealth represented by imports is any evidence, however, Soba relied mostly on domestic products and overall did not engage in extensive trade with neighboring polities (Edwards 1998). The osteological results of this study support this conclusion by demonstrating that Gabati was biologically distant to both Mis Island and Kulubnarti.

Since most burials at Mis Island, Kulubnarti, and Gabati followed the Christian tradition, where grave goods are not included in burials, there is little material evidence for archaeologists to analyze (Adams *et al.,* 1999). Ceramic analysis therefore cannot shed light on manufacture or trade. Settlement data is also difficult or impossible to incorporate at Mis Island and Gabati since no associated settlement was excavated near the Gabati cemetery (Edwards, 1998) and the Mis Island "settlement" site was more likely to have been a livestock holding area and produced very few potsherds or other material culture (Ginns, 2010f). Meanwhile at Kulubnarti, ten medieval and early modern settlements were excavated along with the two cemeteries (Adams and Adams, 1998).

There is little evidence for permanent habitation at Kulubnarti until the eleventh century CE, when poorly constructed houses and a church were built (Adams and Adams, 1998). From crude huts in the eleventh century to expertly-constructed stone houses in the twelfth, the population at Kulubnarti suddenly displays greater access to material wealth. In the Late Medieval Period (1170–1500 CE), Adams and Adams (1998) suggest that increased prosperity might have resulted from foreign trade originating further south, in stark contrast to the Early Medieval Period (550–835 CE), where such contact was practically nonexistent. This transition may be associated with a weakening central Makurian state, no longer able to monopolize foreign trade. Such a decentralization of power would have resulted in increased contact between Kulubnarti and communities both up and downriver.

Biological relationships among samples

In the three-site analysis, where cemeteries from the same site were pooled, Mis Island displayed the highest level of heterogeneity. In the six-cemetery analysis, the three Mis Island cemeteries cluster as moderately heterogeneous. They are significantly more so than Gabati and Kulubnarti cemetery 21-S-46 and significantly less so than Kulubnarti cemetery 21-R-2. The two most heterogeneous cemeteries are the physiologically healthy, mainland Kulubnarti cemetery 21-R-2 and cemetery 3-J-18, which surrounds the church at Mis Island. Although no paleopathological analysis has yet been published on Mis Island cemetery 3-J-18, I suggest that these two populations represent the most mobile individuals and predict that Mis Island cemetery 3-J-18 will show relatively low pathological loads and physiological stress. Whether this represents a sort of “hybrid vigor” or the increased geographic mobility of a wealthier subset of the population is a question that will rely on additional lines of evidence.

Although the individuals in Mis Island cemeteries 3-J-10 and 3-J-11 experienced health, disease, and burial in similar ways, Soler (2012) posits that Mis Island may have functioned as a refuge in the Late Medieval Period (1170–1500 CE) for Lower Nubians fleeing increasing political instability and Egyptian raids into the region, as described by Welsby (2006b, 2002c). Her suggestion that Mis Island began to receive political refugees in the Late Medieval would imply that the Late Medieval cemetery 3-J-10 would be more heterogeneous than the longer-use cemetery 3-J-11, but this is not the case. However, both cemetery 3-J-10 and cemetery 3-J-18 were in use starting in the tenth century (Ginns, 2010c, 2010a). If these were late medieval cemeteries, perhaps the individuals in these two cemeteries represent distinct social groups cohabitating on Mis Island. Cemetery 3-J-18, which surrounds the late medieval church, is significantly more heterogeneous than the late medieval cemetery 3-J-10. Could the church cemetery sample represent a diverse group refugees while locals used a community cemetery located closer to cemetery 3-J-11? Carbon dating and isotopic analysis of the skeletal remains from all cemeteries and paleopathological research on cemetery 3-J-18 would allow for additional interpretation of the political refugee hypothesis.

The two Kulubnarti cemeteries displayed significantly different levels of variation (F_{ST}), with the larger mainland cemetery 21-R-2 being much more heterogeneous than the smaller island cemetery 21-S-46. Paleopathological analyses found that the mainland cemetery 21-R-2 was also relatively healthy while the island cemetery 21-S-46 was under significant physiological stress. The genetically homogenous, physiologically stressed population from Kulubnarti cemetery 21-S-46 was also the outlier in the six-cemetery analysis, suggesting biological isolation. Such isolation suggests that the community using the island cemetery 21-S-46 was not integrated with other local communities, perhaps because it was insular, poor with low economic mobility, or consisted of poor migrant workers who only erected crude temporary shelters where they provided agricultural labor (Van Gerven, personal communication).

The cemeteries at Kulubnarti were initially treated as representing “early” and “late” medieval populations. This assumption continued as recently as Soler (2012) and Vollner’s (2016) dissertations. However, a careful reading of the site reports reveals that contemporaneity of the two Kulubnarti cemeteries was expected, at least in the Early Medieval Period (550–835 CE), in the site reports published more than a decade prior. Adams and colleagues observe:

> "The combination of cultural and biological evidence from Kulubnarti suggests a wholly unexpected possibility: that this region in Early Christian [sic] times was home to two racially and culturally identical, but socially distinct, communities, one of which was considerably better off than the other… we are left to imagine a single culturally homogeneous but socially stratified Nubian population; yet there is neither textual evidence nor archaeological evidence from other sites to support such an interpretation" (1999, p. 88).

New carbon dates showing nearly identical mean ages for both cemeteries (Van Gerven, personal communication) suggest that further analysis should follow Adams *et al.*'s (1999) suggestion: the cemeteries at Kulubnarti represent two populations living in close proximity with similar culture and burial patterns but significantly different pathological loads and levels of biological diversity.

In the sites used in the present study, Gabati, in medieval Alwa, was the outlier in the three-site comparison with Makurian Kulubnarti and Mis Island. However, some of the distinctiveness of the Post-Meroitic and Medieval burials at Gabati versus the other two sites may be related as much to sample composition as it is a reflection of broader political isolation. First, the Gabati sample is the smallest of the three sites and of the six cemeteries. And unlike Kulubnarti and Mis Island, which contained hundreds of graves presumably representing the vast majority of the local population, only a few dozen graves at Gabati represent hundreds of years of inhabitation. The genetic isolation seen in the three-site and six-cemetery analyses may be because the cemetery excavated as Gabati represented only one kin group or clan, while burials for other members of the community remain undiscovered. This is supported by the cranial nonmetric traits, which show biological homogeneity in the Gabati sample (F_{ST}).

The cemetery excavated at Gabati should not be considered representative of the total population because of its small size, long use period, and possibility of additional cemeteries used by this community. Although no cemetery is likely to be representative of the total population in its catchment area, the differences between the Gabati cemetery and the sites of Kulubnarti and Mis Island are important. They suggest that the six-cemetery comparison is likely a more appropriate analysis for contextualizing Gabati because the units of investigation (cemetery) are analogous. In contrast, two or three cemeteries are grouped in the three-site analysis, making the unit of investigation nominally the site, but in fact still one cemetery at Gabati.

Postmarital residence

Postmarital residence patterns address the way communities were regionally integrated through mate exchange. They comprise an important component of social organization, which refers to the ordering of social relations through dynamic processes (Green, 1976). Stojanowski and Schillaci argue that “the dynamic ordering of social relations through individual or collective choice or action… may have consequences with respect to the distribution of material culture, architecture, and biological variation” (2006, p. 64). The presence of stable heterosexual monogamy over the course of adulthood and terms like “husband” and “wife” represent assumptions about binary heteronormative gender roles within postmarital residence analysis, although these concepts may not be universally applicable (Konigsberg and Frankenberg, 2016). With this caveat in mind, the assumption is made in this research that medieval Christian communities recognized heterosexual monogamous marriage as the ideal presented by the church.

Statistical comparisons of biological variability within each sex can reveal patterns of postmarital residence – the sex that demonstrates lower between-group variability is the more mobile sex (Lane and Sublett, 1972). The corollary to this is that the more mobile sex will exhibit greater within-site variability (Spence, 1974a), which is the avenue of investigation in the present study. The analysis of within-site variance does not require knowledge of mating network as between-site variance analyses but still provides information about the relative heterogeneity of the sexes (Konigsberg, 1988; Konigsberg and Frankenberg, 2016). The two variations on this model have been successfully applied at in the American southwest (Birkby, 1982; Schillaci and Stojanowski, 2002), Teotihuacan, Mexico (Spence, 1974b), and Seneca populations from New York State (Lane and Sublett, 1972), although their use in African bioarchaeology is rare. The sex that makes a greater contribution to subsistence is the less mobile sex in many parts of the world (Konigsberg and Frankenberg, 2016). In the present research, equal variance of the sexes was found at all six cemeteries. These results do not suggest virilocal or uxorilocal postmarital residence patterns. Instead, equal variance of the sexes suggests equal contribution by the sexes to subsistence in the rural agricultural hamlets of medieval Nubia.

Spatial analysis

The results of the spatial analyses correspond with preliminary results presented by Seidel and Baker (2013) and Nado and Baker (2013). Both studies spanned the Post-Meroitic–Christian transition at the Fourth Cataract site of Ginefab. Their spatial analyses used dental metrics (Seidel and Baker, 2013) and cranial nonmetrics (Nado and Baker, 2013) and results showed that Post-Meroitic burial clusters included kin clusters of related males, while among Christian burials, related individuals of both sexes were found in several burial clusters. In the present study, kin clusters were not identified as an organizing principle in any of the three medieval cemeteries at Mis Island, despite the even distribution of age cohorts throughout two of the cemeteries. The Ginefab results, Soler's (2012) analysis of Mis Island, and the current study support the idea that social organization in medieval Christian Nubia was not centered around kin groups, but instead emphasized church or community membership.

COMPARING MULTIPLE PHENOTYPIC DATASETS

The second goal of this dissertation was to compare the results of cranial nonmetric trait biodistance analyses, quantitatively when possible, to existing craniometrics analyses. The previously conducted craniometric analyses were represented by Vollner's (2016) dissertation, which analyzed most of the individuals from five of the six cemeteries used in the present research (she did not include Mis Island cemetery 3-J-18). Quantitative comparison was possible between each three-site biodistance analysis and the measures of population differentiation (F_{ST}). Qualitative comparison was possible between the measures of sex-specific variance and regionally contextualized biodistance.

Early research in the application of nonmetric traits to biodistance analysis investigated the relationship between cranial metrics and nonmetric traits in humans (Corruccini, 1976) and non-human primates (Richtsmeier *et al.,* 1984). Both studies rejected the broadly accepted notion that craniometrics and nonmetrics were independent, and Corrucini concluded that “presumably, the greatest amount of genetic information in skeletal studies will be retrievable by using both forms of information in conjunction” (1984, p. 292). Molecular testing has improved our understanding of the relationship between phenotypic and genetic data, and work in the past decade has supported strong correlations between craniometrics, cranial nonmetrics, and genetic information. Ricaut *et al.* found that “phenotypic and genetic distance matrices support broadly the same conclusion, despite the use of different correlation coefficients and distance statistics” (2010, pp. 361–362). A more nuanced conclusion was reached by Herrera *et al.* (2014), who found a significant correlation between metric biodistance and mitochondrial DNA (mtDNA) distance and between non-metric biodistance and Y-chromosome DNA distance (2014:8). These pairings suggest that metric data may be more revealing of the relationships among females in the sample, while cranial nonmetric data reveals more about the relationships between males.

In her dissertation, Vollner (2016): 1) compared two groups at each site; 2) calculated Mahalanobis D^2 distances for the three-site analysis; 3a) conducted a Relethford-Blangero analysis on three Nubian sites; 3b) repeated this analysis with additional African data included for regional context; and 4) calculated sex-specific variance at each site. Overall, her interests lay in uncovering the population history of medieval Nubian populations in a regional context, as evidenced by a desire to pool cemeteries from the same site via MANOVAs and an interest in gene flow via Relethford-Blangero analyses. In contrast, the present study has focused on intra-site analyses, preferring a finer-grained analysis where possible to compare same-site cemeteries, although it also mirrored some of the three-site analyses favored by Vollner (2016).

As reviewed in Chapter Six, the Mantel tests comparing Vollner's and the present three-site analyses were unable to calculate significance to a sufficient degree, because the comparison was between two three-by-three biodistance matrices. Quantitative comparison in this case is limited because while the correlation value is very high, the significance value is poor. But qualitative comparison between the R matrices shows that the pattern of relationships is the same, with the most distant relationship being the one between Kulubnarti and Gabati. In addition, the F_{ST} values for each site are similar using both types of data. Also, Mis Island is significantly more heterogeneous (smaller F_{ST}) than the other two sites using both types of data.

Differences (or lack thereof) between F_{ST} values calculated using craniometrics and cranial nonmetrics may be considered in light of Herrera *et al.*'s (2014) findings. If males at a site showed significantly more variance as calculated by mean pairwise differences, we would expect to see the same information reflected in a lower F_{ST} based on cranial nonmetrics, which Herrera *et al.* (2014) showed to be correlated with Y-chromosome DNA (from the paternal line). However, in the Nubian samples, males and females do not show significant differences in variance using either cranial nonmetrics (this study) or craniometrics (Vollner, 2016). Therefore, as expected, the F_{ST} values produced by each dataset are also not significantly different.

Both Vollner's (2016) dissertation and the present research performed regional comparisons by including other African data from freely available global datasets. Vollner's (2016:117) scatterplot showed Mis Island and Kulubnarti clustering together near Egypt and Gabati and the overall pattern reflecting geographic distribution of the samples. For example, West African and Sub-Saharan groups also clustered together. However, the regional comparison prepared for the present research produced a scatterplot that emphasized the origin of the data by researcher rather than the geographic distribution of the populations. The difference is likely due to the more standardized landmarks and definitions used in craniometric data collection versus cranial nonmetric data collection.

Finally, both Vollner (2016) and the present research tested sex-specific variability at each site. The results included measures of sex-specific variability and ratios of variability between the sexes at each site. Both datasets showed females from Kulubnarti were the most variable while females from Gabati were the least variable (Vollner 2016:118). The same pattern was true for males using both datasets (Vollner 2016:118). However, the sex-specific variability values among sites were not significantly different for either sex for Vollner, while in the present study, the variability of female cohorts was significantly different across sites. Vollner found more male variance only at Kulubnarti and Mis Island, while the present research found more male variance at all three sites. Overall, the differences between these studies are not significant since both studies found equal variance of the sexes at all three sites, indicating that males and females were equally mobile between communities.

BIODISTANCE IN ANTHROPOLOGICAL CONTEXT

Biodistance studies do not occur in a vacuum. They are one of many tools used by bioarchaeologists to reconstruct past lifeways using biological data. Past biological realities such as biological affinity, health, and disease are revealed by biodistance studies, and articulation with material culture sheds light on broader aspects of culture, identity, and social organization. The goals of biodistance analyses in bioarchaeology range from understanding the phylogenetic relationships among migrating groups and their populations of origin (Pietrusewsky, 1983) to identifying kin-based placement of burials within a cemetery (Howell and Kintigh, 1996). The present research focused on several aspects of biological affinity at regional, local, and family scales.

Whatever the research questions, biodistance studies are anthropological inquiries. Therefore, the biological relationships revealed by biodistance studies must articulate with the cultural context from which skeletal samples are derived. This is known as the biocultural approach. It situates skeletal data within the social context of a past population (Baker, 2016; Johnson and Paul, 2016). In the biocultural approach, researchers should integrate available archaeological and bioarchaeological (osteological) data to answer questions about population structure and social organization in human groups. Kakaliouras (2017), among others, also makes the case for integration of sociocultural *theory* into bioarchaeological analyses. She argues that social theory should be integrated into interpretations of osteological data, particularly in the case of social organization and ideas of "community." Johnson and Paul (2016) made the same argument for definitions of family that incorporate social relatedness. They caution Western scholars not to project Western concepts of relatedness as an exclusively biological fact onto past populations.

Ideally, bioarchaeological research expands on existing archaeological frameworks by testing existing hypotheses with new data. Wrobel and Graham (2013) did just that by testing genetic distinctiveness between two groups with differing ceramic traditions. However, in the case of medieval Nubia, existing archaeological frameworks have broad temporal and geographic gaps. In the absence of an internal written record, settlement archaeology, or grave goods, we are forced to rely on loosely related evidence from diverse time periods and distant regions of the Middle Nile. Social organization in medieval Nubia remains grossly understudied, although sweeping political, social, and religious changes including the spread of state-sponsored Christianity spread through the Levant and Northeast Africa.

Following the collapse of the Meroitic Empire in the mid-fourth century CE, there was no centralized power in Nubia. By the mid-sixth century CE, three emerging kingdoms along the Middle Nile were known by Egyptian: Nobadia, Makuria, and Alwa. The ruling elite of these kingdoms converted to Christianity in the mid-sixth century CE, while they were likely still consolidating power. The spread of Christianity in the first millennium CE was an unusual blend of religious, social, and political systems, only sometimes as a result of military conquest. In the case of Nubia, non-elite populations slowly adopted Christian burial forms and, presumably, partially integrated the social norms preached by Byzantine and Egyptian clergy into their culture. Northeast Africa and the Levant were forever changed in the mid-seventh century CE when Islam originated on the Arabian Peninsula. In the first century of its existence, the Arab empire conquered a territory spreading from modern Pakistan to modern Portugal, including Egypt and the rest of North Africa. Religious changes accompanying the formation of new states in Nubia, and the creation of a vast religious and military Empire to the north all affected the Nubian populace in the Medieval Period. The features of indigenous family life, social organization, and community formation that Christianity and Islam may have replaced are unknown, as is the extent to which these religions modified existing structures.

In medieval Nubia, little is known about social organization in any period. From small-scale definitions of family to the regional interactions among communities, this research has attempted to shed light on how non-elite individuals and populations were related in medieval Nubia. Some historical research suggests the importance of the maternal line in Nubia through the millennia (Lohwasser, 2001). However, this example is specific to Nubian royals, the subgroup of elites most socially removed from the general population of non-elites. It is also temporally specific, referring to the Napatan and Meroitic royals. Lohwasser (2001) argues for the presence of sister-son inheritance of royal power, meaning that the ability to pass on royal power rested in the royal women. Mortuary, artistic, and historical sources support this conclusion. However, there is no research indicating whether or not this distribution of power between the sexes extended beyond the royal family into the elite class or the non-elite majority of any era.

The biocultural approach works best when osteological information can be tied to existing archaeological, and by extension sociocultural, narratives. Contextualizing medieval Nubian biodistance studies is difficult because of the nature of the archaeological record (mostly salvage archaeology and mostly in Lower Nubia) and the scanty historical record (mostly traveler’s accounts or centuries-distant histories). Because so much of Nubian archaeology has been the result of salvage efforts responding to dam construction along the Nile, extended projects are relatively rare (Baker, 2016), with the notable

exception of the decades-long efforts at Kerma led by Charles Bonnet (2014). When physical anthropologists are included in the excavation team, osteological results can be integrated into the site report. In such reports, osteological reports can evolve beyond the descriptive to interpretive.
Baker (2016) cites the osteological summary from Gabati as a notable example of this type of integration (Edwards and Judd, 2012). Gabati has no associated settlement excavation, yet data from mortuary contexts, small finds, and osteological reports are tied together in Edwards and Judd's (2012) concluding chapter.

In some studies, osteological analysis fills in gaps left by previous archaeological efforts, which is the case for the present study, while in other cases, osteological analysis is used to confirm or refute the archaeological or historical narrative. In their studies of Mis Island, Soler (2012) used political history to frame osteological results, and Vollner (2016) used osteological data to test existing historical narratives. Analysts presenting bioarchaeological analyses must keep in mind the known limits of each method when providing interpretations of their results. In the case of nonmetric biodistance studies, the obvious limitation is the imperfect relationship between phenotypic data and biological relatedness. However, equally important is the fuzzy relationship between biological affinity and social kinship.

Biological affinity imperfectly reflects social relationships and is only a small portion of socially constructed identities (Knudson and Stojanowski, 2008). Lozada (2012) argues that biodistance studies have often overestimated the interpretive value of genetic relationships, calling instead for more cautious interpretation of results. On the other hand, Stojanowski and Schillachi (2006), do caution that the exact gene genealogical nature of relationship identified by distance studies cannot be accurately determined, and Ricaut *et al.* (2010) showed that pair relationships (siblings and parent/child relationships) could not be accurately detected by cranial nonmetric traits. Bioarchaeological biodistance studies are well-suited to detect kin groups in a mortuary context (local) or to shed light on relationships among populations (regional). Although interpretation of results requires caution, biodistance studies can provide a direct line of evidence about biological relationships in past populations.

In the present study, the living population from which each mortuary population is derived can be named a community based on shared space and practice (Canuto and Yager, 2003), at least as regards disposition of the dead. Previous research (Soler, 2012) noted that absence of grave goods, graves types, and superstructures were consistent across two of the three Mis Island cemeteries. The social process of community at Mis Island was, at least in part, derived from Christian religious norms and associated funerary customs. In addition, the present study determined that no kin-based burial groups were present in any of the three Mis Island cemeteries, suggesting that biological affinity was not a strong component in the process of community on Mis Island. Communities in medieval Makuria were formed only in part by the bonds of biological affinity.

The three Mis Island cemeteries had similar levels of within-group variation, suggesting that the distinctions between communities were either relatively new or that communities were tightly linked by social organizational principles such as mate exchange. The two Kulubnarti cemeteries, on the other hand, were the two most extreme in terms of within-group variability. The differing levels of gene flow experienced by the two Kulubnarti cemeteries indicate that their living communities experienced different social processes of community, in addition to differing health and nutrition, despite living near each other. The small cemetery at Gabati is different from the multi-cemetery sites of Kulubnarti and Mis Island, and not only because of its small size. The cemetery at Gabati has so few burials during the use period (about 1100 years) that it almost certainly does not represent an entire village or socially defined community, but some family subset of that larger community. The mortuary population is extremely homogenous according to the within-group variation analysis, suggesting that the process of community at Gabati, located in the far Upper Nubia kingdom of Alwa, was more influenced by biological affinity than the two Makurian sites to the north.

FUTURE RESEARCH

The human remains from Mis Island cemeteries 3-J-10 and 3-J-11 have been available for study since 2010, and this is the fourth dissertation to use this collection as the main sample (in addition to Hurst, 2013; Soler, 2012; Vollner, 2016). Future work for all research projects includes peer-reviewed publication of results in addition to a combination of data to delve deeper into the lives of this medieval Nile-dwelling population. For example, re-analyzing the raw craniometric data collected by Vollner (2016) by cemetery, rather than grouping by site, would allow for a more robust comparison of biodistance results among cemetery groups, using the methods applied in Research Question 1b of this dissertation. Comparing the biodistances among five cemeteries would provide a more meaningful significance value for the Mantel test results and an improvement over the comparison of two three-by-three distance matrices used in this study.

Although kin groups were not detected in Research Question 4, additional analyses might successfully identify clusters of related individuals in Mis Island cemeteries 3-J-11 and 3-J-18. Based on the preponderance of evidence, Mis Island cemetery 3-J-10 does not need to be further tested for the presence of kin-based burial. Alt and Vach's serial univariate approach (1991) uses a count method to detect trait clustering, and might identify clusters of individuals otherwise lost in the "noise" of surrounding burials. The Alt and Vach (1991) method assumes uniformly distributed burials, meaning that it could identify kin clusters in cemetery 3-J-11 other than those proposed by Soler (2012). Alt and Vach (1991) also includes provisions for unevenly spaced burials, which would be a benefit in cemetery 3-J-18, which is unusually shaped with unevenly spaced burials due to geographic constraints.

Ongoing research on the Kulubnarti collection includes genetic analysis using ancient DNA (aDNA). Genetic data provide a sounding board for both craniometric and cranial nonmetric data at that site. Spatial analyses similar to the ones performed for Research Question 4 could compare genetic, cranial nonmetric, craniometric, and spatial distance matrices for a nuanced view of social organization at Kulubnarti.

Finally, ongoing and future research on the human remains from Mis Island cemetery 3-J-18 will allow for analysis across all three medieval Mis Island cemeteries. Cemetery 3-J-18, which surrounds the Late Medieval church, represents a third contemporaneous mortuary population. At present, paleopathology, mortuary and spatial analyses, growth and development, and inter-cemetery comparisons have only been presented from Mis Island cemeteries 3-J-10 and 3-J-11 via Soler (2012) and Hurst's (2013) dissertations. Subadult burials in Mis Island cemetery 3-J-18 are distributed throughout the cemetery, suggesting a spatial organization similar to cemetery 3-J-11, while its use period in the Late Medieval (1170–1500 CE) is more similar to cemetery 3-J-10. The methods used in Research Question 4b could be applied to the three Mis Island cemeteries to test the correlation between kin clusters found across the site and the placement of individuals in one of the three cemeteries.

CONCLUDING THOUGHTS

This dissertation contributes to the growing body of literature on medieval Nubia, especially the bioarchaeology of this period, and to the quantitative comparison of multiple types of phenotypic or genetic data. I used a suite of nonmetric traits of the skull to analyze population structure, postmarital residence, and spatial organization of six cemeteries from three medieval Upper Nubian sites. Additional tests compared these results with previously published craniometric studies of five of the six cemeteries used in the present research.

Results showed that, as expected, the two sites controlled by the same medieval kingdom (Mis Island and Kulubnarti) were more closely related to each other than either was to Gabati, a site located in the more southerly Upper Nubian kingdom of Alwa. Multiple contemporaneous cemeteries were present at both Mis Island and Kulubnarti. While Mis Island cemeteries were relatively closely related, the mortuary populations from Kulubnarti were biologically different from one another. The Kulubnarti island cemetery, known to have higher rates of physiological stress, was distant to the other Makurian cemeteries and more biologically homogenous. Analysis of the sexes showed that neither virilocal nor uxorilocal postmarital residence practices dominated in any of the cemeteries or sites. Instead, an even exchange of mates among groups was observed, which concurred with previous craniometric findings. Finally, spatial analysis confirmed previous research suggesting that membership in family groups, clans, or moieties was not used as an organizing principle in medieval Mis Island cemeteries, as it had been in earlier periods.

The results of new nonmetric analyses correlated strongly with existing craniometric results on an overlapping sample, when such results were quantitatively comparable. When results were only qualitatively compared, the two sets of data produced the same conclusions. The results of biodistance analyses using craniometrics and cranial nonmetrics have been compared qualitatively since the latter was introduced to anthropologists in the 1960s. Recent quantitative analyses determined that these two phenotypic datasets remain useful in scenarios where DNA is unrecoverable and that they both successfully model the underlying biological relationships among groups. The quantitative comparisons presented here support this finding.

The present study is also the first to consider all three medieval cemeteries on Mis Island by including the cemetery surrounding the Late Medieval church. This third cemetery appeared similar to the other Mis Island cemeteries and did not seem to represent an especially diverse or foreign population of refugees or religious. The results from analyses of the two Kulubnarti cemeteries provide evidence that these neighboring populations differed biologically in addition to experiencing different levels of stress during life. Little other settlement archaeology or bioarchaeological research has been published on Upper Nubia, especially in the Medieval Period. Overall, the results of this dissertation contribute to an understanding of how medieval communities in Upper Nubia were organized, including a comparison of multiple sites from throughout the Middle Nile.

APPENDICES

APPENDIX 1: DESCRIPTIONS AND THRESHOLDS OF NONMETRIC TRAITS OF THE SKULL

Table 1A. Trait names, descriptions, and presence thresholds used in this research are presented here. Please note that in some cases, descriptions presented by Hauser and De Stefano (1989) and Buikstra and Ubelaker (1994) supplement the original trait definitions.

Trait Name	Description	Presence threshold
aperture in floor of acoustic meatus (AAM)	AKA apertures in the floor of the acoustic meatus, Foramen of Huschke, or tympanic dehiscence. "The floor of the external acoustic meatus is formed by the tympanic plate, whose lateral free margin is of an irregular dentate shape. Very rarely there may be complete absence of the tympanic plate. More frequently occurs a dehiscence in the medial third which may vary from pinhole-size apertures to large defects" (Hauser and De Stefano, 1989, p. 143).	At least pinhole sized apertures (Dodo, 1974)
auditory torus (AUT)	"In new observations used here, an identification of an auditory exostosis was made when a discrete, narrowly based hyperostotic lesion occurred anywhere in the external auditory canal" (Kennedy, 1986, p. 407).	Any expression from weak to strong (Nikita, 2010)
coronal ossicle(s) (COO)	"There may occur one or more ossicles at bregma (fontanelle bones) and in the coronal suture" (Hauser and De Stefano, 1989, p. 84).	If observable irrespective of position, size, or number (Nikita, 2010)
divided infraorbital foramen (DIF)	"The infraorbital foramen is situated on the external anterior surface of the maxilla below the infraorbital margin above the canine fossa... There is usually a single infraorbital foramen but there may be several (1-5), and they may also vary in size, form and position" (Hauser and De Stefano, 1989, p. 70).	Only complete bridging (Nikita, 2010)
divided mental foramen (DMF)	"The [mental] foramen my … be double or multiple with varying distances between the apertures, and in rare instances may even be absent… In most cases of multiple foramina these are not of equal size, they may be situated vertically one above the other, horizontally side by side or diagonally to each other" (Hauser and De Stefano, 1989, p. 230).	Only complete division (Nikita, 2010)
divided occipital condyle (DOC)	"This [occipital condylar] surface is an articular surface, which in the living is covered by cartilage, and is smooth, but it may be divided partially or completely into an antero-medial and a postero-lateral half. The two parts are of approximately equal size and the dividing area generally separating them is characterized by a rough surface at a deeper level and by sharp edges separating it from the smooth articular surface" (Hauser and De Stefano, 1989, pp. 116–117).	If a deep furrow cutting into the facet from both sides could be seen, even if it did not completely separate the condyle (Hauser and De Stefano, 1989)

Table 1A (cont'd). Trait names, descriptions, and presence thresholds used in this research are presented here. Please note that in some cases, descriptions presented by Hauser and De Stefano (1989) and Buikstra and Ubelaker (1994) supplement the original trait definitions.

Trait Name	Description	Presence threshold
divided parietal bone (DPB)	"The parietal bone may be completely or incompletely divided by one or more accessory sutures... According to Hrdliçka (1903) such conditions are extremely rare. Division of the bone may result either from a horizontal suture (connecting the lambdoid and the coronal sutures) or a vertical one (between the sagittal and the squamous sutures). But also oblique accessory sutures in the area of the bregma, lambda or asterion… are observed" (Hauser and De Stefano, 1989, pp. 192–193).	If observable for more than 1 cm (Nikita, 2010)
divided temporal squama (DTS)	AKA partitioned temporal squama. "Very rarely an incomplete or complete, approximately horizontal or still less frequently vertical suture may divide the temporal squama partially or completely…" (Hauser and De Stefano, 1989, p. 193).	If observable for more than 5 mm (Nikita, 2010)
epipteric bone (EPI)	"The so-called true and spurious epipteric bones were recorded without any distinction" (Dodo, 1974, p. 34).	If observable irrespective of size, type of articulation with neighboring bones, or number (Nikita, 2010)
foramen of Vesalius (FVS)	"This is an occasional emissary foramen situated anteromedial to the foramen ovale. Those foramina through which a fine wire could be passed were recorded" (Dodo, 1974, p. 35).	Only complete divisions (Nikita, 2010)
foramen ovale incomplete (FOV)	"…Recorded as present was only the foramen ovale communicating the with the foramen spinosum. The communication through only a suture-like gap was neglected" (Dodo, 1974, p. 34).	Any communication except for a suture-like gap (Dodo, 1974)
foramen spinosum incomplete (FSP)	"But also the distances between [the foramen ovale and the foramen spinosum] and the spheno-petrous fissure vary. The separating wall may be well expressed or be dehiscent to varying degrees or may even not be present at all. If the last occurs either one or both foramina are represented by one or two notches in the margin of the greater wing" (Hauser and De Stefano, 1989, p. 151).	Any degree of opening to the spheno-petrous fissure (Hauser and De Stefano, 1989)
hypoglossal canal bridging (HCB)	"Only completely divided canals were recorded" (Dodo, 1974, p. 34).	Only complete division (Dodo, 1974)

Table 1A (cont'd). Trait names, descriptions, and presence thresholds used in this research are presented here. Please note that in some cases, descriptions presented by Hauser and De Stefano (1989) and Buikstra and Ubelaker (1994) supplement the original trait definitions.

Trait Name	Description	Presence threshold
lambdoid ossicle(s) (LDO)	"The ossicles were recorded without making distinction between wormians and preinterparietals. Ossa extending beyond the medial one-third of the lambdoid suture were regarded as interparietals and excluded from this category" (Dodo, 1974, p. 35).	If observable irrespective of position, size, or number (Nikita, 2010)
lesser palatine foramen multiple (LPF)	"Immediately medial to each of the [most posterior part of the alveolar processes of the maxillae] is situated one major palatine foramen. In the area behind it the horizontal palatine lamina continues with the postero-laterally directed pyramidal process of the palatine bone. In this area one or more lesser palatine foramina are observed. Absence of lesser palatine foramina has not been reported so far" (Hauser and De Stefano, 1989, p. 163).	If observable irrespective of position, size, shape, or number (Nikita, 2010)
mandibular torus (MNT)	"…a lingually (medially) directed bony protuberance of varying size, shape and extent on the lingual surface of the mandible below its free alveolar margin, centred [sic] approximately over the root of the second premolar. Projected to the external surface his would correspond approximately to the position of the mental foramen. The mandibular torus usually appears bilaterally in the form of a swelling of varying size, or a series of swellings (tubercular type) and consists entirely of compact bone... The surface of the mandibular torus is generally rather rounded and regularly shaped, only its superior margin tending to be irregular" (Hauser and De Stefano, 1989, p. 182).	Any expression from weak to strong; "Weak tori recognized only by palpation were excluded" (Dodo, 1974, p. 34)
marginal tubercle (MAR)	"The temporal border of the frontal process of the zygomatic bone frequently shows a tubercle or projection of varying size and shape. This tubercle is situated below the frontozygomatic suture and may be felt in the living through the skin " (Hauser and De Stefano, 1989, p. 226).	If projecting for more than 4 mm (Nikita, 2010)
maxillary torus (MXT)	"…Irregular bony nodules of varying sizes or a mound-like thickening of the lingual margin of the alveolar process in the molar area of the maxilla. Kajeva (1912) reported that these protrusions may also involve the buccal side of the molars, resulting in such a hypertrophy of the alveolar margin that it gives the impression that the molars had been implanted into a sort of plastic mass which had then yielded to masticatory pressure… In rare cases the bony overgrowth may extend to the second premolar, or very exceptionally as far as the canine…" (Hauser and De Stefano, 1989, p. 180).	Any expression from weak to strong (Nikita, 2010)

Table 1A (cont'd). Trait names, descriptions, and presence thresholds used in this research are presented here. Please note that in some cases, descriptions presented by Hauser and De Stefano (1989) and Buikstra and Ubelaker (1994) supplement the original trait definitions.

Trait Name	Description	Presence threshold
metopic fissure (MFS)	"Remnants of [the metopic fontanelle], mostly in the form of short irregular, transverse, V- or W- shaped sutures or fissures, rarely fontanelle bones, may occur also in the adult… According to Fischer (1902) in the majority of cases the trait is located between 17 mm and 22.2 mm above the nasion and always below the tubera frontalia" (Hauser and De Stefano, 1989, pp. 46–47).	Present in any of its variables (Hauser and De Stefano, 1989)
metopic suture (MET)	"When observed from the anterior aspect the metopic suture passed downwards from the bregma to the nasion. It may persist either partially or totally" (Hauser and De Stefano, 1989, p. 41).	Present along more than half of the frontal arc (Dodo, 1974)
mylohyoid bridging (MHB)	"This variation includes two kinds of bony bridging of the mylohyoid groove – the one (proximal type) is a bridging by posterior extension of the lingual resulting from ossification of the spheno-mandibular ligament, and the other (distal type) is a simple mid-way bridging formed by partial ossification of the periosteum lying over the groove…" (Dodo, 1974, p. 34).	If osseous bridge observable irrespective of location and degree of expression (Dodo, 1974)
occipitomastoid wormian(s) (OMW)	"Both asterionic bone and occipito-mastoid wormians were included in this category. Since there often existed both of them in the same occipito-mastoid suture, it seemed reasonable to deal with them as a single trait" (Dodo, 1974, p. 35).	If observable irrespective of exact position, size, or number (Dodo, 1974)
ossicle(s) at asterion (ASO)	"The asterion is defined as the external point of junction of the parieto-mastoid, occipito-mastoid and the lambdoid sutures… If one or more ossicles are present at this point they are named ossicles at asterion" (Hauser and De Stefano, 1989, p. 196).	If observable irrespective of predominant position, size, shape, or number (Ossenberg, 1969)
palatine torus (PLT)	"The term palatine torus describes a paramedian, rarely median, bony protuberance of varying size, form and extent, which is situated along the median suture of the hard palate. It may extend anteriorly to the incisive foramen (rarely to both sides of it) and posteriorly to the posterior border of the palate bones." (Hauser and De Stefano, 1989, p. 175).	Any expression from weak to strong (Nikita, 2010)
parietal foramen (PAF)	"One or two, rarely more… pierce the parietal bone near or in the sagittal suture in the obelion area (about 3.5 cm in front of the lambda) in the juvenile and adult skull… They may vary in position and size as well as in number… The foramen may pierce only the outer or inner table ending in the diploe" (Hauser and De Stefano, 1989, p. 78).	If observable irrespective of position, size, or number (Nikita, 2010)

Table 1A (cont'd). Trait names, descriptions, and presence thresholds used in this research are presented here. Please note that in some cases, descriptions presented by Hauser and De Stefano (1989) and Buikstra and Ubelaker (1994) supplement the original trait definitions.

Trait Name	Description	Presence threshold
parietal notch bone (PNB)	"Any ossicle at the parietal notch was recorded" (Dodo, 1974, p. 35).	If observable irrespective of predominant position, size, or number (Dodo, 1974)
posterior ethmoidal foramen absent (PEF)	"At the line of junction with the medial edge of the orbital plate of the frontal bone (which forms the roof of the orbital cavity) there are generally two foramina. These foramina may interrupt the suture between these two bones but may also be situated exsutural in the orbital plate of the frontal bone only" (Hauser and De Stefano, 1989, p. 58).	If the posterior foramen is absent (Nikita, 2010)
pterygo-alar bridge (PAB)	"Bony bridge due to fusion of lateral lamina between lateral pterygoid plate of sphenoid and anterior foramen spinosum/ medial foramen ovale" (Buikstra and Ubelaker, 1994, p. 90). "May occur lateral to the foramen ovale if the lateral lamina and the inferior surface of the grater wing are connected" (Hauser and De Stefano, 1989, p. 156).	Complete bridging or bridging with only a small fissure (Ossenberg, 1969)
pterygo-spinous bridge (PSB)	"Bony bridge due to fusion of lateral lamina between lateral pterygoid plate of sphenoid and posterior foramen spinosum/ lateral foramen ovale" (Buikstra and Ubelaker, 1994, p. 90). "The downward projecting tip of the spina angularis may protrude to a varying degree, and indeed to such an extent that it forms an osseous bridge with the elongated spine number 1 of the lamina lateralis" (Hauser and De Stefano, 1989, p. 156).	Complete bridging or bridging with only a small fissure (Ossenberg, 1969)
sagittal ossicle(s) (SGO)	"Sutural ossicles in the sagittal suture (sagittal ossicles) are quite rare but may occur also along the whole suture" (Hauser and De Stefano, 1989, p. 85).	If observable irrespective of position, size, or number (Nikita, 2010)
squamous ossicle(s) (SQO)	"Single or multiple squamous ossicles of different sizes and shapes may occur either at one spot only or along the whole suture" (Hauser and De Stefano, 1989, p. 220).	If observable irrespective of size or number (Hauser and De Stefano, 1989)
supranasal suture (SNS)	"In the adult, the supranasal suture consists of bony spicules interlocking with each other from the right and the left sides and leading to transverse elaborate structures after fusion" (Hauser and De Stefano, 1989, p. 44).	If observable irrespective of degree of persistence or shape (Nikita, 2010)

Table 1A (cont'd). Trait names, descriptions, and presence thresholds used in this research are presented here. Please note that in some cases, descriptions presented by Hauser and De Stefano (1989) and Buikstra and Ubelaker (1994) supplement the original trait definitions.

Trait Name	Description	Presence threshold
supraorbital osseous structures (SOS)	"…any foramen in the supraorbital margin opening to the orbital cavity was recorded as *supraorbital foramen*, thus the frontal and supratrochlear foramina being included in this trait" (Dodo, 1974, p. 33). "The supraorbital margin of the orbit... may show either notches or foramina or both in varying positions and numbers and of varying sizes" (Hauser and De Stefano, 1989, p. 51).	No distinction between notches and foramina present if open to the orbital cavity (Dodo, 1974)
symmetrical thinness of parietal bones (STP)	"Its most constant position is just above the temporal ridge and about equidistant from the coronal and lambdoid sutures. The thinness does not extend beyond the temporal ridge, and the parietal foramina when present are not involved… The area concerned is often elliptic with the long axis in fronto-occipital direction, sometimes approximately triangular or of other shapes. The condition is manifest on the external surface of the skull only, the thinness being restricted to the outer table and the diploe" (Hauser and De Stefano, 1989, p. 83).	When ranging from slight flattening to a saucer-shaped appearance (Hauser and De Stefano, 1989)
trace biasterionic suture (TBS)	AKA Inca bone or sutura mendosa. "Remains longer than 10 mm were recorded as present" (Dodo, 1974, p. 35).	If more than 10 mm of the suture remained (Dodo, 1974)
trace transverse zygomatic suture (TZS)	AKA os japonicum. "The suture dividing the zygomatic bone into two parts may vary in the extent and alignment of division. Both partial and total division are rare and mostly horizontal dividing the bone into an upper larger and a lower smaller part" (Hauser and De Stefano, 1989, p. 222).	If observable for more than 5 mm (Dodo, 1974)
zygomaxillary tubercle (ZYG)	"The maxillary bone articulates bilaterally with the zygomatic bone at the zygomatico-maxillary suture. On the inferior margin of the zygomatic process of the maxillary bone or of the zygomatico-maxillary suture, or of the zygomatic bone, a caudally protruding bony tubercle of varying size and shape may occur" (Hauser and De Stefano, 1989, p. 74).	If projecting for more than 2 mm (Nikita, 2010)

APPENDIX 2: DATA COLLECTION FORM

NONMETRIC TRAITS RECORDING FORM

Site Name ____________________ **Observer** ____________________

Skeleton Number ____________________ **Date** ____________________

TRAIT	R	M	L
Metopic suture			
Metopic fissure			
Supranasal suture			
Supraorbital structures			
Posterior ethmoidal f. absent			
Divided infraorbital f.			
Zygomaxillary tubercle			
Marginal tubercle			
Trace trans. zygomatic suture			
Epipteric bone			
Coronal ossicles			
Sagittal ossicles			
Parietal f.			
Trace biasterionic suture			
Lambdoid ossicles			
Parietal notch bone			
Ossicle at asterion			
Occipitomastoid wormians			
Squamous ossicles			
Auditory torus			

TRAIT	R	M	L
Divided temporal squama			
Divided parietal bone			
Parietal thinness			
Inferior			
Divided occipital condyles			
Hypoglossal canal bridging			
Tympanic dehiscence			
F. ovale incomplete			
F. spinosum incomplete			
F. of Vesalius			
Pterygo-spinous bridge			
Pterygo-alar bridge			
Lesser palatine f. multiple			
Palatine torus			
Maxillary torus			
Mandible			
Mylohyoid bridging			
Mandibular torus			
Divided mental f.			

ALL TRAITS

0 = absent *1 = present* *9 = unobservable*

LITERATURE CITED

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Acsádi, G., Nemeskéri, J., 1970. History of Human Life Span and Mortality. Akadémiai Kiadó, Budapest.

Adam, L., 1947. Virilocal and uxorilocal. Am. Anthropol. 49, 678–678.

Adams, W.Y., 2011. Kulubnarti I: The Architectural Remains. Archaeopress, Oxford, England.

Adams, W.Y., 2001. Meinarti II: The Early and Classic Christian Phases. Archaeopress, Oxford, England.

Adams, W.Y., 2000. Meinarti I: The Late Meroitic, Ballaña and Transitional Occupation. Archaeopress, Oxford, England.

Adams, W.Y., 1998. Toward a comparative study of Christian Nubian burial practice. Archeol. Nil Moyen 8, 13–41.

Adams, William Y, 1994. Kulubnarti I: The Architectural Remains. Program for Cultural Resource Assessment, University of Kentucky, Lexington, KY.

Adams, W. Y., 1994. Castle-houses of late medieval Nubia. Archéologie Nil Moyen 6, 11–46.

Adams, W.Y., 1991. The united kingdom of Makouria and Nobadia: A medieval Nubian anomaly, in: Davies, W.V. (Ed.), Egypt and Africa: Nubia from Prehistory to Islam. British Museum Press, London.

Adams, W.Y., 1977. Nubia: Corridor to Africa. Princeton University Press, Princeton, N.J.

Adams, W.Y., 1974. Sacred and secular polities in ancient Nubia. World Archaeol. 6, 39–51. https://doi.org/10.2307/124177

Adams, W.Y., 1966. Post-Pharaonic Nubia in the light of archaeology. III. J. Egypt. Archaeol. 147–162. https://doi.org/10.2307/3855828

Adams, W.Y., 1965. Post-Pharaonic Nubia in the light of archaeology. II. J. Egypt. Archaeol. 160–178. https://doi.org/10.2307/3855629

Adams, W.Y., 1964. Post-Pharaonic Nubia in the light of archaeology. I. J. Egypt. Archaeol. 50, 102–120. https://doi.org/10.2307/3855744

Adams, W.Y., Adams, N.K., 1998. Kulubnarti II: The Artifactual Remains. SARS, London.

Adams, W.Y., Adams, N.K., Van Gerven, D.P., Greene, D.L., 1999. Kulubnarti III: The Cemeteries, BAR International Series. Archaeopress, Oxford, England.

Ahmed, K.A., 1984. Meroitic Settlement in the Central Sudan: An Analysis of Sites in the Nile Valley and the Western Butana. B.A.R., Oxford, England.

Ahmed, S.M., 2014a. An introduction to the Merowe Dam Archaeological Salvage Project (MDASP), in: Anderson, J.R., Welsby, D.A. (Eds.), The Fourth Cataract and Beyond: Proceedings of the 12th International Conference for Nubian Studies. Peeters, Leuven, pp. 5–8.

Ahmed, S.M., 2014b. Kushites at the fourth cataract, in: Anderson, J.R., Welsby, D.A. (Eds.), The Fourth Cataract and Beyond: Proceedings of the 12th International Conference for Nubian Studies. Peeters, Leuven, pp. 111–118.

Ahmed, S.M., 2003. Merowe Dam Archaeological Salvage Project (MDASP). Sudan Nubia 7, 11–14.

Alt, K.W., Vach, W., 1991. The reconstruction of "genetic kinship" in prehistoric burial complexes—problems and statistics, in: Bock, H., Ihm, P. (Eds.), Classification, Data Analysis, and Knowledge Organization. Springer, pp. 299–310.

Anderson, J.R., Welsby, D.A. (Eds.), 2014. The Fourth Cataract and Beyond: Proceedings of the 12th International Conference for Nubian Studies. Peeters, Leuven.

Anthony, D.W., 1990. Migration in archeology: the baby and the bathwater. Am. Anthropol. 92, 895–914.

Azim, M., 1975. Quatre campagnes de fouilles sur la forteresse de Saï, 1970-1973. 1ère partie: L'installation pharaonique. Cah. Rech. Inst. Papyrol. DÉgyptologie Lille 3, 91–125.

Baadsgaard, A., Boutin, A.T., Buikstra, J.E., 2012. Breathing New Life into the Evidence of Death: Contemporary Approaches to Bioarchaeology. School for Advanced Research Press, Santa Fe, N.M.

Baker, B.J., 2016. Biocultural investigations of ancient Nubia, in: Zuckerman, M.K., Martin, D.L. (Eds.), New Directions in Biocultural Anthropology. John Wiley & Sons, Hoboken, NJ, pp. 181–200.

Berry, A.C., Berry, R.J., 1967. Epigenetic variation in the human cranium. J. Anat. 101, 361–379.

Berry, R.J., 1969. Non-metrical skull variation in two Scottish colonies of the Grey seal. J. Zool. 157, 11–18. https://doi.org/10.1111/j.1469-7998.1969.tb01685.x

Binder, M., 2014. Cultural traditions and transitions during the New Kingdom colonial period and Its aftermath: Recent discoveries from the cemeteries of Amara West, in: Anderson, J.R., Welsby, D.A. (Eds.), The Fourth Cataract and Beyond: Proceedings of the 12th International Conference for Nubian Studies. Peeters, Leuven, pp. 487–506.

Birkby, W.H., 1982. Biosocial interpretations from cranial nonmetric traits of Grasshopper Pueblo skeletal remains, in: Longacre, W.A., Holbrook, S.J., Graves, M.W., Agenbroad, L.D. (Eds.), Multidisciplinary Research at Grasshopper Pueblo, Arizona, Anthropological Papers of the University of Arizona. University of Arizona Press, Tucson, pp. 36–41.

Bonnet, C., 2014. Forty years research on Kerma cultures, in: Anderson, J.R., Welsby, D.A. (Eds.), The Fourth Cataract and Beyond: Proceedings of the 12th International Conference for Nubian Studies. Peeters, Leuven, pp. 81–94.

Borcowski, Z., Welsby, D.A., 2012. The Merowe Dam Archaeological Salvage Project: Provisional Type Series of Monuments. MDASP Type Series.

Brooks, S., Suchey, J., 1990. Skeletal age determination based on the os pubis: A comparison of the Acsádi-Nemeskéri and Suchey-Brooks methods. Hum. Evol. 5, 227–238. https://doi.org/10.1007/BF02437238

Brothwell, D.R. (Ed.), 1963. Dental Anthropology. Pergamon, New York.

Buikstra, J.E., 2006. Preface, in: Buikstra, J.E., Beck, L.A. (Eds.), Bioarchaeology: The Contextual Analysis of Human Remains. Academic Press, New York, pp. xvii–xx.

Buikstra, J.E., Beck, L.A., 2006. Bioarchaeology: The Contextual Analysis of Human Remains. Academic Press, New York.

Buikstra, J.E., Frankenberg, S.R., Konigsberg, L.W., 1990. Skeletal biological distance studies in American physical anthropology: Recent trends. Am. J. Phys. Anthropol. 82, 1–7. https://doi.org/10.1002/ajpa.1330820102

Buikstra, J.E., Ubelaker, D.H., 1994. Standards for Data Collection from Human Skeletal Remains: Proceedings of a Seminar at the Field Museum of Natural History, Organized by Jonathan Haas, Arkansas Archaeological Survey Research Series. Arkansas Archeological Survey, Fayetteville, Arkansas.

Burmeister, S., 2000. Archaeology and migration: Approaches to an archaeological proof of migration. Curr. Anthropol. 41, 539–567. https://doi.org/10.1086/317383

Burstein, S.M., 2009. Ancient African civilizations: Kush and Axum. Markus Wiener Publishers, Princeton, N.J.

Buzon, M.R., 2008. A bioarchaeological perspective on Egyptian colonialism in Nubia during the New Kingdom. J. Egypt. Archaeol. 94, 165–181.

Buzon, M.R., 2006. Biological and ethnic identity in New Kingdom Nubia: A case study from Tombos. Curr. Anthropol. 47, 683–695. https://doi.org/10.1086/506288

Buzon, M.R., Bowen, G.J., 2010. Oxygen and carbon isotope analysis of human tooth enamel from the New Kingdom site of Tombos in Nubia. Archaeometry 52, 855–868. https://doi.org/10.1111/j.1475-4754.2009.00503.x

Buzon, M.R., Judd, M.A., 2008. Investigating health at Kerma: Sacrificial versus nonsacrificial individuals. Am. J. Phys. Anthropol. 136, 93–99.

Buzon, M.R., Richman, R., 2007. Traumatic injuries and imperialism: the effects of Egyptian colonial strategies at Tombos in Upper Nubia. Am. J. Phys. Anthropol. 133, 783–791.

Buzon, M.R., Simonetti, A., 2013. Strontium isotope (87Sr/86Sr) variability in the Nile Valley: identifying residential mobility during ancient Egyptian and Nubian sociopolitical changes in the New Kingdom and Napatan periods. Am. J. Phys. Anthropol. 151, 1–9.

Buzon, M.R., Simonetti, A., Creaser, R.A., 2007. Migration in the Nile Valley during the New Kingdom period: a preliminary strontium isotope study. J. Archaeol. Sci. 34, 1391–1401. https://doi.org/10.1016/j.jas.2006.10.029

Byrt, T., Bishop, J., Carlin, J.B., 1993. Bias, prevalence and kappa. J. Clin. Epidemiol. 46, 423–429. https://doi.org/10.1016/0895-4356(93)90018-V

Cadien, J.D., Harris, E.F., Jones, W.P., Mandarino, L.J., 1974. Biological lineages, skeletal populations, and microevolution. Yearb. Phys. Anthropol. 18, 194–201.

Canuto, M.-A., Yaeger, J., 2003. Archaeology of Communities: A New World Perspective. Routledge, London.

Carson, E.A., 2006a. Maximum likelihood estimation of human craniometric heritabilities. Am. J. Phys. Anthropol. 131, 169–180.

Carson, E.A., 2006b. Maximum-likelihood variance components analysis of heritabilities of cranial nonmetric traits. Hum. Biol. 78, 383–402.

Cheverud, J.M., Buikstra, J.E., 1982. Quantitative genetics of skeletal nonmetric traits in the rhesus macaques of Cayo Santiago. III. Relative heritability of skeletal nonmetric and metric traits. Am. J. Phys. Anthropol. 59, 151–155. https://doi.org/10.1002/ajpa.1330590205

Cheverud, J.M., Buikstra, J.E., 1981a. Quantitative genetics of skeletal nonmetric traits in the rhesus macaques on Cayo Santiago. I. Single trait heritabilities. Am. J. Phys. Anthropol. 54, 43–49.

Cheverud, J.M., Buikstra, J.E., 1981b. Quantitative genetics of skeletal nonmetric traits in the rhesus macaques on Cayo Santiago. II. Phenotypic, genetic, and environmental correlations between traits. Am. J. Phys. Anthropol. 54, 51–58. https://doi.org/10.1002/ajpa.1330540107

Cohen, J., 1960. A coefficient of agreement for nominal scales. Educ. Psychol. Meas. 20, 37–46.

Corruccini, R.S., 1976. The interaction between nonmetric and metric cranial variation. Am. J. Phys. Anthropol. 44, 285–293. https://doi.org/10.1002/ajpa.1330440211

Corruccini, R.S., 1974. An examination of the meaning of cranial discrete traits for human skeletal biological studies. Am. J. Phys. Anthropol. 40, 425–445. https://doi.org/10.1002/ajpa.1330400315

Dann, R.J., 2009. The Archaeology of Late Antique Sudan: Aesthetics and Identity in the Royal X-Group Tombs at Qustul and Ballana. Cambria Press.

de Voogt, A., Döhla, H.-J., 2011. Nubian graffiti messages and the history of writing in the Sudanese Nile basin. Idea Writ. Writ. Bord. 2, 53.

Dixon, D.M., 1964. The Origin of the Kingdom of Kush (Napata-Meroë). J. Egypt. Archaeol. 50, 121–132. https://doi.org/10.2307/3855745

Dodo, Y., 1974. Non-Metrical cranial traits in the Hokkaido Ainu and the Northern Japanese of recent times. J. Anthropol. Soc. Nippon J. Anthropol. Soc. Nippon 82, 31–51.

Doyen, F., 2009. The New Kingdom town on Sai Island (northern Sudan). Sudan Nubia 13, 17–20.

Dudar, J.C., 1993. Identification of rib number and assessment of intercostal variation at the sternal rib end. J. Forensic Sci. 38, 788–788.

Edwards, D.N., 2014. Medieval Nobadia, in: Anderson, J.R., Welsby, D.A. (Eds.), The Fourth Cataract and Beyond: Proceedings of the 12th International Conference for Nubian Studies. Peeters, Leuven, pp. 171–182.

Edwards, D.N., 2007. The archaeology of Sudan and Nubia. Annu. Rev. Anthropol. 36, 211–228. https://doi.org/10.1146/annurev.anthro.36.081406.094305

Edwards, D.N., 2004a. History, archaeology and Nubian identities in the Middle Nile, in: Reid, A.M., Lane, P.J. (Eds.), African Historical Archaeologies, Contributions to Global Historical Archaeology. Springer US, pp. 33–58.

Edwards, D.N., 2004b. Kerma and Bronze Age Kush, in: The Nubian Past: An Archaeology of the Sudan. Routledge, London, pp. 75–111.

Edwards, D.N., 2004c. Meroitic Kush (c. 300 BC-AD 350), in: The Nubian Past: An Archaeology of the Sudan. Routledge, London, pp. 141–181.

Edwards, D.N., 2004d. The Kushite revival: the XXVth Dynasty and the kingdom of Napata, in: The Nubian Past: An Archaeology of the Sudan. Routledge, London, pp. 112–140.

Edwards, D.N., 2004e. The Nubian Past: An Archaeology of the Sudan. Routledge, London.

Edwards, D.N., 2004f. Post-Meroitic transitions (c. AD 350-550), in: The Nubian Past: An Archaeology of the Sudan. Routledge, London, pp. 182–211.

Edwards, D.N., 2004g. Medieval Nubia (c. AD 500-1500), in: The Nubian Past: An Archaeology of the Sudan. Routledge, London, pp. 212–255.

Edwards, D.N., 2001. The Christianisation of Nubia: Some archaeological pointers. Sudan Nubia 5, 89–96.

Edwards, D.N., 1998. Gabati: A Meroitic, Post-Meroitic and Medieval Cemetery in Central Sudan, BAR International Series. Archaeopress, Oxford, England.

Edwards, D.N., 1996a. Sorghum, Beer and Kushite society. Nor. Archaeol. Rev. 29, 65–77. https://doi.org/10.1080/00293652.1996.9965599

Edwards, D.N., 1996b. The Archaeology of the Meroitic State: New Perspectives on its Social and Political Organisation. Tempus Reparatum: Distributed by Hadrian Books, Oxford.

Edwards, D.N., 1994. Post-Meroitic ('X-Group') and Christian burials at Sesebi, Sudanese Nubia. J. Egypt. Archaeol. 80, 159–178.

Edwards, D.N., Judd, M.A., 2012. Gabati revisited, in: Gabati: a Meroitic, Post-Meroitic and Medieval Cemetery in Central Sudan, BAR International Series. Sudan Archaeological Research Society, London, pp. 75–83.

el-Tayeb, M., 2010. The post-Meroitic from Kirwan to the present. Sudan Nubia 14, 2–14.

Emberling, G., 2012. Archaeological salvage in the fourth cataract, northern Sudan (1991-2008), in: Fisher, M.M., Lacovara, P., Ikram, S., D'Auria, S. (Eds.), Ancient Nubia: African Kingdoms on the Nile. American University in Cairo Press, Cairo, pp. 71–77.

Emery, W.B., 1948. Nubian Treasure: An Account of the Discoveries at Ballana and Qustul. Methuen, London.

Emery, W.B., Kirwan, L.P., 1935. Mission Archeologique de Nubie, 1929-1934: The Excavations and Survey Between Wadi Es-Sebua and Adindan, 1929-1931. Government Press.

Ensor, B.E., 2013. The archaeology of kinship: Advancing interpretation and contributions to theory. The University of Arizona Press, Tucson.

Ensor, B.E., 2011. Kinship theory in archaeology: From critiques to the study of transformations. Am. Antiq. 76, 203–227.

Fage, J.., Oliver, R., 1978. The Cambridge History of Africa Vol. 2, From c. 500 BC to AD 1050. Cambridge University Press, Cambridge.

Fairman, H.W., 1948. Preliminary report on the excavations at Amarah West, Anglo-Egyptian Sudan, 1947-8. J. Egypt. Archaeol. 34, 3–11.

Fairman, H.W., 1939. Preliminary report on the excavations at Amārah West, Anglo-Egyptian Sudan, 1938-9. J. Egypt. Archaeol. 139–144.

Fairman, H.W., 1938. Preliminary report on the excavations at Sesebi (Sudla) and'Amārah West, Anglo-Egyptian Sudan, 1937-8. J. Egypt. Archaeol. 151–156.

Falconer, D.S., 1967. The inheritance of liability to diseases with variable age of onset, with particular reference to diabetes mellitus. Ann. Hum. Genet. 31, 1–20.

Falconer, D.S., 1965. The inheritance of liability to certain diseases, estimated from the incidence among relatives. Ann. Hum. Genet. 29, 51–76.

Falconer, D.S., 1960. Introduction to Quantitative Genetics. Oliver and Boyd, London.

Fauvelle-Aymar, F.-X., 2013. Desperately seeking the Jewish Kingdom of Ethiopia: Benjamin of Tudela and the horn of Africa (Twelfth century). Speculum 88, 383–404. https://doi.org/10.1017/S0038713413000857

Felsenstein, J., 1985. Confidence limits on phylogenies: an approach using the bootstrap. Evolution 783–791.

Finnegan, M., 1978. Non-metric variation of the infracranial skeleton. J. Anat. 125, 23–37.

Fuller, D.Q., 2004. Early Kushite agriculture: Archaeobotanical evidence from Kawa. Sudan Nubia Bull. 8, 70–74.

Fuller, D.Q., 1997. The confluence of history and archaeology in Lower Nubia: Scales of continuity and change. Archaeol. Rev. Camb. 14, 105–128.

Galili, T., 2015. dendextend: an R package for visualizing, adjusting, and comparing trees of hierarchical clustering. Bioinformatics. https://doi.org/DOI: 10.1093/bioinformatics/btv428

Gamer, M., Lemon, J., Puspendra Singh, I.F., 2012. irr: Various Coefficients of Interrater Reliability and Agreement. R package version 0.84.

Garstang, J., 1913. Third Interim Report on the Excavations at Meroe in Ethiopia.

Garstang, J., 1912. Second Interim Report on the Excavations at Meroë in Ethiopia.

Garstang, J., 1910. Preliminary Note on an Expedition to Meroe in Ethiopia.

Garstang, J., George, W.S., 1914. Fourth Interim Report on the Excavations at Meroe in Ethiopia.

Garstang, J., Griffith, F.L., 1911. Meroë, the City of the Ethiopians: Being an Account of a First Season's Excavations on the Site, 1909-1910. Clarendon press.

Geus, F., 1995. Archaeology and history of Sai Island. Sudan Archaeol. Res. Soc. Newsl. 8, 27–34.

Ginns, A., 2010a. The cemetery associated with the church at 3-J-18. Sudan Archaeol. Res. Soc. Draft publications.

Ginns, A., 2010b. Medieval cemetery 3-J-11. Sudan Archaeol. Res. Soc. Draft publications.

Ginns, A., 2010c. Medieval cemetery 3-J-10. Sudan Archaeol. Res. Soc. Draft publications.

Ginns, A., 2010d. Church 3-J-18. Sudan Archaeol. Res. Soc. Draft publications.

Ginns, A., 2010e. Medieval cemetery 3-J-20. Sudan Archaeol. Res. Soc. Draft publications.

Ginns, A., 2010f. Medieval settlement 3-J-19. Sudan Archaeol. Res. Soc. Draft publications.

Ginns, A., 2007. Preliminary report on the second season of excavations conducted on Mis Island (AKSC). Sudan Nubia 11, 20–25.

Ginns, A., 2006. Preliminary report on the excavations conducted on Mis Island (AKSC), 2005-2006. Sudan Nubia 10, 13–19.

Gissema, K.H., 2014. The Merowe Dam Salvage Archaeological Project (Sudan), in: Anderson, J.R., Welsby, D.A. (Eds.), The Fourth Cataract and Beyond: Proceedings of the 12th International Conference for Nubian Studies. Peeters, Leuven, pp. 1049–1056.

Godde, K., 2013. An Examination of the Spatial–Temporal Isolation Model in a Nilotic Population: Variation across Space and Time in Nubians Using Cranial Discrete Traits. Int. J. Osteoarchaeol. 23, 324–333. https://doi.org/10.1002/oa.1252

Godde, K., 2012. A fresh perspective on Nubian population structure: a population genetics approach using cranial discrete traits in Mesolithic – C-Group Nubians. South Afr. Archaeol. Bull. 67, 44–51.

Godde, K., 2009a. An examination of Nubian and Egyptian biological distances: Support for biological diffusion or in situ development? HOMO - J. Comp. Hum. Biol. 60, 389–404. https://doi.org/10.1016/j.jchb.2009.08.003

Godde, K., 2009b. Population Structure of Lower Nubia In the Mesolithic-Christian Groups (Ph.D., Anthropology). University of Tennessee, Knoxville, United States -- Tennessee.

Godlewski, W., 2014. The kingdom of Makuria, in: Anderson, J.R., Welsby, D.A. (Eds.), The Fourth Cataract and Beyond: Proceedings of the 12th International Conference for Nubian Studies. Peeters, Leuven, pp. 155–170.

Gower, J.C., 1971. A general coefficient of similarity and some of its properties. Biometrics 857–871.

Gower, J.C., 1966. Some distance properties of latent root and vector methods used in multivariate analysis. Biometrika 53, 325–338.

Green, E., 1976. Social organization, in: Hunter, D. (Ed.), Encyclopedia of Anthropology. Harper and Row, New York, p. 358.

Greene, D.L., 1982. Discrete dental variations and biological distances of Nubian populations. Am. J. Phys. Anthropol. 58, 75–79. https://doi.org/10.1002/ajpa.1330580109

Grewal, M., 1962. The development of an inherited tooth defect on the mouse. J. Embryol. Exp. Morphol. 10, 202–211.

Griffith, F.L., 1911. Karanòg: the Meroitic Inscriptions of Shablûl and Karanòg, Eckley B. Coxe Junior Expedition to Nubia. University Museum, Philadelphia.

Grüneberg, H., 1963. The Pathology of Development: A Study of Inherited Skeletal Disorders in Animals. Blackwell, Oxford.

Grüneberg, H., 1955. Genetical studies on the skeleton of the mouse XV. Relations between major and minor variants. J. Genet. 53, 515–533.

Grüneberg, H., 1954. Variation within inbred strains of mice 173, 674–676. https://doi.org/10.1038/173674a0

Grüneberg, H., 1952. Genetical studies on the skeleton of the mouse. J. Genet. 51, 95–114. https://doi.org/10.1007/BF02986708

Hafsaas-Tsakos, H., 2011. Ethical implications of salvage archaeology and dam building: The clash between archaeologists and local people in Dar al-Manasir, Sudan. J. Soc. Archaeol. 11, 49–76. https://doi.org/10.1177/1469605310388372

Hallgren, K.A., 2012. Computing inter-rater reliability for observational data: An overview and tutorial. Tutor. Quant. Methods Psychol. 8, 23–34.

Hanihara, T., 2008. Morphological variation of major human populations based on nonmetric dental traits. Am. J. Phys. Anthropol. 136, 169–182. https://doi.org/10.1002/ajpa.20792

Hanihara, T., Ishida, H., 2001a. Frequency variations of discrete cranial traits in major human populations. I. Supernumerary ossicle variations. J. Anat. 198, 689–706. https://doi.org/10.1046/j.1469-7580.2001.19860689.x

Hanihara, T., Ishida, H., 2001b. Frequency variations of discrete cranial traits in major human populations. II. Hypostotic variations. J. Anat. 198, 707–725. https://doi.org/10.1046/j.1469-7580.2001.19860707.x

Hanihara, T., Ishida, H., 2001c. Frequency variations of discrete cranial traits in major human populations. III. Hyperostotic variations. J. Anat. 199, 251–272. https://doi.org/10.1046/j.1469-7580.2001.19930251.x

Hanihara, T., Ishida, H., 2001d. Frequency variations of discrete cranial traits in major human populations. IV. Vessel and nerve related variations. J. Anat. 199, 273–287. https://doi.org/10.1046/j.1469-7580.2001.19930273.x

Hanihara, T., Ishida, H., 2001e. Os incae: variation in frequency in major human population groups. J. Anat. 198, 137–152. https://doi.org/10.1046/j.1469-7580.2001.19820137.x

Hanihara, T., Ishida, H., Dodo, Y., 2003. Characterization of biological diversity through analysis of discrete cranial traits. Am. J. Phys. Anthropol. 121, 241–251.

Hanihara, T., Ishida, H., Dodo, Y., 1998. Os zygomaticum bipartitum: frequency distribution in major human populations. J. Anat. 192, 539–555. https://doi.org/10.1046/j.1469-7580.1998.19240539.x

Hartl, D.L., Clark, A.G., 2007. Population substructure, in: Principles of Populations Genetics. Sinauer Associates, U.S.A, pp. 111–162.

Hasegawa, M., Kishino, H., 1989. Confidence limits of the maximum-likelihood estimate of the hominoid three from mitochondrial-DNA sequences. Evolution 43, 672–677.

Hauser, G., De Stefano, G.F., 1989. Epigenetic Variants of the Human Skull. Schweizerbart, Stuttgart.

Hefner, J.T., 2009. Cranial nonmetric variation and estimating ancestry. J. Forensic Sci. 54, 985–995. https://doi.org/10.1111/j.1556-4029.2009.01118.x

Hefner, J.T., Ousley, S.D., 2014. Statistical classification methods for estimating ancestry using morphoscopic traits. J. Forensic Sci. 59, 883–890.

Hefner, J.T., Pilloud, M.A., Buikstra, J.E., Vogelsberg, C.C., 2016. A brief history of biological distance analysis, in: Pilloud, M.A., Hefner, J.T. (Eds.), Biological Distance Analysis: Forensic and Bioarchaeological Perspectives. Academic Press, Amsterdam, pp. 3–22.

Herrera, B., Hanihara, T., Godde, K., 2014. Comparability of multiple data types from the Bering Strait region: Cranial and dental metrics and nonmetrics, mtDNA, and Y-chromosome DNA. Am. J. Phys. Anthropol. 154, 334–348. https://doi.org/10.1002/ajpa.22513

Hess, R.L., 1965. The itinerary of Benjamin of Tudela: A twelfth-century Jewish description of North-East Africa. J. Afr. Hist. 6, 15–24.

Holsinger, K.E., Weir, B.S., 2009. Genetics in geographically structured populations: defining, estimating and interpreting FST. Nat. Rev. Genet. 10, 639–650.

Howe, W.L., Parsons, P.A., 1967. Genotype and environment in the determination of minor skeletal variants and body weight in mice. J Embryol Exp Morphol 17, 283–92.

Howell, T.L., Kintigh, K.W., 1996. Archaeological identification of kin groups using mortuary and biological data: An example from the American Southwest. Am. Antiq. 61, 537–554.

Howells, W.W., 1973. Cranial Variation in Man: A Study by Multivariate Analysis of Patterns of Difference Among Recent Human Populations. Peabody Museum of American Archaeology and Ethnology, Harvard University, Cambridge (Mass.).

Hubbard, A.R., Guatelli-Steinberg, D., Irish, J.D., 2015. Do nuclear DNA and dental nonmetric data produce similar reconstructions of regional population history? An example from modern coastal Kenya. Am. J. Phys. Anthropol. 157, 295–304.

Hummert, J., 1983. Childhood growth and morbidity in medieval population from Kulubnarti in the Batn el Hajar of Sudanese Nubia.

Hummert, J.R., 1983. Cortical bone growth and dietary stress among subadults from Nubia's Batn El Hajar. Am. J. Phys. Anthropol. 62, 167–176.

Hunt, D.R., Bullen, L., 2007. The frequency of os acromiale in the Robert J. Terry collection. Int. J. Osteoarchaeol. 17, 309–317.

Hurst, C.V., 2013. Growing Up in Medieval Nubia: Health, Disease, and Death of a Medieval Juvenile Sample from Mis Island (Ph.D., Anthropology). Michigan State University, United States -- Michigan.

Irish, J.D., 2016. Alternate methods to assess phenetic affinities and genetic structure among seven South African "Bantu" groups based on dental nonmetric data, in: Pilloud, M.A., Hefner, J.T. (Eds.), Biological Distance Analysis: Forensic and Bioarchaeological Perspectives. Academic Press, Amsterdam, pp. 363–388.

Irish, J.D., 2010. The mean measure of divergence: its utility in model-free and model-bound analyses relative to the Mahalanobis D(2) distance for nonmetric traits. Am. J. Hum. Biol. 22, 378–395. https://doi.org/10.1002/ajhb.21010

Irish, J.D., 2005. Population continuity vs. discontinuity revisited: Dental affinities among late Paleolithic through Christian-era Nubians. Am. J. Phys. Anthropol. 128, 520–535. https://doi.org/10.1002/ajpa.20109

Irish, J.D., Friedman, R., 2010. Dental affinities of the C-group inhabitants of Hierakonpolis, Egypt: Nubian, Egyptian, or both? HOMO - J. Comp. Hum. Biol. 61, 81–101.

Işcan, M.Y., Loth, S.R., Wright, R.K., 1987. Racial variation in the sternal extremity of the rib and its effect on age determination. J. Forensic Sci. 32, 452–466.

Işcan, M.Y., Loth, S.R., Wright, R.K., 1985. Age estimation from the rib by phase analysis: white females. J. Forensic Sci. 30, 853.

Işcan, M.Y., Loth, S.R., Wright, R.K., 1984. Age estimation from the rib by phase analysis: white males. J. Forensic Sci. 29, 1094–1104.

Ishida, H., Dodo, Y., 1997. Cranial variation in prehistoric human skeletal remains from the Marianas. Am. J. Phys. Anthropol. 104, 399–410. https://doi.org/10.1002/(SICI)1096-8644(199711)104:3<399::AID-AJPA9>3.0.CO;2-Q

Jackes, M., 2011. Representativeness and bias in archaeological skeletal samples, in: Agarwal, S.C., Glencross, B.A. (Eds.), Social Bioarchaeology. Wiley-Blackwell, Oxford England, pp. 107–146.

Johnson, A.L., Lovell, N.C., 1995. Dental morphological evidence for biological continuity between the A-group and C-group periods in lower Nubia. Int. J. Osteoarchaeol. 5, 368–376. https://doi.org/10.1002/oa.1390050407

Johnson, K.M., Paul, K.S., 2016. Bioarchaeology and kinship: Integrating theory, social relatedness, and biology in ancient family research. J. Archaeol. Res. 24, 75–123. https://doi.org/10.1007/s10814-015-9086-z

Judd, M., Irish, J., 2009. Dying to serve: The mass burials at Kerma. Antiquity 83, 709–722.

Judd, M.A., 2012. Gabati: a Meroitic, Post-Meroitic and Medieval Cemetery in Central Sudan. Volume 2: the physical anthropology, BAR International Series. Sudan Archaeological Research Society, London.

Judd, M.A., 2006. Continuity of interpersonal violence between Nubian communities. Am. J. Phys. Anthropol. 131, 324–333.

Kakaliouras, A.M., 2017. Theory for a bioarchaeology of community: Potentials, practices, and pitfalls. Archeol. Pap. Am. Anthropol. Assoc. 28, 13–23.

Katz, D., Suchey, J.M., 1986. Age determination of the male os pubis. Am. J. Phys. Anthropol. 69, 427–435.

Kendall, T., 2002. Napatan temples: A case study from Gebel Barkal, in: Paper Delivered at the 10th International Conference for Nubian Studies, Rome.

Kendall, T., 1999a. A response to Laszlo Torok's "Long chronology" of El Kurru, in: Wenig, S. (Ed.), Studien Zum Antiken Sudan: Akten Der 7. Internationalen Tagung Für Meroitische Forschungen Vom 14. Bis 19. September 1992 in Gosen/Bei Berlin, Meroitica. Harrassowitz Verlag, Wiesbaden, pp. 164–175.

Kendall, T., 1999b. The origin of the Napatan state: El Kurru and the evidence for the royal ancestors, in: Wenig, S. (Ed.), Studien Zum Antiken Sudan: Akten Der 7. Internationalen Tagung Für Meroitische Forschungen Vom 14. Bis 19. September 1992 in Gosen/Bei Berlin, Meroitica. Harrassowitz Verlag, Wiesbaden, pp. 3–117.

Kendall, T., 1997. Kings of the sacred mountain: Napata and the Kushite Twenty-Fifth Dynasty of Egypt, in: Wildung, D., Institut du monde arabe (France) (Eds.), Sudan: Ancient Kingdoms of the Nile. Flammarion, Paris, pp. 161–203.

Kendall, T., 1996. Kerma and the Kingdom of Kush, 2500-1500 B.C.: The Archaeological Discovery of an Ancient Nubian Empire. National Museum of African Art, Smithsonian Institution, Washington, D.C.

Kennedy, G.E., 1986. The relationship between auditory exostoses and cold water: a latitudinal analysis. Am. J. Phys. Anthropol. 71, 401–415.

Kirwan, L., 2002. Post-Meroitic Nubia: A reappraisal, in: Kirwan, L., Hägg, T., Török, L., Welsby, D.A. (Eds.), Studies on the History of Late Antique and Christian Nubia. Ashgate Publishing Limited, Aldershot, pp. 1–9.

Kirwan, L., 1987. The birth of Christian Nubia: Some archaeological problems. Rev. Degli Studi Orient. 63, 119–134.

Kirwan, L., Hägg, T., Török, L., Welsby, D.A., 2002. Studies on the History of Late Antique and Christian Nubia. Ashgate/Variorum, Aldershot, Hampshire, Great Britain; Burlington, Vt.

Kirwan, L.P., 1935. Notes on the topography of the Christian Nubian kingdoms. J. Egypt. Archaeol. 21, 57–62. https://doi.org/10.2307/3854492

Kleinitz, C., Näser, C., 2011. The Loss of Innocence: Political and Ethical Dimensions of the Merowe Dam Archaeological Salvage Project at the Fourth Nile Cataract (Sudan). Conserv. Manag. Archaeol. Sites 13, 253–280. https://doi.org/10.1179/175355211X13179154166231

Knudson, K.J., Stojanowski, C.M., 2008. New directions in bioarchaeology: Recent contributions to the study of human social identities. J. Archaeol. Res. 16, 397–432. https://doi.org/10.1007/s10814-008-9024-4

Konigsberg, L.W., 2017. tdistR. University of Illinois, Urbana-Champaign, IL.

Konigsberg, L.W., 2006. A post-Neumann history of biological and genetic distance studies in bioarchaeology, in: Buikstra, J.E., Beck, L.A. (Eds.), Bioarchaeology: The Contextual Analysis of Human Remains. Academic Press, New York, pp. 263–280.

Konigsberg, L.W., 1990. Analysis of prehistoric biological variation under a model of isolation by geographic and temporal distance. Hum. Biol., Special Issue on Quantitative Traits and Population Structure 62, 49–70.

Konigsberg, L.W., 1988. Migration models of prehistoric postmarital residence. Am. J. Phys. Anthropol. 77, 471–482.

Konigsberg, L.W., 1987. Population Genetic Models for Interpreting Prehistoric Intra-Cemetery Biological Variation (Ph.D.). Northwestern University, United States -- Illinois.

Konigsberg, L.W., Frankenberg, S.R., 2016. Postmarital residence analysis, in: Pilloud, M.A., Hefner, J.T. (Eds.), Biological Distance Analysis: Forensic and Bioarchaeological Perspectives. Academic Press, Amsterdam, pp. 335–348.

Konigsberg, L.W., Kohn, L.A.P., Cheverud, J.M., 1993. Cranial deformation and nonmetric trait variation. Am. J. Phys. Anthropol. 90, 35–48. https://doi.org/10.1002/ajpa.1330900103

Kuba, C.L., 2006. Nonmetric traits and the detection of family groups in archaeological remains (Ph.D.). Arizona State University, United States -- Arizona.

Łajtar, A., 2014. A survey of Christian textual finds from Gebel Adda in the collections of the Royal Ontario Museum, Toronto, in: Anderson, J.R., Welsby, D.A. (Eds.), The Fourth Cataract and Beyond: Proceedings of the 12th International Conference for Nubian Studies. Peeters, Leuven, pp. 951–960.

Landis, J.R., Koch, G.G., 1977. The measurement of observer agreement for categorical data. Biometrics 159–174.

Lane, R.A., Sublett, A.J., 1972. Osteology of social organization: Residence pattern. Am. Antiq. 186–201.

Larsen, C.S., 2015. Bioarchaeology: Interpreting Behavior from the Human Skeleton, Second edition. ed, Cambridge studies in biological and evolutionary anthropology. Cambridge University Press, Cambridge.

Ligges, U., Machler, M., 2003. Scatterplot3d - an R package for visualizing multivariate data. J. Stat. Softw. 8, 1–20.

Lohwasser, A., 2001. Queenship in Kush: Status, role and ideology of royal women. J. Am. Res. Cent. Egypt 38, 61–76. https://doi.org/10.2307/40000552

Lovejoy, C.O., Meindl, R.S., Pryzbeck, T.R., Mensforth, R.P., 1985. Chronological metamorphosis of the auricular surface of the ilium: a new method for the determination of adult skeletal age at death. Am. J. Phys. Anthropol. 68, 15–28.

Lozada, M.C., 2012. Cultural determinants of ancestry: A lesson for studies of biological relatedness and ethnicity in the past, in: Baadsgaard, A., Boutin, A.T., Buikstra, J.E. (Eds.), Breathing New Life into the Evidence of Death: Contemporary Approaches to Bioarchaeology. School for Advanced Research Press, Santa Fe, N.M., pp. 135–149.

Maechler, M., Rousseuw, P., Struyf, A., Hubert, M., Hornik, K., 2017. cluster: Cluster Analysis Basics and Extensions. R package version 2.0.6.

Mahalanobis, P.C., 1936. On the generalized distance in statistics. Proc. Natl. Inst. Sci. India 2, 49–55.

Manly, B.F.J., 2007. Randomization, Bootstrap and Monte Carlo Methods in Biology, Third edition. ed, Texts in Statistical Science. Chapman & Hall/ CRC, Boca Raton, FL.

Mantel, N., 1967. The detection of disease clustering and a generalized regression approach. Cancer Res. 27, 209–220.

Meyer, C., Ganslmeier, R., Dresely, V., Alt, K.W., 2012. New approaches to the reconstruction of kinship and social structure based on bioarchaeological analysis of Neolithic multiple and collective graves, in: Kolář, J. (Ed.), Theoretical and Methodological Considerations in Central European Neolithic Archaeology: Proceedings of the “Theory and Method in Archaeology of the Neolithic (7th - 3rd Millennium BC)” Conference Held in Mikulov, Czech Republic, 26th - 28th of October 2010, BAR International Series. Archaeopress, Oxford, England.

Morkot, R., 2000. The Black Pharaohs: Egypt's Nubian Rulers. Rubicon Press, London.

Morkot, R., 1999. The origin of the Napatan state: A contribution to T. Kendall's main paper, in: Wenig, S. (Ed.), Studien Zum Antiken Sudan: Akten Der 7. Internationalen Tagung Für Meroitische Forschungen Vom 14. Bis 19. September 1992 in Gosen/Bei Berlin, Meroitica. Harrassowitz Verlag, Wiesbaden, pp. 139–148.

Morkot, R., 1994. The Nubian Dark Age, in: Études Nubiennes: conférence de Genève: actes du VIIe Congrès international d'études nubiennes, 3-8 septembre 1990, International Conference for Nubian Studies. Charles Bonnet, pp. 45–47.

Morkot, R.G., 1991. The political geography of New Kingdom Nubia, in: Davies, W.V. (Ed.), Egypt and Africa: Nubia from Prehistory to Islam. British Museum Press, London, pp. 294–301.

Nado, K.L., Baker, B.J., 2013. Cranial non-metric affinities and kinship ideologies among Post-Meroitic and Christian period Nubians from the 4th Cataract Region, Sudan., in: American Journal of Physical Anthropology. Wiley-Blackwell, p. 204.

Nikita, E., 2015. A critical review of the mean measure of divergence and Mahalanobis distances using artificial data and new approaches to the estimation of biodistances employing nonmetric traits: Assessing biodistances for nonmetric traits. Am. J. Phys. Anthropol. 157, 284–294. https://doi.org/10.1002/ajpa.22708

Nikita, E., 2010. The Garamantes of Fazzān: Bioarchaeological Evaluation of Desert-Induced Stress and Late Holocene Human Migrations Through the Sahara (Ph.D.). University of Cambridge, Cambridge.

Nikita, E., Mattingly, D., Lahr, M.M., 2012. Sahara: Barrier or corridor? Nonmetric cranial traits and biological affinities of North African Late Holocene populations. Am. J. Phys. Anthropol. 147, 280–292. https://doi.org/10.1002/ajpa.21645

Oksanen, J., Blanchet, F.G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P.R., O'Hara, R.B., Simpson, G.L., Solymos, P., Henry, M., Stevens, H., Szoecs, E., Wagner, H., 2017. vegan: Community Ecology Package. R package version 2.4-2.

Osborne, D.L., Simmons, T.L., Nawrocki, S.P., 2004. Reconsidering the auricular surface as an indicator of age at death. J. Forensic Sci. 49, 1–7.

Ossenberg, Nancy S., 2013. Cranial Nonmetric Trait Database. Nancy S. Ossenberg (producer). Queen's University Library, Data and Government Information Centre (distributor), Kingston, Ontario, Canada.

Ossenberg, Nancy Suzanne, 2013. Brief communication: Cranial nonmetric trait database on the internet. Am. J. Phys. Anthropol. 152, 551–553.

Ossenberg, N.S., 1976. Within and between race distances in population studies based on discrete traits of the human skull. Am. J. Phys. Anthropol. 45, 701–715. https://doi.org/10.1002/ajpa.1330450337

Ossenberg, N.S., 1970. The influence of artificial cranial deformation on discontinuous morphological traits. Am. J. Phys. Anthropol. 33, 357–371. https://doi.org/10.1002/ajpa.1330330310

Ossenberg, N.S., 1969. Discontinuous Morphological Variation in the Human Cranium (Ph.D.). University of Toronto (Canada), Toronto.

Osypiński, P., 2014. Prehistory of the fourth cataract, in: Anderson, J.R., Welsby, D.A. (Eds.), The Fourth Cataract and Beyond: Proceedings of the 12th International Conference for Nubian Studies. Peeters, Leuven, pp. 9–18.

Paner, H., 2014. Kerma culture in the fourth cataract of the Nile, in: Anderson, J.R., Welsby, D.A. (Eds.), The Fourth Cataract and Beyond: Proceedings of the 12th International Conference for Nubian Studies. Peeters, Leuven, pp. 53–80.

Paradis, E., Claude, J., Strimmer, K., 2004. APE: Analyses of Phylogenetics and Evolution in R language. Bioinformatics 20, 289–290. https://doi.org/10.1093/bioinformatics/btg412

Passalacqua, K.Z., 2015. An Investigation of Late Woodland and Mississippian Biological Relationships Using Odontometric and Dental Non-Metric Trait Analyses (Ph.D.). Indiana University, United States -- Indiana.

Paul, K.S., Stojanowski, C.M., Butler, M.M., 2013. Biological and spatial structure of an early classic period cemetery at Charco Redondo, Oaxaca. Am. J. Phys. Anthropol. 152, 217–229. https://doi.org/10.1002/ajpa.22347

Petersen, H.C., 2000. On statistical methods for comparison of intrasample morphometric variability: Zalavár revisited. Am. J. Phys. Anthropol. 113, 79–84.

Phenice, T.W., 1969. A newly developed visual method of sexing the os pubis. Am. J. Phys. Anthropol. 30, 297–301. https://doi.org/10.1002/ajpa.1330300214

Pietrusewsky, M., 2008. Metric analysis of skeletal remains: Methods and applications, in: Katzenberg, M.A., Saunders, S. (Eds.), Biological Anthropology of the Human Skeleton. John Wiley & Sons, Hoboken, NJ, pp. 375–416.

Pietrusewsky, M., 1983. Multivariate analysis of New Guinea and Melanesian skulls: A review. J. Hum. Evol. 12, 61–76.

Pilloud, M.A., Larsen, C.S., 2011. “Official” and “practical” kin: Inferring social and community structure from dental phenotype at Neolithic Çatalhöyük, Turkey. Am. J. Phys. Anthropol. 145, 519–530.

Pink, C.M., Maier, C., Pilloud, M.A., Hefner, J.T., 2016. Cranial nonmetric and morphoscopic data sets, in: Pilloud, M.A., Hefner, J.T. (Eds.), Biological Distance Analysis: Forensic and Bioarchaeological Perspectives. Academic Press, Amsterdam, pp. 91–108.

Prowse, T.L., Lovell, N.C., 1995. Biological continuity between the A- and C-groups in lower Nubia: Evidence from cranial non-metric traits. Int. J. Osteoarchaeol. 5, 103–114. https://doi.org/10.1002/oa.1390050202

R Core Team, 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Reisner, G.A., 1923a. The Meroitic kingdom of Ethiopia: A chronological outline. J. Egypt. Archaeol. 9, 34–77. https://doi.org/10.2307/3853492

Reisner, G.A., 1923b. The Meroitic kingdom of Ethiopia: Additional note. J. Egypt. Archaeol. 9, 157–160. https://doi.org/10.2307/3854033

Reisner, G.A., 1921. Historical inscriptions from Gebel Barkal. Sudan Notes Rec. 4, 59–75.

Reisner, G.A., 1920. Note on the Harvard-Boston excavations at El-Kurruw and Barkal in 1918-1919. J. Egypt. Archaeol. 61–64.

Reisner, G.A., 1910. The Archaeological Survey of Nubia, Report for 1907-1908. Egypt Survey Department, Cairo.

Reisner, G.A., 1909a. The archaeological survey of Nubia, in: The Archaeological Survey of Nubia Bulletin No. 3. National Printing Department, Cairo, pp. 5–20.

Reisner, G.A., 1909b. The archaeological survey of Nubia, in: The Archaeological Survey of Nubia Bulletin No. 4. National Printing Department, Cairo, pp. 5–20.

Reisner, G.A., 1908. The archaeological survey, in: The Archaeological Survey of Nubia Bulletin No. 1. National Printing Department, Cairo, pp. 9–24.

Relethford, J., 2012. Gene flow, in: Human Population Genetics. Wiley-Blackwell, Hoboken, NJ, pp. 205–236.

Relethford, J.H., 2016. Biological distances and population genetics in bioarchaeology, in: Pilloud, M.A., Hefner, J.T. (Eds.), Biological Distance Analysis: Forensic and Bioarchaeological Perspectives. Academic Press, Amsterdam, pp. 23–34.

Relethford, J.H., 1994. Craniometric variation among modern human populations. Am. J. Phys. Anthropol. 95, 53–62.

Relethford, J.H., Blangero, J., 1990. Detection of differential gene flow from patterns of quantitative variation. Hum. Biol. 62, 5–25.

Relethford, J.H., Harpending, H.C., 1994. Craniometric variation, genetic theory, and modern human origins. Am. J. Phys. Anthropol. 95, 249–270.

Ricaut, F.X., Auriol, V., von Cramon-Taubadel, N., Keyser, C., Murail, P., Ludes, B., Crubézy, E., 2010. Comparison between morphological and genetic data to estimate biological relationship: The case of the Egyin Gol necropolis (Mongolia). Am. J. Phys. Anthropol. 143, 355–364.

Richtsmeier, J.T., Cheverud, J.M., Buikstra, J.E., 1984. The relationship between cranial metric and nonmetric traits in the rhesus macaques from Cayo Santiago. Am. J. Phys. Anthropol. 64, 213–222. https://doi.org/10.1002/ajpa.1330640303

Richtsmeier, J.T., McGrath, J.W., 1986. Quantitative genetics of cranial nonmetric traits in randombred mice: Heritability and etiology. Am. J. Phys. Anthropol. 69, 51–58. https://doi.org/10.1002/ajpa.1330690107

Rightmire, G.P., 1972. Cranial measurements and discrete traits compared in distance studies of African Negro skulls. Hum. Biol. 44, 263.

Rightmire, G.P., 1969. On the computation of Mahalanobis' generalized distance (D2). Am. J. Phys. Anthropol. 30, 157–160. https://doi.org/10.1002/ajpa.1330300121

Rowley-Conwy, P., 1989. Nubia AD 0–550 and the "Islamic" agricultural revolution: Preliminary botanical evidence from Qasr Ibrim, Egyptian Nubia. Archeol. Nil Moyen 3, 131–138.

Salih, A.O.M., 2004. Archaeology and settlement in the third cataract region during the medieval and post-medieval periods. Azania Archaeol. Res. Afr. 39, 34–49. https://doi.org/10.1080/00672700409480385

Saunders, S.R., 1989. Nonmetric skeletal variation, in: Işcan, M.Y., Kennedy, K.A.R. (Eds.), Reconstruction of Life from the Skeleton. Liss, New York, pp. 95–108.

Saunders, S.R., 1977. The Development and Distribution of Discontinuous Morphological Variation of the Human Infracranial Skeleton (Ph.D.). University of Toronto, Canada.

Saunders, S.R., Rainey, D.L., 2008. Nonmetric trait variation in the skeleton: Abnormalities, anomalies, and atavisms, in: Katzenberg, M.A., Saunders, S. (Eds.), Biological Anthropology of the Human Skeleton. John Wiley & Sons, Hoboken, NJ, pp. 533–559.

Säve-Söderbergh, T., 1987. Temples and Tombs of Ancient Nubia. The International Rescue Campaign at Abu Simbel, Philae and Other Sites. UNESCO, London.

Schillaci, M.A., Stojanowski, C.M., 2002. A reassessment of matrilocality in Chacoan culture. Am. Antiq. 343–356.

Schrader, S., Buzon, M., Irish, J., 2014. Illuminating the Nubian "Dark Age": A bioarchaeological analysis of dental non-metric traits during the Napatan period. HOMO - J. Comp. Hum. Biol. 65, 267–280. https://doi.org/10.1016/j.jchb.2014.05.001

Scott, R.E., 2012. Religious identity and mortuary practice: The significance of Christian burial in Early Medieval Ireland, in: Baadsgaard, A., Boutin, A.T., Buikstra, J.E. (Eds.), Breathing New Life into the Evidence of Death: Contemporary Approaches to Bioarchaeology. School for Advanced Research Press, Santa Fe, N.M., pp. 55–77.

Shennan, S., 1997. Quantifying Archaeology, Second edition. ed. University of Iowa Press, Iowa City.

Shinnie, P.L., Shinnie, M., 1978. Debeira West: A Mediaeval Nubian Town. Aris & Phillips.

Shinnie, P.L., Shinnie, M., 1965. New light on medieval Nubia. J. Afr. Hist. 6, 263–273. https://doi.org/10.2307/180167

Sijpesteijn, P., 2007. The Arab conquest of Egypt and the beginning of Muslim rule, in: Bagnall, R.S. (Ed.), Egypt in the Byzantine World, 300-700. Cambridge University Press, Cambridge, UK; New York, pp. 437–455.

Sirak, K., 2015. No longer the 1%: Optimizing ancient DNA yields from Saharan African samples, in: Program of the 84th Annual Meeting of the American Association of Physical Anthropologists. Presented at the Annual Meeting of the American Association of Physical Anthropologists, American Journal of Physical Anthropology, St. Louis, MO, p. 289. https://doi.org/DOI: 10.1002/ajpa.22718

Sjøvold, T., 1984. A report on the heritability of some cranial measurements and non-metric traits, in: Van Vark, G.N., Howells, W.W. (Eds.), Multivariate Statistical Methods in Physical Anthropology. D. Reidel Publishing Company, Boston, pp. 223–246.

Smith, C.A.B., 1972. Coefficients of biological distance. Ann. Hum. Genet. 36, 41–45.

Smith, H.F., Hulsey, B.I., West, F.L. (Pack), Cabana, G.S., 2016. Do biological distances reflect genetic distances? A comparison of craniometric and genetic distances at local and global scales, in: Pilloud, M.A., Hefner, J.T. (Eds.), Biological Distance Analysis: Forensic and Bioarchaeological Perspectives. Academic Press, Amsterdam, pp. 157–180.

Smith, S.T., 2003. Wretched Kush: Ethnic Identities and Boundaries in Egypt's Nubian Empire. Psychology Press.

Smith, S.T., Buzon, M.R., 2014. Colonial entanglements: "Egyptianization" in Egypt's Nubian empire and the Nubian dynasty, in: Anderson, J.R., Welsby, D.A. (Eds.), The Fourth Cataract and Beyond: Proceedings of the 12th International Conference for Nubian Studies. Peeters, Leuven, pp. 431–442.

Smouse, P.E., Long, J.C., 1992. Matrix correlation analysis in anthropology and genetics. Am. J. Phys. Anthropol. 35, 187–213.

Soler, A., 2012. Life and Death in a Medieval Nubian Farming Community: The Experience at Mis Island (Ph.D., Anthropology). Michigan State University, United States -- Michigan.

Spaulding, J., 1995. Medieval Christian Nubia and the Islamic world: A reconsideration of the Baqt treaty. Int. J. Afr. Hist. Stud. 28, 577–594. https://doi.org/10.2307/221175

Spence, M.W., 1974a. The study of residential practices among prehistoric hunters and gatherers. World Archaeol. 5, 346–357.

Spence, M.W., 1974b. Residential practices and the distribution of skeletal traits in Teotihuacan, Mexico. Man 9, 262–273.

Stevenson, M., 2016. epiR: Tools for the Analysis of Epidemiological Data. R package version 0.9-79.

Stojanowski, C.M., 2005. Biological structure of the San Pedro y San Pablo de Patale mission cemetery. Southeast. Archaeol. 165–179.

Stojanowski, C.M., Schillaci, M.A., 2006. Phenotypic approaches for understanding patterns of intracemetery biological variation. Am. J. Phys. Anthropol. 131, 49–88. https://doi.org/10.1002/ajpa.20517

Strouhal, E., Jungwirth, J., 1979. Paleogenetics of the late Roman-early Byzantine cemeteries at Sayala, Egyptian Nubia. J. Hum. Evol. 8, 699–703.

Stynder, D.D., Braga, J., Crubezy, E., 2009. Craniometric evidence for biological continuity between Meroitic and post-Meroitic populations buried at the necropolis of Missiminia, Middle Nubia. South Afr. Archaeol. Bull. 122–129.

Sutter, R.C., Mertz, L., 2004. Nonmetric cranial trait variation and prehistoric biocultural change in the Azapa Valley, Chile. Am. J. Phys. Anthropol. 123, 130–145.

Thomas, R., 2008. The origin and use of ceramics on the islands of Mis and Umm Muri, in the Late Meroitic to Christian periods. Sudan Nubia 12, 52–63.

Török, L., 2006. Hellenistic goods and ideas in Meroe, in: Caneva, I., Roccati, A. (Eds.), Acta Nubica: Proceedings of the X International Conference of Nubian studies, Rome 9-14 September 2002. Universitá di Roma "La Sapienza," Rome.

Török, L., 1999. The origin of the Napatan state: The long chronology of the El Kurru cemetery, in: Wenig, S. (Ed.), Studien Zum Antiken Sudan: Akten Der 7. Internationalen Tagung Für Meroitische Forschungen Vom 14. Bis 19. September 1992 in Gosen/Bei Berlin, Meroitica. Harrassowitz Verlag, Wiesbaden, pp. 149–159.

Török, L., 1997a. Introduction, in: The Kingdom of Kush: Handbook of the Napatan-Meroitic Civilization. Brill, Leiden, pp. 7–52.

Török, L., 1997b. The Kingdom of Kush: handbook of the Napatan-Meroitic civilization. Brill, Leiden.

Török, L., 1997c. Historical and archaeological evidence, in: The Kingdom of Kush: Handbook of the Napatan-Meroitic Civilization. Brill, Leiden, pp. 53–81.

Török, L., 1997d. The end of the Egyptian domination and the emergence of the kingdom of Kush (c. 1188-760 BC), in: The Kingdom of Kush: Handbook of the Napatan-Meroitic Civilization. Brill, Leiden, pp. 53–81.

Török, L., 1997e. The kingdom of Kush between the withdrawal from Egypt and the end of the "Napatan" dynasty (from 656 to the mid-3rd century BC), in: The Kingdom of Kush: Handbook of the Napatan-Meroitic Civilization. Brill, Leiden, pp. 342–408.

Török, L., 1997f. The kingdom of Kush between the emergence of the "Meroitic" dynasty and the disintegration of the kingdom (from the middle of the 3rd century BC to the early 5th century AD), in: The Kingdom of Kush: Handbook of the Napatan-Meroitic Civilization. Brill, Leiden, pp. 409–532.

Török, L., 1995. The birth of an ancient African kingdom: Kush and her myth of the state in the first millennium BC. Université Charles-De-Gaulle, Lille.

Trigger, B.G., 1969. The royal tombs at Qusṭul and Ballâna and their Meroïtic antecedents. J. Egypt. Archaeol. 55, 117–128. https://doi.org/10.2307/3856008

Trigger, B.G., 1965. History and Settlement in Lower Nubia. Dept. of Anthropology, Yale University, New Haven.

Turner, B.L., Edwards, J.L., Quinn, E.A., Kingston, J.D., Van Gerven, D.P., 2007. Age-related variation in isotopic indicators of diet at medieval Kulubnarti, Sudanese Nubia. Int. J. Osteoarchaeol. 17, 1–25. https://doi.org/10.1002/oa.862

Tyrrell, A.J., 2000. Skeletal non-metric traits and the assessment of inter- and intra-population diversity: past problem and future, in: Cox, M., Mays, S. (Eds.), Human Osteology in Archaeology and Forensic Science. Cambridge University Press, pp. 289–306.

Van Gerven, D.P., 1982. The contribution of time and local geography to craniofacial variation in Nubia's Batn el Hajar. Am. J. Phys. Anthropol. 59, 307–316. https://doi.org/10.1002/ajpa.1330590312

Van Gerven, D.P., Armelagos, G.J., Rohr, A., 1977. Continuity and change in cranial morphology of three Nubian archaeological populations. Man 12, 270–277. https://doi.org/10.2307/2800798

Van Gerven, D.P., Beck, R., Hummert, J.R., 1990. Patterns of enamel hypoplasia in two medieval populations from Nubia's Batn el Hajar. Am. J. Phys. Anthropol. 82, 413–420. https://doi.org/10.1002/ajpa.1330820403

Van Gerven, D.P., Greene, D.L., 1999. The human remains, in: Kulubnarti III: The Cemeteries, BAR International Series. Archaeopress, Oxford, England, pp. 73–88.

Van Gerven, D.P., Sandford, M.K., Hummert, J.R., 1981. Mortality and culture change in Nubia's Batn el Hajar. J. Hum. Evol. 10, 395–408. https://doi.org/10.1016/S0047-2484(81)80003-6

Vantini, G., 1975. Oriental Sources Concerning Nubia. Heidelberger Akademie der Wissenschaften, Heidelberg.

Vollner, J.M., 2016. Examining the Population History of Three Medieval Nubian Sites Through Craniometric Analyses (Ph.D., Anthropology). Michigan State University, United States -- Michigan.

Walker, R.S., 2015. Human residence patterns, in: Scott, R.A., Kosslyn, S.M. (Eds.), Emerging Trends in the Social and Behavioral Sciences. John Wiley & Sons, New York, N.Y., pp. 1–8.

Ward, J.H., 1963. Hierarchical grouping to optimize an objective function. J. Am. Stat. Assoc. 58, 236–244.

Weiss Krejci, E., 2011. The formation of mortuary deposits: Implications for understanding mortuary behavior of past populations, in: Social Bioarchaeology. John Wiley and Sons, pp. 68–106.

Welsby, D.A., 2014. The kingdom of Alwa, in: Anderson, J.R., Welsby, D.A. (Eds.), The Fourth Cataract and Beyond: Proceedings of the 12th International Conference for Nubian Studies. Peeters, Leuven, pp. 183–200.

Welsby, D.A., 2007. The Merowe Dam Archaeological Survey. Survey and excavations in the vicinity of ed-doma (AKSE) and et-Tereif (AKSCW), 2006-2007. Sudan Nubia 11, 15–19.

Welsby, D.A., 2006a. The Merowe Dam Archaeological Survey. Excavations in the vicinity of ed-Doma (AKSE), 2005-2006. Sudan Nubia 10, 8–12.

Welsby, D.A., 2006b. Settlement in Nubia in the medieval period, in: Caneva, I., Roccati, A. (Eds.), Acta Nubica: Proceedings of the X International Conference of Nubian studies, Rome 9-14 September 2002. Universitá di Roma "La Sapienza," Rome.

Welsby, D.A., 2003. The Amri to Kirbekan Survey: the 2002-2003 Season. Sudan Nubia 7, 26–32.

Welsby, D.A., 2002a. The Medieval Kingdoms of Nubia: Pagans, Christians and Muslims Along the Middle Nile. British Museum Press, London.

Welsby, D.A., 2002b. The collapse of the Nubian kingdoms, in: The Medieval Kingdoms of Nubia: Pagans, Christians and Muslims Along the Middle Nile. British Museum Press, London.

Welsby, D.A., 2002c. The Nubians and their neighbours, seventh to early thirteenth century, in: The Medieval Kingdoms of Nubia: Pagans, Christians and Muslims Along the Middle Nile. British Museum Press, London.

Welsby, D.A., 2002d. The arrival and impact of Christianity, in: The Medieval Kingdoms of Nubia: Pagans, Christians and Muslims Along the Middle Nile. British Museum Press, London, pp. 31–67.

Welsby, D.A., 2002e. The economy, in: The Medieval Kingdoms of Nubia: Pagans, Christians and Muslims Along the Middle Nile. British Museum Press, London, pp. 183–215.

Welsby, D.A., 1996a. The Kingdom of Kush: The Napatan and Meroitic Empires. Published for the Trustees of the British Museum by British Museum Press, London.

Welsby, D.A., 1996b. The early history of Kush, in: The Kingdom of Kush: The Napatan and Meroitic Empires. Published for the Trustees of the British Museum by British Museum Press, London, pp. 10–17.

Welsby, D.A., 1996c. The heyday of Kush, in: The Kingdom of Kush: The Napatan and Meroitic Empires. Published for the Trustees of the British Museum by British Museum Press, London, pp. 18–56.

Welsby, D.A., 1996d. Religion and funerary ritual, in: The Kingdom of Kush: The Napatan and Meroitic Empires. Published for the Trustees of the British Museum by British Museum Press, London, pp. 72–98.

Welsby, D.A., 1996e. The decline and "fall" of the Kushite kingdom, in: The Kingdom of Kush: The Napatan and Meroitic Empires. Published for the Trustees of the British Museum by British Museum Press, London.

Welsby, D.A., Anderson, J.R., 2004. Sudan: Ancient Treasures. British Museum Press, London.

Welsby, D.A., Daniels, C., 1991. Soba: Archaeological Research at a Medieval Capital on the Blue Nile. British Institute in Eastern Africa, London.

Welsby, D.A., Daniels, C., Allason-Jones, L., 1998. Soba II: Renewed Excavations Within the Metropolis of the Kingdom of Alwa in Central Sudan. Published for the Trustees of the British Museum by British Museum Press, London.

Weschenfelder, P., 2014. Linking the Eastern Desert and the Nile Valley: Pan-Grave people from the Late Middle Kingdom to the Early New Kingdom, in: Anderson, J.R., Welsby, D.A. (Eds.), The Fourth Cataract and Beyond: Proceedings of the 12th International Conference for Nubian Studies. Peeters, Leuven, pp. 357–366.

White, C.D., Schwarcz, H.P., 1994. Temporal trends in stable isotopes for Nubian mummy tissues. Am. J. Phys. Anthropol. 93, 165–187. https://doi.org/10.1002/ajpa.1330930203

Williams-Blangero, S., Blangero, J., 1989. Anthropometric variation and the genetic structure of the Jirels of Nepal. Hum. Biol. 1–12.

Willmore, K.E., Buikstra, J.E., Cheverud, J.M., Richtsmeier, J.T., 2012. Developmental origins of and covariation between metric and nonmetric cranial traits, in: Wang, Q. (Ed.), Bones, Genetics, and Behavior of Rhesus Macaques, Developments in Primatology: Progress and Prospects. Springer New York, pp. 61–84. https://doi.org/10.1007/978-1-4614-1046-1_3

Wolf, P., 2004. Fieldwork of the Humboldt-University of Berlin at Musawwarat el Sufra 1993-2000: A summary, in: Wenig, S. (Ed.), Neueste Feldforschungen Im Sudan Und in Eritrea: Akten Des Symposiums Vom 13. Bis 14. Oktober 1999 in Berlin, Meroitica. Harrassowitz, Wiesbaden, pp. 47–62.

Wolf, P., 2002. Die Ausgrabungen in Hamadab bei Meroe. Antike Sudan 13, 92–111.

Wood, J.W., Milner, G.R., Harpending, H.C., Weiss, K.M., 1992. The osteological paradox: problems of inferring prehistoric health from skeletal samples [and comments and reply]. Curr. Anthropol. 33, 343–370.

Wright, L.E., Yoder, C.J., 2003. Recent progress in bioarchaeology: Approaches to the osteological paradox. J. Archaeol. Res. 11, 43–70.

Wright, S., 1951. The genetical structure of populations. Ann. Eugen. 15, 323–354.

Wrobel, G., Graham, E., 2013. Los entierros de la fase Buk en Belice: comprobando las relaciones genéticas entre grupos del Posclásico Temprano en Belice a través de la morfología dental. Afinidades Biológicas Dinámicas Poblacionales Entre Los Antig. Mayas Una Visión Multidiscip. 19–38.

Wrobel, G.D., 2014. Introduction, in: Wrobel, G.D. (Ed.), The Bioarchaeology of Space and Place: Ideology, Power, and Meaning in Maya Mortuary Contexts. Springer Press, New York, pp. 1–14.

Wrobel, G.D.G., 2004. Metric and Nonmetric Dental Variation Among the Ancient Maya of Northern Belize (Ph.D.). Indiana University, United States -- Indiana.

Zegura, S.L., 1975. Taxonomic congruence in Eskimoid populations. Am. J. Phys. Anthropol. 43, 271–284.

Zurawski, B., 2014. The fourth cataract in the medieval period, in: Anderson, J.R., Welsby, D.A. (Eds.), The Fourth Cataract and Beyond: Proceedings of the 12th International Conference for Nubian Studies. Peeters, Leuven, pp. 135–154.

Zurawski, B., 2006. Nubian mortuary complex of the Christian Period, in: Caneva, I., Roccati, A. (Eds.), Acta Nubica: Proceedings of the X International Conference of Nubian studies, Rome 9-14 September 2002. Universitá di Roma “La Sapienza,” Rome.