HUMAN MOBILITY AND LAND-USE PATTERNS DURING THE HOLOCENE: LITHIC ANALYSIS OF HOLOCENE SITES FROM KOOBI FORA, NORTHERN KENYA

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DECLARATION

This project report is my original work and has not been presented for the award of a degree in any other university

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DEDICATION

This work is dedicated to my parents (Giffan and Judith) and my son, Gian.

For their unending love, support and prayers

and

For understanding my absence and always cheering me on

ABSTRACT

The Holocene period recorded a global climate variability phenomenon. The manifestation of these changes varied greatly across the globe. In Turkana Basin, northern Kenya, evidence of this climatic variability is preserved both in the terrestrial landscapes and lacustrine sediments. The lake Turkana experienced lake-level changes, where it was highest in the early Holocene and declined in the mid-Holocene. It is obvious that these changes affected the Holocene populations and influenced their behaviour, especially mobility. This study analysed obsidian stone tools as a proxy to understand the extent of the mobility of these communities across the Holocene landscape in the east Turkana basin. This study was carried out on laboratory artefacts to investigate the effect of climate change on Holocene populations and how they culturally responded to the drastically changing environments. Specifically, mobility and land use by different Holocene populations were examined. The project aimed at establishing the distances between raw material resources and the sites where the artefacts were recovered and compared the results to those obtained from cortex ratio analyses, another novel method in understanding mobility established in the last decade that was used in this study. The cortical ratio analyses showed extremely low ratios, ranging from 0.046 to 0.086, which indicates that the artifacts were found farther from their place of manufacture. Only 6 core fragments were found across 5 archaeological sites. This supports the claim that the tools were used and reused for prolonged periods of time and came from far-off locations. For early Holocene populations, the distances between sites and sources varied between 38km and 162km versus between 26 km and 235 km for mid-Holocene populations. It was evident that climatic change influenced Holocene populations' land use patterns and mobility. The early Holocene populations relied on resources from the East Turkana Basin with reliance on one source by all the sites (Surgei) as well as other two sources. On the other hand, populations during the mid-Holocene were more mobile as resources became more limited and unpredictable and the habitats dried up and explored resources outside the east Turkana Basin. This led to increased movements and longer distances and often returns to original locations where vegetation had regenerated at locations likely used as livestock enclosures. More samples are needed from different locations to understand intra-site source variations, more surveys and samples are required for archaeological sites to increase sample size to draw accurate conclusions and it is vital to assert the chronology of FxJj 108 to comprehend various dynamics across time.

TABLE OF CONTENTS

DECLARATION ..... *i*

DEDICATION ..... *ii*

ABSTRACT ..... *iii*

ACKNOWLEDGMENTS ..... *vii*

LIST OF TABLES ..... *viii*

LIST OF FIGURES ..... *ix*

LIST OF ABBREVIATIONS ..... *xii*

CHAPTER ONE: INTRODUCTION *1*

1.1 Introduction 1

1.2 Background to the study 1

1.3 Statement of the problem 3

1.4 Goal and objectives of the study 4

1.5 Justification of the Study 4

1.6 Scope and Limitations of the Study 5

1.7 Definition of Operative Terms 6

CHAPTER TWO: LITERATURE REVIEW *7*

2.1 Introduction 7

2.2 Later Stone Age and Neolithic Cultures 7
2.2.1. Hunter-gatherers in East Africa 8
2.2.2 The Pastoral Neolithic and Spread of Pastoralism in East Africa 9

2.3 Mobility and land use dynamics 11

2.4 Theoretical framework 15
2.4.1 Interpretive Theory 15
2.4.2 Cultural Ecology Theory 16

2.5 Research hypotheses 17

CHAPTER THREE: THE RESEARCH AREA AND STUDY SITES *18*

3.1 Introduction 18

3.2 Geological, Environmental and Population Setting 18
3.2.1 Geology 18
3.2.2 Contemporary Climate and Vegetation 20

3.3 Archaeological history information and sites 21
3.3.1 History of Holocene Archaeology Studies in the Turkana Basin 22

3.3.2 Early Holocene sites 25
3.3.2.1 FxJj108 27

3.3.2.2 FxJj12N 27
3.3.2.3 GeJk4 (Lowasera) 28

3.3.3 Mid-Holocene sites 29
3.3.3.1 FwJj25W 29
3.3.3.2 FwJj27 30

3.4 Sources of obsidian, East of Lake Turkana 33

CHAPTER FOUR: METHODOLOGY 35

4.1 Introduction 35

4.2 Materials 35

4.3 Methods 35
4.3.1 Data collection, recording, processing and analysis 36
4.3.2 Cortex ratio analysis 38
4.3.3 Geochemical analysis 39

4.4 Presentation of findings 40

4.5 Ethical issues 40

CHAPTER FIVE: RESEARCH FINDINGS 42

5.1 Introduction 42

5.2 Raw material and raw material sourcing 42

5.3 Geochemical characterization 42

5.4 Cortex ratios 51

CHAPTER SIX: DISCUSSION, CONCLUSION AND RECOMMENDATIONS 56

6.1 Introduction 56

6.2 Mobility during the Holocene period 56

6.3 Land Use Patterns 60

6.4 Conclusion 61

6.5 Recommendations 62

REFERENCES 64

APPENDICES 73

Appendix 1: XRF sample geochemically characterized at the University of Nairobi's Institute of Nuclear Science lab 73

Appendix 2: Sample of lab data sheet for cortex ratio at the east Turkana Basin 75

Appendix 3: Site coordinates 76

Appendix 4: Cortex ratios of obsidian artefacts by use of R 77

Appendix 5: ED-XRF setup at the University of Nairobi's Institute of Nuclear Science. 78

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LIST OF TABLES

Table 3.1: Sites under study and their dates (Adapted from Phillipson, 1977; Ndiema, 2011) ... 33

Table 5.1:Distances in kilometres between sites and sources in east Turkana Basin................... 48

Table 5.2: Cortex ratios for the sites under study 55

LIST OF FIGURES

Figure 3.1:Turkana Lake level changes during the Holocene (adopted from Harvey & Grove, 1982:382). 19

Figure 3.2: Lake Turkana Lake levels recorded in the last 20 years. (Retrieved online: TOPEX/Poseidon GDR 10Hz altimetry, Jason-1 GDR 20Hz altimetry, OSTM/Jason-2 GDR 20Hz altimetry (ice retracker) & Jason-3 Interim GDR 20Hz altimetry (ice retracker)) 20

Figure 3.3: Kenya SASES map (By Susan Ongoro, NMK, 2021) 24

Figure 3.4: Map showing some pastoral Neolithic sites and fisher settlement sites in the Turkana Basin (Source: Ndiema, 2011: 56).. 26

Figure 3.5: Map showing mid-Holocene sites in Northern Kenya (Source: Ndiema, 2011:85). . 30

Figure 3.6: Map showing some Holocene sites East of Lake Turkana (Source: Akinyi, 2017)... 32

Figure 3.7: Map showing obsidian sources considered for this study (Source: Ndiema, 2011:61). 34

Figure 5.1: Sources of obsidian within the East Turkana basin as a result of plotting ratios of Zirconium (Zr) and Yttrium (Y) against Zr and Niobium (Nb)... 43

Figure 5.2: Bivariate plots for Zr/Y, Zr/Nb for obsidian artefacts from the early Holocene sites 44

Figure 5.3: Elemental plots of Zr against Nb for early Holocene sites.. 45

Figure 5.4: Zr/Y against Zr/Nb plot for sources and sites in the east Turkana basin 46

Figure 5.5: Sites against sources in the East Turkana Basin... 47

Figure 5.6: Results of Zr/Y against Zr/Nb for FxJj 108 and the sources.................................... 49

Figure 5.7: Sources for GeJk 4 50

Figure 5.8: Results of the Zr/Y against Zr/Nb plots for FxJj 12N and the sources in the east Turkana Basin 51

Figure 5.9: Plots of mass (g) and maximum length (mm) against sites under study.................... 53

LIST OF PLATES

Plate 4.1: showing a summary of different stages taken for data analysis and contextualization 37

Plate 5.1: Cortical obsidian pieces from Holocene sites in Northern Kenya................................ 52

Plate 5.2: Core fragments from the early Holocene sites... 54

LIST OF ABBREVIATIONS

LSA: Later Stone Age

Nb: Niobium

Y: Yttrium

Ti: Titanium

Zr: Zirconium

Mb: Molybdenum

SASES: Standard African Sites Enumeration System

NMK: National Museums of Kenya

Kya: Thousand Years Ago

BP: Before Present

ED-XRF: Energy-dispersive X-ray Fluorescence

dGPS: Differential Global Positioning System

CHAPTER ONE

INTRODUCTION

1.1 Introduction

This chapter gives background information on Holocene studies in East Africa, the palaeoenvironment as well as studies that have used cortex ratio as a proxy to understand how humans interacted with their landscapes. It highlights raw material sourcing through ED-XRF analysis and introduces the statement of the problem and justification of the study. The main goal, specific objectives as well as scope of the study are stated. Finally, operational terms are defined at the end of the chapter.

1.2 Background to the study

The Holocene period in East Africa is associated with drastic climatic changes shifting from wet and humid in the early Holocene (~10-7 Kya) to dry and arid in mid-Holocene (~5-4.5 Kya) (Ashley et al., 2011:832). During the early Holocene, the Turkana Lake level was 80m higher than the present levels while the mid-Holocene Lake levels were low (Forman et al., 2014). The changes in the lake levels have been captured through different proxies such as digital models of ancient shorelines (Ashley et al., 2011:815) and kinematic dGPS surveys (Garcin et al., 2012:324). These changes in lake levels, in turn, influenced the availability of food and water resources for Holocene communities (Hildebrand & Marshall, 2002, cited in Ashley et al., 2011:81) who responded by shifting subsistence strategies from fishing, hunting, and gathering in the early Holocene to incorporate pastoralism in the mid-Holocene (Ndiema et al., 2011).

Previous studies have indicated that people around the Lake Turkana basin were fisher-hunter-gatherers during the early Holocene (Barthelme, 1985; Ndiema et al., 2011). This is evident in the presence of artefacts associated with fishing such as bone harpoons. Deep-water fish bones and obsidian sourced from water-logged sites such as North Island indicate the exploitation of lake resources using watercraft (Ndiema et al., 2011:1093). The earliest evidence of livestock domestication comes from Dongodien (GaJi 4), east of lake Turkana and is dated to around 4300-4500BP (Marshall et al., 1984:120). Teeth and other caprine faunal remains were recovered in association with other archaeological artefacts (stone tools and ceramics) from the site. Other mid-

Holocene sites in the region have also been characterized with similar remains. Assemblages from the early Holocene sites are however, dominated by fish bones while those from the mid-Holocene are dominated by both wild and domesticated animals, as well as fish fauna (Prendergast, 2010).

Climatic changes might also have increased mobility among populations especially during the mid-Holocene as it became increasingly dry (Stojanowski & Knudson, 2014). People moved longer distances to acquire resources. Those within close range would be quickly depleted and take longer times to regenerate necessitating movement to distant places. During the mid-Holocene, new materials were introduced by the populations in their everyday activities and rare materials became common. For instance, the use of obsidian tools in the Turkana basin increased during this period (Ndiema et al., 2010). Obsidian sources within the basin include the Turkana basin margin, North Island, and the Suguta valley (Merrick & Brown, 1984). There are, however, other small sources of obsidian at Shin and Surgei (Ndiema, 2011:254). The exploitation of obsidian is evident during both high and low lake stands; however, previous research shows lower use of obsidian tools during high lake stands than in low lake stands (Ndiema et al., 2011).

Studies by Braun et al. (2008) and Blegen (2017) have demonstrated that the movement of stone artefacts tracks human mobility. Methods linking stone artefacts to their sources characterize the scale and pattern of movements (Braun et al., 2009) and the fragmentation of lithic production chains in space holds information regarding the structure of human movement (Braun et al., 2008). Variations in different production stages provide insights into the parameters that influence human movement and tool use (Blumenschine et al., 2008). It has also been established that the measure of cortex ratios provides additional analysis that sheds light on human mobility and land use patterns (Douglass et al., 2008).

Movement patterns across ancient landscapes correlate with shifts in subsistence strategies (Rosen et al., 2005). The mobility patterns can therefore be predicted as people tend to use familiar resources even when the acquisition costs are high (Siliman, 2005). This persisted until the people became more cognizant of locally available resources. The appearance of obsidian from distant sources could be indicative of highly mobile people (Ndiema, 2011). Depending on resource predictability and availability, there would be more intensively reduced stone tool assemblage with greater mobility (Bousman, 2005).

Douglass et al. (2008:522) suggest that the cortex ratio analysis of a given archaeological assemblage shows repeated patterns of selective removal of artefacts away from their location of manufacture for efficient and effective transportation. Mid-Holocene climates became increasingly dry (Ashley et al., 2011) and humans and their livestock moved further from the obsidian sources in search of greener pastures and water. The people, however, retained their already possessed tools which they kept on reworking, thereby reducing the cortex of the stone artefact. This reduction of the cortex has, therefore, been considered to be a function of human mobility. During wet seasons humans tend to be closer to the resources and stone tools are in the early stages of reduction (with lots of cortex on them). In contrast, during the dry season, resources are scattered in the landscape, prompting greater mobility of humans in search of these resources. Consequently, the further they are from the raw material, the more reduction intensity of the tools in their possession leading to lesser amounts of cortex on their tools (Dibble et al., 2005).

1.3 Statement of the problem

Human mobility and land use patterns in the archaeological record provide an opportunity to investigate interactions between human behaviour and the environment. Archaeological research targeting the Holocene period has gained popularity in the last decade to shed light on the cultural responses to climatic variability (Ndiema et al., 2011; Ashley et al., 2011).

Previous research in East Lake Turkana (Barthelme, 1985; Roberts, 2013; Moore, 1989) indicate shifts in human social organizations, technology and subsistence. With new improved and innovative methods, more and more studies have been undertaken to accurately address questions of mobility and land use patterns. However, earlier studies have mainly focused on the Mid-Holocene period (Ashley et al., 2011; Marshall et al., 1984). This has been motivated by the new mode of economy, pastoralism, and the fact that this region has produced the earliest evidence of this mode of subsistence. The last two decades have, however, seen a decline in early Holocene research, a gap this study intends to fill. Cultural sophistication through different resource acquisition and management practices needs to be understood for the entire Holocene population.

On a temporal scale, the environmental record is well documented as opposed to the understanding of the behavioural changes of the humans interacting with these environments. The climatic shift from wet and humid early Holocene to dry and arid mid-Holocene was a major change that forced humans to change their lifestyles and adapt to new strategic behaviours to survive (Nyanchoga, 2012). Ndiema (2011) investigated the subsistence and mobility patterns of the mid-Holocene populations in this region through geochemical characterization of obsidian artefacts. In addition to pottery, human and animal fauna and lithics in general, obsidian artefacts have also been recovered from early Holocene sites. It is, therefore, pertinent to conduct comprehensive research to determine these changes and the adaptation strategies adopted by the Holocene communities by geochemically analysing artefacts from the early Holocene sites to provide room for comparisons. This study, therefore, sought to understand the cultural responses to climatic variability by addressing three questions:

1. To what extent do the cortex ratios of the early and mid-Holocene sites compare with each other?
2. How did access to raw materials in the environment influence human movements during the Holocene?
3. How do resource distances compare between the two climatic phases?

1.4 Goal and objectives of the study

The **general** objective of this study was to reconstruct and map the land use patterns and human mobility of the eastern Turkana basin during the Holocene period using ED-XRF and Cortex ratio analysis.

The **specific** objectives of the study were:

1. To establish whether the cortex ratios are significantly different for the two time periods.
2. To determine whether the Holocene population movements were influenced by access to raw materials.
3. To investigate the relationship between mobility and/or land use with changing environments

1.5 Justification of the Study

The study sites are based in the Koobi Fora basin, along the eastern shores of Lake Turkana, where the earliest known evidence of pastoralism is recorded. These archaeological sites date to between the early- and mid-Holocene periods, providing an opportunity for direct comparisons between the two time periods. It is important to compare the archaeological remains, especially using obsidian artefacts between the two time periods, to make inferences on the differences in the behaviour of the populations responsible for them.

Reconstructing ancient mobility and land-use patterns should provide a link through behaviour between the archaeological record and the changing environment. Once past human-environment interactions are understood, the findings could contribute to the formulation of policies that govern present-day land-use patterns, address conflicts that involve the acquisition of and competition over resources and advise on community preparedness regarding climate change, especially for the pastoralist communities in arid and semi-arid regions similar to the East Turkana basin.

The project also employed two different approaches to reconstruct past lifeways. First, the application of cortex ratio on the East African archaeological record for instance continues to show that it is a reliable method that can be used across different regions of the world. Secondly, raw material sourcing was applied to obsidian stone tools for the mid-Holocene sites. The two proxies point towards a similar outcome affirming that both methods can be used to infer mobility.

1.6 Scope and Limitations of the Study

The Holocene deposits (dated to between ~10,000 and 4,000 years ago) geologically referred to as the Galana Boi beds have an archaeologically rich locality in the broader Koobi Fora region (FxJj12N and FxJj108) and Ileret (FwJj25W and FwJj27) and further south, Lowasera, were studied. Lithic artefacts recovered from these sites and housed at the National Museums of Kenya (NMK) were analysed through the ED-XRF to determine the sources of the raw materials. In addition, cortex ratios were utilized as a measure of mobility to determine the land-use patterns of east Turkana during the Early-to-Mid-Holocene period.

The study, however, focused only on flakes and angular fragments as there are no complete cores, and what might have been core fragments are too small and hence classified as angular fragments. There is a specific formula for calculating cortex ratios for cores and these might have resulted in slightly different results. These were, however, very few and mostly non-cortical. With the core fragments being non cortical, this project assumed that this could not entirely affect the outcome of the cortex ratio method and thus applied the same method for flakes and angular fragments. To ensure that this was the case, the source locations of the artefacts were established and compared to the results from the cortex ratio method.

1.7 Definition of Operative Terms

Cortex: The outer layer of an organ formed by tissues. In this study it refers to the stone tools' outer region, that is, the outer covering before flaking was done. It is an attribute in archaeology that is used to assess the artefact reduction sequence, raw material exploitation, transportation and mobility (Lin et al., 2015).

Cortex ratio: Observed cortex over the expected surface area with the cortex (Dibble et al., 2005).

Holocene: Approximately the last 11,000 years (Cambridge English Dictionary). In this study, it is used to refer to the period of our dataset between 10,000 years and 4,000 years ago.

Land-use: Process of land management and modification of the natural environment (Encycolopedia.com). In this study, it refers to how humans exploited the landscapes for their basic utilities, depending on the available resources and habitats, that is, grasslands versus wooded grasslands

Mobility: The ability to move across space. In this study, it refers to the ability of populations to move about in order to access and utilize raw materials and other resources. As Clarkson (2008:488) puts it, "It is a primary mode of human engagement with the landscape".

Obsidian: A hard and dark glasslike volcanic rock formed as a result of rapid solidification of lava without crystallization (Oxford Dictionary). In this study, it refers to the cryptocrystalline silica raw material.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents the literature review, discusses the theoretical framework, and outlines the research hypotheses. The literature review is divided into two main thematic areas. The first section reviews the literature on Later Stone Age (LSA) and Neolithic cultures. It specifically discusses the prehistoric hunter-gatherers and Pastoral Neolithic (pastoralism) in Africa in order to provide the rationale and context for the study. The second section looks at mobility and land use studies in archaeology. It delves into previous studies, both experimental and archaeological, that have been undertaken including those done in other parts of the world to verify the cortex ratio analysis as a method to infer mobility. Theories guiding this research are then discussed followed by the research hypotheses.

2.2 Later Stone Age and Neolithic Cultures

Later Stone Age (LSA) cultures were adopted by early Holocene populations with the mid-Holocene adopting the Neolithic. The shift has been documented through material remains at different sites with the latter dominated by domestic fauna. These cultures span the period between 40,000- and 2,000 years BP. However, Ambrose (1998) has contested the LSA dates and argued that the dates can be pushed as far back as 50,000 years BP and vary depending on transitions to managed food production at local levels. The LSA saw populations foraging, hunting, and fishing as well as the domestication of both plants and animals towards the end of the period. Obsidian, a cryptocrystalline silica raw material, has been recovered at LSA sites and identified as having been the preferred raw material for both early and mid-Holocene sites. These raw materials are often located farther from where the people reside and thus long-distance procurement, directly and/or through social exchange (Ndiema, 2011:26). The LSA toolkit is characterized by increased core reduction with formal tools such as blades, bladelets and crescents appearing in the archaeological record.

Neolithic technology was a continuation of LSA microliths that included Savannah Pastoral Neolithic, Eburan and Elmentaitan traditions (Ambrose, 2001). These specific traditions have not been recorded in Northern Kenya but have similar characteristics as those that define settlement patterns. For instance, ethnoarchaeological and micromorphological studies revealed that pastoral settlements possibly resembled those of modern pastoralists where animal dung accumulations were confined in specific areas in the compounds (Dale et al., 2004; Shahack-Gross et al. 2003). Also, neolithic sites are characterized by burial cairns with some containing stone bowls, polished pestles, and grindstones stained with ochre (Ambrose, 2001). Holocene populations were first hunter-gatherers before incorporating pastoralism during the mid-Holocene.

2.2.1. Hunter-gatherers in East Africa

Archaeologists, ethnographers, and amateurs have written historical documents for hunter, gatherer, and fisher societies across the world (Prendergast, 2009; Dale & Ashley, 2010). Ethnography, for instance, has been applied to different hunter-gather communities in the past and findings projected to past lifeways to generate literature that has improved the understanding of the Later Stone Age populations (Dale et al., 2004). These accounts reveal the numerous variations in settlements as well as social and economic relations (Binford, 1982). Additionally, patterns of mobility, social interactions and subsistence have been established. Human beings have always foraged and evidence shows that they have hunted for as long as two million years (Parkinson et al., 2022). The early Holocene sites in the region show evidence of complete reliance on wild terrestrial and aquatic fauna. They only began to embrace different sustenance techniques as the climates changed and their cognitive abilities advanced over time.

Anthropologists have established several categories of hunter-gatherers that include, but are not limited to, foragers versus collectors (Binford, 1980), non-storing versus storing (Testart, 1982), generalized versus specialized (Price and Brown, 1985), immediate return versus delayed return (Woodburn, 1991), egalitarian versus non-egalitarian (Kelly, 1992), and simple versus complex (Arnold, 1996). In recent years Woodburn's model has been applied to studies in East Africa (Dale & Marshall, 2004; Prendergast 2009; Ndiema et al., 2010). The immediate return system is whereby consumption follows immediate acquisition (Woodburn, 1980). This implies that weapons or stone tools, for instance, get disposed and there are less transport hence minimal investments. Consequently, delayed return systems require more investments with activities focused on the past, present, and future (Dale & Marshall, 2004). There is deliberate planning, actions are predetermined and results are anticipated (Woodburn, 1982). With regard to settlements, for example, the immediate return foragers only occupy small camps briefly as opposed to delayed return foragers. The variations in different systems could be a result of ecological shifts, as well as interactions between different communities.

2.2.2 The Pastoral Neolithic and Spread of Pastoralism in East Africa

Pastoralism is the general dominant form of food production strategy globally in grassland ecosystems (Reid et al., 2008) and has been a significant feature of the East African cultural and economic landscape since the mid-Holocene. In East Africa, it is associated with the Neolithic phase primarily referred to as the Pastoral Neolithic and abbreviated as PN (Bower et al., 1977). Specifically, the appearance of managed food production including cattle domestication and what have been identified as goat or sheep alongside stone tools (microliths) mark this period. The PN is also characterized by a variety of ceramic traditions e.g., Nderit, Ileret (Bower et al., 1977).

The early pastoralist sites in East Africa are remarkably visible thanks to the fact that the pastoralists were reliant on flaked stone tools through a reductive technology that does not decay (Robertshaw, 2021). There are archaeological sites that date to this period in parts of southern Sahel, Northern Kenya and the Kenyan central rift that have greatly contributed to the understanding of the origin and practice of Pastoralism in East Africa (Gautier & Neer, 2006; Gifford-Gonzalez, 2003; Marshall et al., 1984). Further south, Pastoralism has been documented in central Kenya rift in sites like Ngamuriak, Prolonged drift, and Enkampune Ya Muto (Ambrose, 1998). As opposed to the lake Turkana single-package pastoralism model, stable isotope analysis of the central rift sites show that the population here did not engage in transhumance (Robertshaw, 2021). They are believed to have kept their livestock close to their settlements all year round. This demonstrates variations in pastoral lifestyles and has ramifications for various demographic lifestyles.

Pastoralism has been the main economic activity at most of the mid and late-Holocene sites. This mode of the economy has, however, been practiced alongside other economic pursuits, namely, foraging, fishing, hunting, domestic herding as well as trade (Prendergast, 2010). These strategies are a result of numerous factors including climatic, environmental, socio-cultural, and disease (Gifford-Gonzalez, 1998). Aridification in the Turkana Basin resulted in vegetational changes where xeric-adapted shrubs and bushes replaced grasslands (Chritz et al., 2019). The altered vegetation impacted the hunter-gatherer lifestyles as the herbs and roots were not readily available and this increased their foraging distances and adoption of new subsistence strategies. Consequently, the changing environments led to wild animal species' decline either through deaths or migration to places with more readily available resources for their survival.

Early pastoralism around Lake Turkana saw the arrival of people together with lithic technology, domestic animals and a new ceramic technology, nderit ware, (Robertshaw, 2021: 14). Further south however, pastoralism has been argued a two-stage process: where evidence shows that caprines arrived in the region after pottery but was followed by cattle almost a thousand years later (Bower, 1991). The introduction of herding in East Africa was, therefore, non-uniform and might have resulted from different diffusion events. What is constant, however, is that the people's lifestyle changed by this new mode of subsistence. They were gradually transformed to find pastures and water for their livestock as opposed to only tending to themselves.

There are numerous pastoral sites both to the south of the Sahel and Northern Kenya but uncommon farther south, for example, the Lake Victoria basin. The reported sites in the Southern Rift Valley, and the eastern and western highlands date to 3000 BP or later (Gifford-Gonzalez, 2003). The caprines' ability to reproduce quickly, easy acquisition through trade and less attention than cattle (Karega-Munene, 2002) might have led to their quick diffusion into the forager hunter communities (Prendergast, 2010). According to Gifford-Gonzalez (1998), cattle diffused through southern and central Africa around 2000 BP by groups of rather specialized pastoral populations. Tracking the arrivals of pastoral animals in different parts of Africa helps to track the movements and migrations of populations. Adoption of one domesticate over the others has implications for the environment as well as the foraging behaviour of the livestock.

It has been established that pastoralism was a primary subsistence economy during the mid-Holocene to the east of Lake Turkana at around 4000 BP. Their livestock provided them with a variety of dietary resources, including milk, meat, and blood (Grillo et al., 2020). Additionally, because they could use hide skins to produce clothing, these populations found domestication to be quite beneficial. In addition to the hunter-gatherer way of life, fishing and hunting, these populations also moved about with their livestock in search of water and pasture. This involved people moving from place to place to ensure they acquired resources that facilitated their well-being as well as that of their livestock.

2.3 Mobility and land use dynamics

Considerable research has been dedicated to the study of mobility and land use patterns for ancient populations in East Africa (see, for example, Kusimba & Kusimba, 2011; Ndiema et al., 2011; Nyanchoga, 2012). These include Later Stone Age populations as well as more recent east African civilization period on the coast and hinterland east Africa. People move around for a variety of reasons: to forage for food, to hunt, to trade as well as visit distant relatives and attend religious ceremonies. The stone pillars in the Turkana Basin, the change in subsistence strategies as well as use of a sophisticated stone tool kit with the use of exotic raw materials show that the people in the region were mobile. The question however is how mobile were they, and whether there are observable differences between similar landscapes experiencing different climatic conditions.

Ninety-nine percent of human history is accounted for by lithics, the primary archaeological remains whose analysis sheds light on the past (Peregrine, 2016). This is because they are better preserved as opposed to their organic counterparts. The obsidian stone tools of the Holocene east Turkana basin are only a small portion of the entire lithic assemblage. They come from many different sources, which provides proof for the various distances that were traversed to obtain them. Populations become quite mobile as a result of the massive travel. This dictates the number of material possessions owned either by individuals or families in society. Highly mobile communities also own very little material possessions and the chances of these materials preserving are quite low (Ndiema, 2011).

The lithic residues mark places with histories of human visitations, activity and associations that help with the interpretation of the human-land-use activities, occupations and interactions in the past (Clarkson, 2008: 490). For instance, archaeological patterns in the African region can be connected to broader trajectories of food production through the lithic record (Goldstein, 2019:1496). Faunal and ceramic studies in Northern Kenya show that populations relied on different food sources and moved about to different extents. Recently, lithics have proved to be a reliable approach through raw material sourcing and thus an understanding of resource availability and exploitation (Ndiema, 2011).

Reduced mobility and early sedentism by fisher/hunter/gatherers have been suggested by African communities in Libya and Sudan (Garcea, 2004). In Eastern Africa, studies conducted in the Lake Victoria basin and Northern Tanzania have shown delayed return foragers (Prendergast, 2009). The sites under study lie in tropical Africa and thus add to data for the African hunter-gatherer theory. The people east of Lake Turkana practiced fishing and relied on wild fauna during the early Holocene. However, they also started to incorporate domestic fauna during the mid-Holocene. The people's knowledge of their environment (resources, landscape and climate) might have led to reliance on particular resources as well as the diversification of the resource bases.

It has been established that obsidian occurs in most parts of Ethiopia, Eritrea, Tanzania and Kenya and that this rock has been used in toolmaking (Frahm et al., 2017). Successful documentation of obsidian source locations as well as chemical composition has been carried out in Kenya and Tanzania (Brown et al., 2013). According to Nash et al. (2011), there are more than eighty chemically distinct obsidian sources in Kenya and over 2000 electronic microprobe analyses have been reported from the greater Lake Turkana region. Obsidian hydration, fission tracks, and radiogenic argon isotope ratios methods have been used to date many of these sites (Frahm et al., 2017). However, significant evidence for long-distance transportation of obsidian is rare until the second half of the Middle Stone Age.

Long-distance obsidian transportation in the later Middle Stone Age has been said to have resulted in the large-scale development of regional social networks (Blegen, 2017). The development of social networks is a notable facet of modern human evolution and behaviour. Evidence for obsidian use in Kenya and Tanzania during the Holocene is seen as a reflection of adaptation to changing surroundings by hunter-gatherers and exchange patterns of Neolithic pastoralists. Trade networks and social interactions facilitated the acquisition of resources during the later Stone Age. Obsidian artefacts were widely used by early Holocene hunter-gatherers and pastoral Neolithic groups in most parts of Northern Kenya (Ndiema et al., 2010). A wide variety of the dominant type is observed from the Barrier in the South to Ileret in the North and East as far as Kargi.

Humans are rarely completely sedentary and must move and interact socially and economically over varying distances to accomplish various goals (Clarkson, 2008:491). Hence, their mobility is often prompted by change. Forces that cause these changes are technological innovations, environmental changes or catastrophes, internal conflicts over labour organization and access to resources (Peregrine, 2016:4). People moving frequently across landscapes with uncertainties about places to be visited or a few opportunities for foraging and raw material replacement typically provision themselves with portable multifunctional, long-life tools that can easily be maintained using the transported toolkits at hand (Clarkson, 2008: 491-492). The unpredictability of resources leads to diverse settlement patterns where people have home bases, fishing camps along the lakes and bomas in the fora (satellite camps) hence using land differently than they do when resources are readily available. In wet and humid environments, the vegetation composed of tall trees, shrubs, herbs and grasses is available almost everywhere in the landscape as opposed to arid conditions.

A low-mobile population that exploited aquatic resources resided in the Lake Turkana region (Barthelme, 1985, cited in Wright, 2015; Roberts, 2013). Small populations require fewer resources to survive. Resources are under strain as a result of population growth, which causes them to become more scarce and forces people to expand their foraging areas. Higher mobile foragers practicing a generalized subsistence strategy have also been identified farther from the lake shores (Barthelme, 1985: 277-278). The transition from fisher-forager-hunting to food-producing was done by people already residing in the basin as opposed to major population movements (Prendergast, 2009). Ndiema (2011:22) notes that the shift from hunter-gathering to pastoralism is, however, not clear (see also Gifford-Gonzalez, 2003). Domestication and/or pastoralism might have developed gradually via trial and error, only becoming a reality when it became the only means of surviving in the more arid landscapes.

Mobility is conceptualized by the abundance of knapping products at different localities whenever lithic assemblages' formation and occupation interact (Dibble et al., 2005). In contexts where raw materials are abundant, there is minimal transportation of stone artefacts because people continue moving about and carrying out their activities in the environment (Douglass et al., 2008). The stone tool assemblage recovered at a site where the knapping took place is likely to have boulders or cobbles depending on the available resources, this could be manuports or entirely unmodified. There would be more cortical cores and flakes and angular fragments at the site. Stone artefact assemblages from the Galana Boi deposits, mainly obsidian, give clues on human mobility patterns in diverse settings and, by extension, subsistence strategies (Ndiema, 2011:224). Additionally, human interactions with diverse resources and environments are significantly caused by increased distances in the transportation of raw materials (Blegen, 2017:15).

Transportation of artefacts is key in constructing the range, frequency and predictability of residential movements in past societies (Clarkson, 2008:491). Different methods have been used to build a broad understanding of raw material transportation between sources and places of discard including XRF, colour and texture (Clarkson & Lumbe, 2005, cited in Clarkson, 2008:491). The procurement of traceable resources, for example, obsidian, can be used to assess the mobility patterns of populations (Ndiema et al, 2011:1094). Ndiema (2011:228) used XRF to identify sources of different obsidian artefacts from Mid-Holocene sites. Application of the same method to early Holocene sites has shed light on the mobility during this particular time period and allowed for comparison.

Ndiema et al. (2010:1095) conclude that clear association at the earliest Pastoral Neolithic sites at Lake Turkana possibly implies that the mid-Holocene populations adopted a new land-use strategy typical of subsistence diversity in systems where populations were able to exploit different resources. They suggest that the mid-Holocene was characterized by high mobility that included water-based transportation. This study, therefore, aimed at using a different method to reconstruct mobility and land use patterns to the east of Lake Turkana during the early and mid-Holocene.

The LSA stone tools were made by *Homo sapiens* earlier than 40,000 years ago and included microliths (Ambrose, 1998) from farther sources. However, most notably, are obsidian stone tools found at distant places from their sources. The cortex ratios of stone tools have been used to suggest that there was a difference in distances traveled by different populations during different seasons in the archaeological record (Lin et al., 2015; Holdaway & Fanning, 2008). The cortex ratio has often been used as a measure of transport (Dibble et al., 2005:558). The amount of cortex in lithic assemblages is applicable to questions on both transport and land use (Roth & Dibble, 1998) and mobility (Fernandez et al., 2008:12).

Lin et al. (2015) state that the quantification of cortex ratios on different types of artefacts leads to an understanding of the overall composition of an assemblage. This provides a practical alternative for determining the extent and nature of land use patterns. This approach has been applied in other regions, for example, in Western New South Wales in Australia by Matthew Douglass (2010). In

Africa, a similar study has been done by Dibble and colleagues (2005) on artefacts from Contrebandiers Cave, a Middle Stone Age site in Morocco, and another one by Philip (2012) on Neolithic artefacts from the Fayum in Egypt. These have indeed proved that the cortex ratio is an effective proxy for identifying and ascertaining movements across ancient landscapes in the archaeological record.

There are distinct climatic phases during the Holocene that saw the people adapt differently. The populations were more sedentary at some point and were forced into a more mobile lifestyle as the weather conditions became adverse. Lithic analysis and specifically mobility have been studied using the cortex ratio method as well as raw material sourcing in other parts of the world. There is, however, a need to apply the cortex ratio model to the east African archaeological record to ascertain and/or establish the mobility patterns and land-use strategies employed by the people that lived to the East of Lake Turkana during the Holocene. This will facilitate the understanding of the different population responses to the lake level changes as well as the changes in the vegetation structure.

2.4 Theoretical framework

Theories systematically explain relationships among phenomena (Kombo & Tromp, 2006). Archaeological research assumes that the archaeological material remains are a true record of past human behaviour which can be reconstructed from those material remains (Peregrine, 2016:16). The archaeological record is, however, interpreted by the application of different schools of thought since all of them come back to the same idea at some level. Using a theory or a set of theories can aid an archaeologist to reconstruct the past. This study applied the following two theories:

2.4.1 Interpretive Theory

The interpretive theory is a post-processual theory that suggests that the archaeological record is a documentation of ancient behaviour that can help in the recovery of ancient thoughts, motivations and beliefs. The thoughts of past populations cannot manifest in the archaeological record as behaviour but must be teased out of the archaeological record through an interpretive process (Peregrine, 2016:18). Ian Hodder is one of the most influential proponents of the interpretive theory and suggests that the archaeological record can be understood and interpreted to get the underlying meanings, motivations and feelings just like in a book. His work focused on the Neolithic period (a time of transition from a mobile hunter-gathering lifestyle to sedentary agriculture). According to him, changes in decoration in pottery patterns in South Scandinavia reflect the increased differentiation in society. In his view, the underlying social conditions are transferred to pottery decorations and such decorations can be "read" and interpreted to disclose their underlying meaning (Hodder 1990 in Peregrine 2016:19).

In this study, the interpretive theory has been used to explain the reduction intensity, site use and raw material exploitation and transportation. The difference in the amounts of the available cortex on the artefacts was interpreted as a measure of distances traveled by populations during the Holocene. A decrease in the amounts of available cortex on the stone tools as well as the resultant cortex ratio values was, therefore, a reflection of increased mobility. This theory, however, falls short of explaining the relationship between the existing environmental conditions and the adaptation strategies employed by the Holocene populations. Consequently, the study also employed the theory of Cultural Ecology to fill this gap.

2.4.2 Cultural Ecology Theory

This theory was proposed by Julian Steward in 1955 who argued that even present-day traditional economies are precisely based on adaptations to particular environments. Phillipson (1977:252) observes that human beings continue to be affected by environmental conditions. Therefore, environmental resources, plants and animals, weather patterns, geography and topography need to be considered to understand human adaptive strategies.

The concept of Cultural Ecology has continued to evolve, becoming a subfield that primarily looks at the relationship between settlements, environments, geomorphology, social organizations and subsistence strategies. This theory helps to explain the adaptive strategies of the Holocene populations to the East of Lake Turkana. This study aimed at understanding the relationship between different climatic periods, a wet and humid phase and a dry and arid phase, and the adaptation strategies applied for their survival. For instance, with adverse conditions, the raw materials could have been procured from distant sources owing to the depletion of those in close proximity, resources utilized maximally, and retouching applied to lengthen the tool use period.

The artefacts could also have been used for longer periods, especially during the mid-Holocene. The study, therefore, sought to establish the relationship between the prevailing environmental conditions and their cultural adaptations through stone tool technology.

2.5 Research hypotheses

1. Temporal and spatial variation in stone tool modification reflects the different mobility patterns.
2. Temporal and spatial differences in land use patterns are related to varying access to raw material as well as changes in the palaeoenvironment.
3. Resource distances reflect the climatic conditions of the region

CHAPTER THREE

THE RESEARCH AREA AND STUDY SITES

3.1 Introduction

This chapter describes the research area. It begins by presenting a detailed description of the environmental and archaeological histories of the Turkana Basin. In particular, the chapter describes the geological setting, the palaeoenvironment as well as the palaeoecology. The chapter also presents information on sites under study, that is, their location, archeological histories and the finds recovered from them. The obsidian source sites to the East of Lake Turkana are also discussed.

3.2 Geological, Environmental and Population Setting

3.2.1 Geology

The base rock geology north of the lake comprises tertiary and Pleistocene basalts, phonolites, rhyolites and trachytes of the Ethiopian highlands. On the other hand, outcrops to the south consist of granites and gneiss that are largely covered by alluvium from the Omo River. There are Precambrian rocks that include quartzite, schists, and amphibolite in the basin. To the east of the research area, are the volcanic highlands of Surgei. According to Butzer (1980) Lake Turkana basin geology reflects very high stands at the onset of the Holocene, up to 80 m above recent lake levels, in which the present non-outlet lake sustained a connection to the Nile via the Sobat channel system northwest of the present Omo River delta. The different Lake Turkana levels during different phases of the Holocene are shown in Figure 3.1.

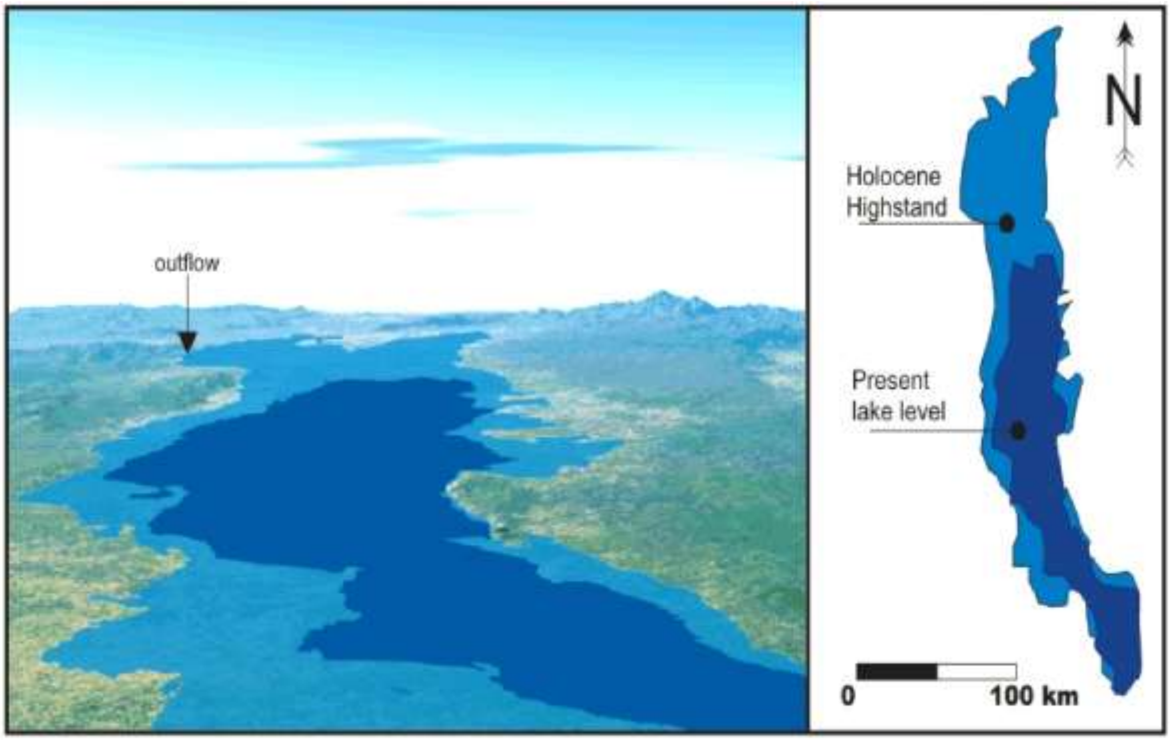

Figure 3.1:Turkana Lake level changes during the Holocene (adopted from Harvey & Grove, 1982:382).

Records of Lake Turkana levels have continued to be captured and show rise and fall over the years. Figure 3.2 shows the situation of the lake level changes for the last two decades. The constant falling and rising of the lake can be used alongside mobility patterns to better understand the past.

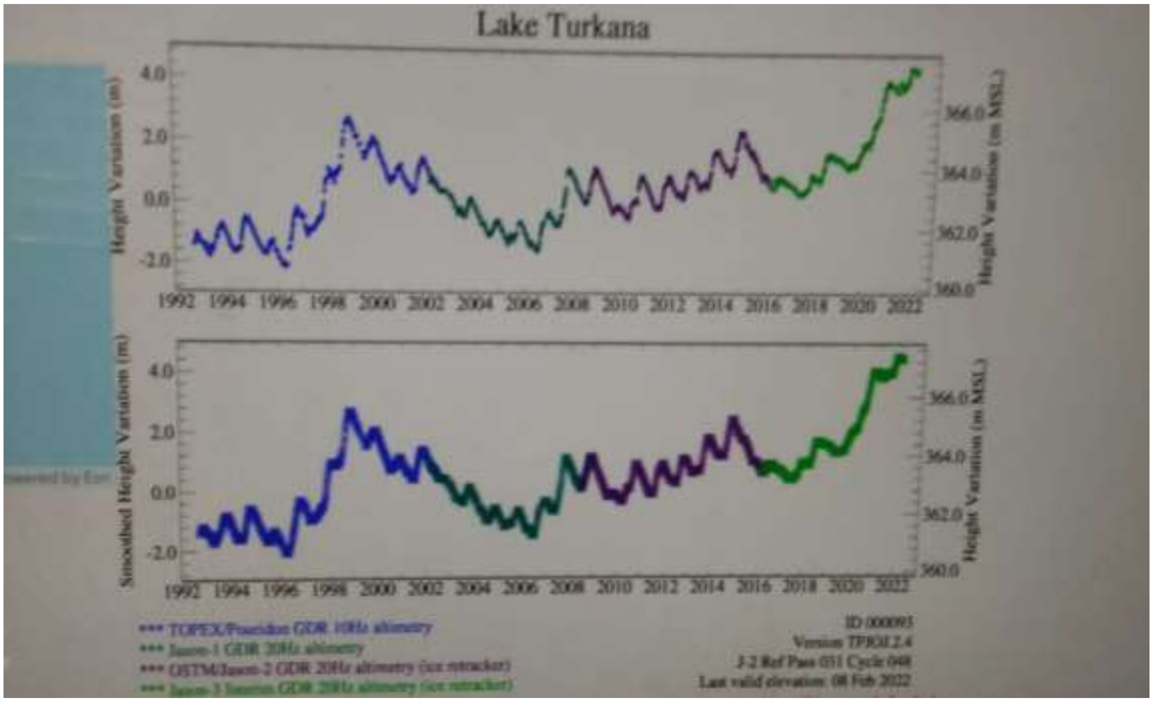

Figure 3.2: Lake Turkana Lake levels recorded in the last 20 years. (Retrieved online: 08/08/2022 TOPEX/Poseidon GDR 10Hz altimetry, Jason-1 GDR 20Hz altimetry, OSTM/Jason-2 GDR 20Hz altimetry (ice retracker) & Jason-3 Interim GDR 20Hz altimetry (ice retracker))

The sediments in the Turkana Basin date to more than 6 million years and have provided evidence of both biological and cultural evolution (Braun et al., 2009). There is a reduction in sediment for younger periods and most notable is the hiatus between 40,000- and 10,000-years BP, the late Pleistocene Holocene transition. The Galana Boi Formation dates to 10,000 BP and occurs around the lake margins (Owen et al., 1982). The sediments rise up to 80m above the average 365m present-day lake levels. The Formation preserves one of the most complete archaeological Holocene records in East Africa (Barthelme, 1985).

3.2.2 Contemporary Climate and Vegetation

The present landscape is dry and barren as opposed to the once fertile grasslands that supported both wild and domestic animals as well as human populations. The northeastern side of the lake supports diverse populations of plants and animals that are adapted to dry and semi-arid environments. The area currently receives two periods of monsoon-driven rain. There are long rains from March through April and short rains from October to December (Olago et al., 2009).

More recently, more irregular rainfall patterns culminating in ravaging droughts that kill large numbers of both livestock and wildlife have been observed and witnessed (Personal observation).

Spike grasses *(Sporobolus spicatus)* dominate the areas along the shores of the lake and are submerged when lake levels rise. The zones farther from the lake shores are sparsely covered with *Commiphora* and Acacia shrubs and trees with shifting sand dunes (Owen & Renaut, 1986). There is, however, relatively dense vegetation cover in areas covered by valleys and flood plains of seasonal rivers. In addition, vegetation along the main river channels is lined with taller acacia. The vast landscape is however bare and rocky with pockets of grasses viewed from a distance.

3.3 Archaeological history information and sites

Acknowledging the environmental and archaeological history of East Africa is essential in understanding the mobility, subsistence patterns, and origins of domestication and/or managed food production in sub-Saharan Africa. The Holocene in east Africa experienced different significant climatic episodes as recorded by palaeoenvironment data. These were marked by dramatic changes from the Early Holocene through the mid-Holocene (Garcin et al., 2012:328).

Lake Turkana reached a maximum of ~455m above sea level during the early Holocene and saw a decrease in-depth during the mid-Holocene (Butzer, 1980; Garcin et al., 2012:331). The lakes within the rift valley have provided excellent records of past climates. Core sediments and diatoms have been studied to understand lake-level changes. The lake levels have coincided with different climatic conditions over time.

According to Forman et al (2014:98), there have been four major fluctuations of up to thirty metres between 8500Kya and 4500Kya. These fluctuations are marked by seasons of overflowing waters during wet periods and receding waters during drier conditions. The water level shifts of Lake Turkana during the Holocene correspond to changes in the settlement and subsistence economies of the region and inform human adaptation strategies to environmental change (Wright, 2015:359). Climatic variation, as well as the shifts in subsistence strategies, affected the resource exploitation and mobility of the Turkana basin people during the Holocene.

The African humid period was characterized by brief wet seasons and/or events. The early Holocene was, therefore, cooler and wetter than the mid-Holocene and had reduced forest and woodlands and more grasslands (deMenocal et al., 2000). Reliability of fishing by the Holocene populations reduced during the Holocene dry phase which was still wetter than today. The Turkana region currently faces unpredictable weather patterns that comprise long droughts that are followed by floods (Personal observation). The vegetation cover and structure varied across the Holocene landscape, demonstrating heterogeneous habitats that were resourceful to the communities and livestock (Kinyanjui, 2018).

The reconstruction of shorelines during different phases of the Holocene Lake Turkana has not only allowed the connection between lake level changes and the archaeology of the Turkana basin— but also helped with predicting Holocene's reliance on aquatic resources. The prehistoric human diet also changed with the changing climatic conditions. Faunal evidence shows this shift from fishing to reliance on domestic animals. The mid-Holocene lithic data show the mobility of the populations at the time. Establishing the early Holocene mobility patterns as well as comparing them to those of the mid-Holocene gives a glimpse into how the Holocene populations responded to climate change.

3.3.1 History of Holocene Archaeology Studies in the Turkana Basin

Larry Robbins initiated studies in Holocene Archaeology in the Turkana Basin in 1967. He continued studying Holocene sites to the west of Lake Turkana through 1972, 1984 and 2006. In 1977, Gifford-Gonzalez (1985) scouted and analyzed materials from Holocene sites to the east of the lake. These were followed by Barthelme (1985), Stewart (1989), Kiura (2005) and Ndiema (2011). Recently, researchers have worked collaboratively to contextualize their findings from both sides of the lake. Hildebrand et al. (2011), Grillo et al. (2020), and Sawchuck et al. (2019), among others, have used different proxies to understand the Holocene lifeways. The second generation of Holocene research to the east of Lake Turkana was started by Ndiema (2010). This study is, therefore, a continuation of the second phase of the second-generation research.

Holocene research in the Turkana Basin has resulted in major discoveries and an understanding of how past populations interacted with their landscapes. Noteworthy are the burial pillars both to the west of the Lake at Namorotunga and Lothagam and to the east at Jarigole. Later Stone Age fishing settlement sites as well as the introduction of domesticates into diets have been documented. Pottery associated with different groups of people and time periods (Wavy line pottery, as well as

Ileret and Nderit wares) have all been recovered from these archaeological sites contributing to the migration and exchange narratives during the Holocene. The pottery sherds have further been analysed through molecular and isotopic evidence to hypothesize about the reliance on secondary livestock products, specifically, milk and meat as early as 5000 years present in Northern Kenya (Grillo et al., 2020).

The early Holocene sites have yielded numerous bone harpoons, fish bones, stone tools, mammalian fauna (mostly wild) and wavy line pottery (Robbins, 2006; Phillipson, 1977). The mid-Holocene sites, on the other hand, have yielded domestic faunal remains in addition to those finds at early Holocene sites (Barthelme, 1985; Marshall & Barthelme, 1984)). Barthelme concluded that the mid-Holocene communities that settled in this region practiced three distinct economies, namely, fishing, hunting and gathering as well as pastoralism.

Archaeological sites in Kenya are identified by SASES numbers as shown in Figure 3.3 below. Once a site is reported and coordinates shared, it is given a unique standard number that separates it from the closest site in proximity. In addition to the SASES provided by collection managers and IT experts at the NMK, some sites have names that are also used interchangeably. These are the sites that are further named by the locals and/or researchers working in that particular place. This could be names of physical features like hills or mountains in the region or could be the first word spoken following the discovery of the site, like Hallelujah in the Western Turkana Basin. In this study, only one site has both the SASES and a name while the rest are completely identified by their SASES numbers. The aforementioned named site is Lowasera, a name of a hill next to the site.

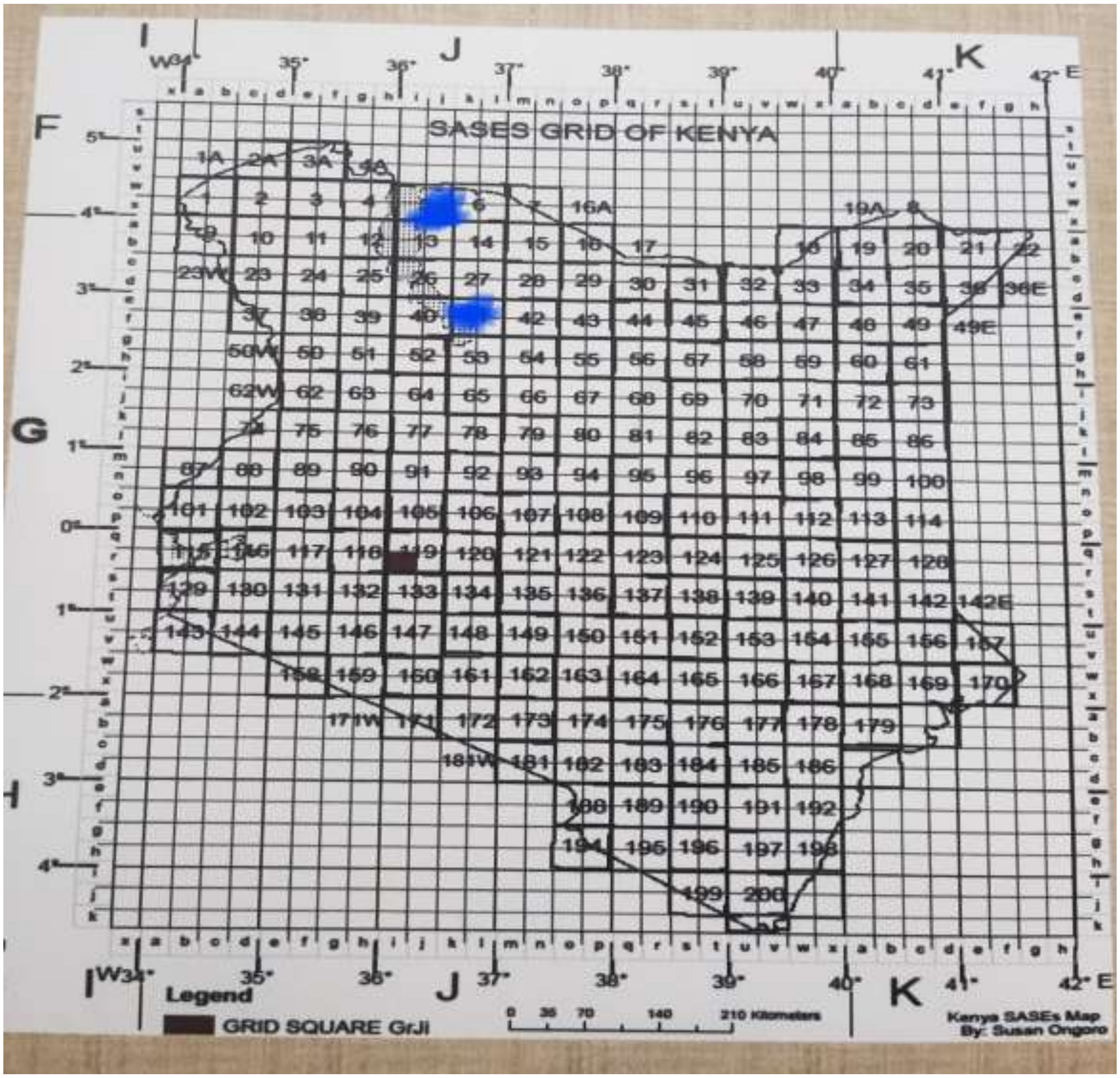

Figure 3.3: Kenya SASES map (By Susan Ongoro, NMK, 2021)

Five sites were studied, among them 3 early Holocene sites (FxJj 108, FxJj 12N) located on the Karari ridge and GeJk 4 (Lowasera) further south of the lake at Loiyangalani, and 2 mid-Holocene sites (FwJj 27 & FwJj 25W) in Ileret. These sites are part of the Galana Boi Formation, deposits that present ancient lake margins and they range from less than 1 metre to between 10 and 32 metres thick at different locations to the east of the Lake Turkana Basin. The Galana Boi unconformably overlies the Koobi Fora Formation (0.6 Ma) and extends to about 2000 km^2 (Owen et al., 1982). They are characterized by a grey sequence of lacustrine, marginal lacustrine and shoreline sediments, including poorly consolidated diatomaceous sediments, silts, sands, mollusks and fish remains (Barthelme, 1985; Owen & Renaut, 1986).

The Galana Boi deposits preserve a nearly complete Holocene archaeological record in the Turkana Basin (Barthelme, 1985; Owen et al., 1982). The site coordinates were recorded using a Garmin handheld GPS. Surface collections were mapped using the Garmin handheld GPS while the excavated materials were mapped using both the Leica builder 505 and the top corn (Ndiema, 2011). The Holocene sites have been differentiated according to dates confirmed through radiocarbon and OSL dating techniques, similarities and differences of material remains recovered at the sites as well as the elevation that would signify the depth of the lake at different Holocene periods.

3.3.2 Early Holocene sites

The early Holocene sites to the east of lake Turkana date to between 6000 and 10000 years ago (Ashley et al., 2011) and averagely have an elevation of 450m asl. They are distributed along the shores of the lake from the North to the southern tip of Lake Turkana.

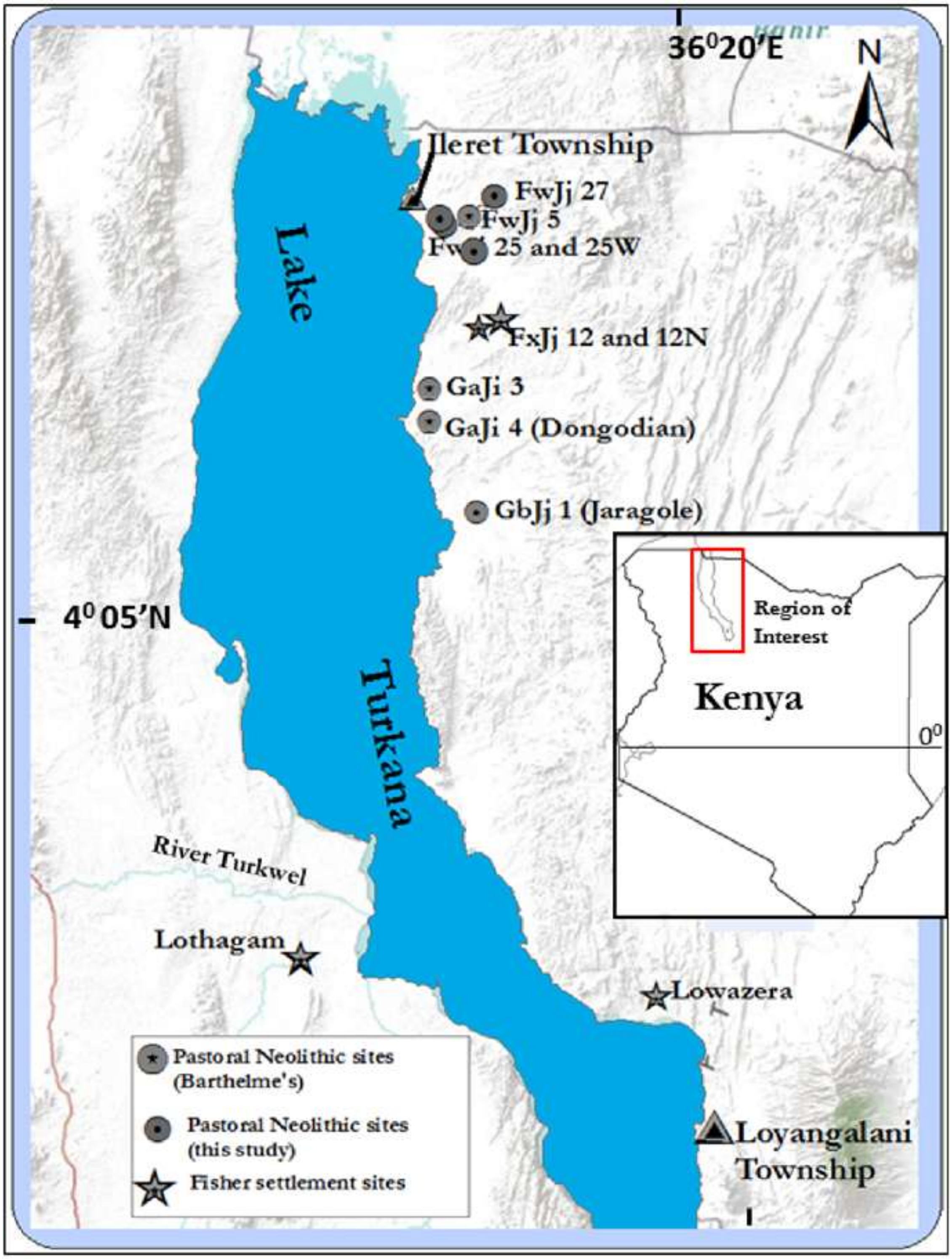

Figure 3.4: Map showing some pastoral Neolithic sites and fisher settlement sites in the Turkana Basin (Source: Ndiema, 2011: 56)

3.3.2.1 FxJj108

This site is located approximately 2.5 kilometers north of FxJj 12 in palaeontological collection Area 117. It was first surveyed in 2003 by Jack Harris and the team on the Koobi Fora Research and Training Project. The site yielded poor exposures and thus the researchers recorded it and did not explore it further during that field season. The site has beach sediments that are mostly stabilized by *Commiphora* shrubs on top and they spread all the way to the Karari ridge. Seven 1x1 metre squares have been excavated in 10 cm spits to a depth of approximately 0.5 metre for the last seven years. The materials were sieved using a 2mm sieve to ensure recovery of both macro and micro specimens. The findings are characterized by a large number of mammal and fish remains, stone tools (especially of the bladelet type), and wavy line pottery.

The raw materials for the stone tools at this site include lava/basalt, as well as chert, chalcedony and obsidian microliths. According to John Barthelme, this was a high-priority site for excavation, a recommendation he made after stumbling on it during one of his field seasons. The site has had numerous excavations under the leadership of Emmanuel Ndiema with the Koobi Fora Research and Training Program in the last decade to establish a sample size and to allow for dating. This site is yet to be dated and its classification is entirely based on elevation in addition to the archaeological finds recovered. The site has recently been inhabited by the Dassanach community as an abandoned boma sits on top of the site with livestock waste mixed with archaeological materials.

3.3.2.2 FxJj12N

This is a fishing campsite located in palaeontological collection area 117 on a prominent ridge adjacent to *Laga Aberegaye* (Barthelme, 1985). It is North of another early Holocene site less than a kilometre away, FxJj 12. The Galana Boi outcrops at this site cover approximately 100 metres in length and directly overlie the Tulu Bor tuff indicative of a very high wave beach concentration. Today, the Galana Boi deposits are thin, barely a few, meters due to heavy erosion in the area. In the 1980s the site had an artefact horizon which is associated with small pebbles and diatomaceous silts that yielded archaeological remains.

Cut-marked bones and other faunal (mammal and fish) remains have been recovered from this site (Barthelme, 1985). There are huge concentrations of artefacts (predominantly of basalt). A *Homo* skull has also been recovered in one of the gullies at this site. The site dates to about 9000 years. A younger date of 3200 years BP (Barthelme, 1985) was recorded for a higher horizon, and the 2017 field season recorded fish and mammal bones seen eroding from the surface that could be useful in case an excavation needs to be carried out (Ndiema, personal comm.). Materials from this site have been allocated 4001 as the KNM number.

3.3.2.3 GeJk4 (Lowasera)

Lowasera is a settlement site of stone tool fishers located on the southeast shoreline of the palaeo Lake Turkana near Loiyangalani. The site was discovered through a cinematographic expedition in 1974 by a team led by Couffer and reported to Phillipson. The first archaeological site visit happened later the same year with one of the expedition team members accompanying Phillipson's team and excavations followed in 1975. The site lies 22km north of Loiyangalani and is approximately 6.7km from the closest point of the modern shoreline. The site was named after a sand river/laga situated to the east of the site. The hill next to the site is also referred to by the same name, Lowasera.

The local geology includes a yellow-brown volcanic tuff on a ridge covered with lava boulders. There is also a narrow outcrop of Basement gneiss as well as a lava flow. Currently, there are only a few lakebed and beach deposits as most were eroded away by high Lake Turkana levels. Three areas remain that contain substantial deposits in situ that have evidence of prehistoric occupation. In 2018, a team of archaeologists led by Savino Di Lernia of Sapienza University relocated Phillipson's excavations and carried out more surveys and excavations at the site. According to Phillipson (1977), the beach stood between 73 and 82 m above the current lake level.

The site has yielded potsherds (both decorated (wavy line) and undecorated pieces), shell beads, barbed bone harpoons, fauna and lithics. Microliths are relatively abundant at the site with occasional macro lithics. There is a diverse range of raw materials from quartz, quartzite, chalcedony, chert, obsidian and basalts. Faunal remains mainly comprise fish but modern human skeletal and other mammalian remains have also been recovered from this site. The site dates to about 7,000 years BP (Phillipson 1977: 9).

3.3.3 Mid-Holocene sites

As already stated above, this study examined materials from two of the mid-Holocene sites located east of Lake Turkana (Fig. 3.4). They generally date to between 6000 and 4000 years ago and are part of the Galana Boi formation. The sites under study are generally located in paleontological collection area 10 in the Ileret sub-region in Koobi Fora.

3.3.3.1 FwJj25W

This site is located in the Koobi Fora palaeontological collection area 10 on the eastern shores of Lake Turkana and has produced the largest Holocene archaeological assemblage in this region. It was discovered in 1995 but was first excavated in 2005. It was dated by OSL to 4.2+/-0.28 Kya (Ndiema, 2011:86). Galana Boi deposits at this site are distributed discontinuously over the landscape. Faunal remains, lithics and pottery have been recovered from the site. The site is 442m in elevation and thus lower than the ~445m lake level during the mid-Holocene. Targeted surveys, as well as excavations, have been undertaken at this site. In 2008 while carrying out targeted surveys, a dense scatter of artefacts led to the decision for the site to be excavated (Ndiema, 2011: 87). A substantial amount of archaeological evidence has been recovered from this site.

The sediments are well-stratified and get coarser with increasing elevation. Those close to the surface are fine while the ones towards the bedrock are pebbly and coarse. This sediment record is indicative of receding lake levels that produced beach deposits blanketed with sand dunes. Archaeological evidence recovered from this site includes stone tools, ceramic sherds, faunal remains (domestic and wild fauna), charcoal fragments, red ochre and ostrich eggshell fragments and beads (Ndiema, 2011).

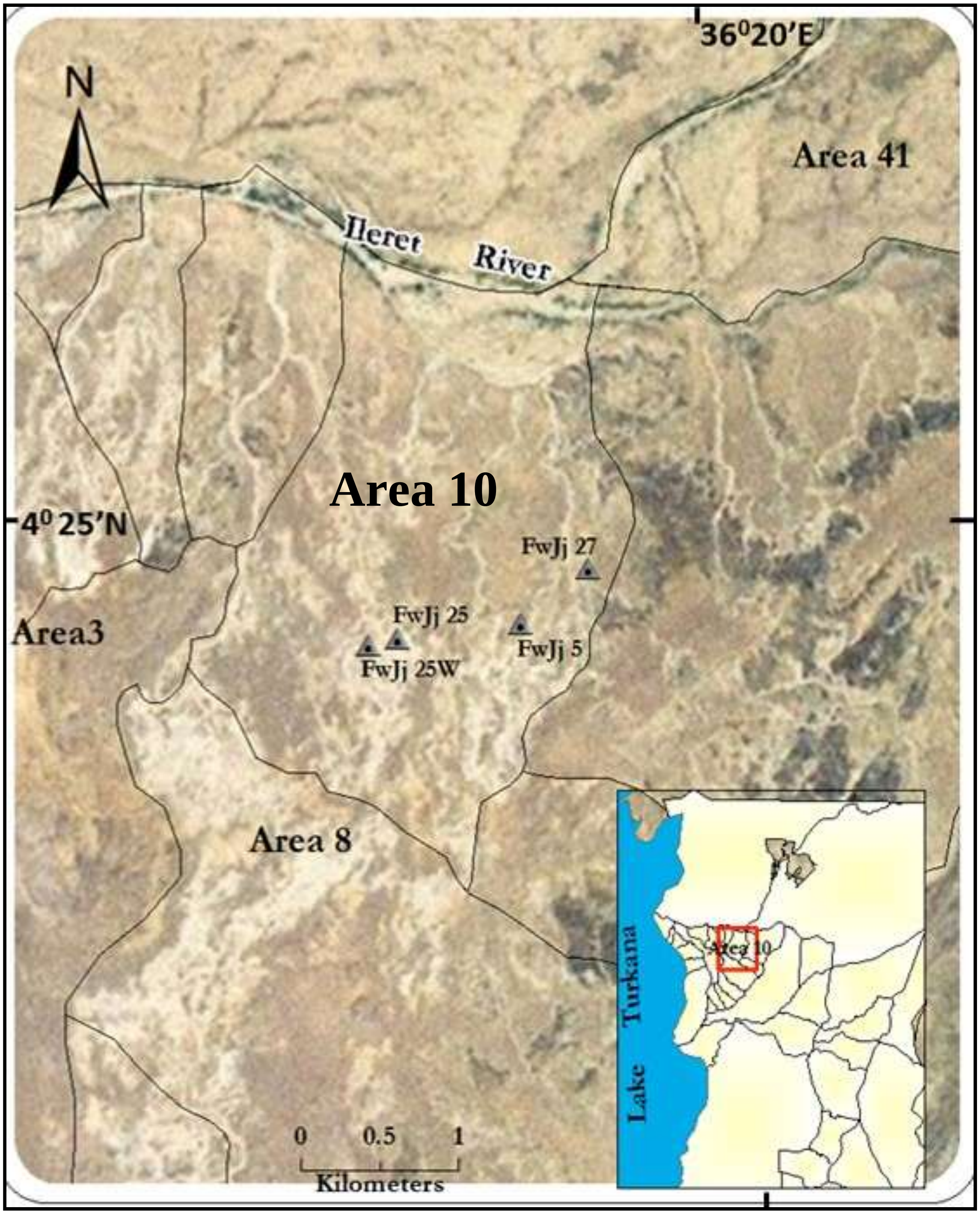

Figure 3.5: Map showing mid-Holocene sites in Northern Kenya (Source: Ndiema, 2011:85).

3.3.3.2 FwJj27

This site is located in the palaeontological collection area 10 to the east of Lake Turkana. It was discovered in the late 2000s and its mid-Holocene transition is represented by nearly complete modern human skeletal remains interstratified with an artefact assemblage in situ. The site stands at 442m above sea level and so it is lower than the ~455 position of the highest lake level during the mid-Holocene. Targeted surveys and excavations were carried out by a team led by Dr. Emmanuel Ndiema from the National Museums of Kenya. Archaeological finds as well as geological features and topographic profiles were mapped using a total station. The upper beds consist of individual shells and shell fragments of gastropods and mollusks. The lower beds, on the other hand, have lenses of shell on a sharp erosive surface underlying the early Holocene grayish silt-clay sediment.

The sediments from this site were dated using OSL-dating to 4.30+/-0.27BP (Ndiema, 2011:108). The site has yielded a relatively small assemblage with a few pieces from the surface and in situ. The assemblage comprises faunal remains (mainly fish bones), lithic artefacts and potsherds (Ndiema, 2011:111). Figure 3.5 shows some Holocene sites to the East of Lake Turkana. The East of Lake Turkana Basin has extensive coverage of Galana Boi deposits that stretch mostly along the lake and shorter distances for those relatively further away. There exist both reported and studied sites. Figure 3.5 below shows some of the Holocene sites

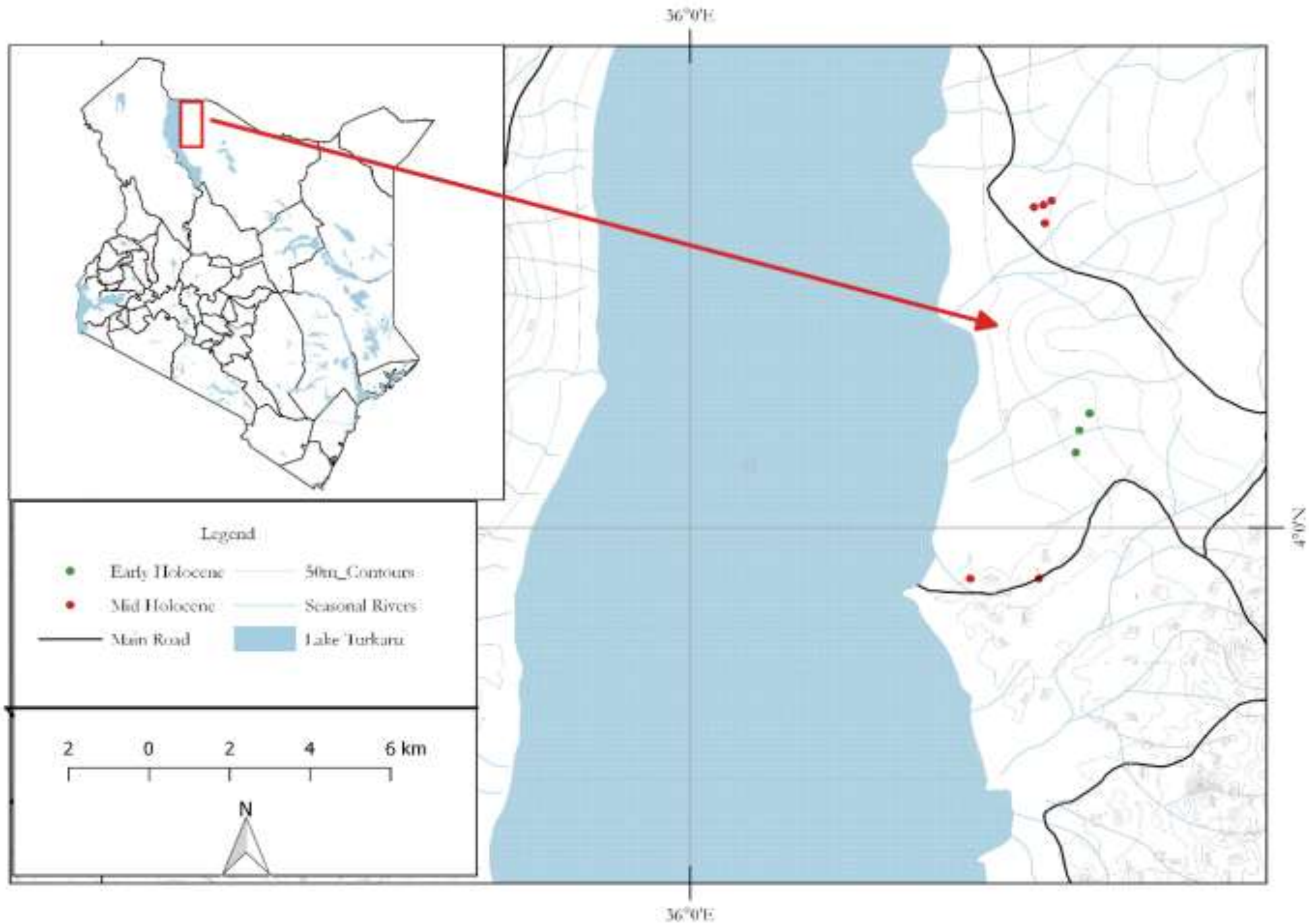

Figure 3.6: Map showing some Holocene sites East of Lake Turkana (Source: Akinyi, 2017)

The Holocene sites in the Turkana basin have been dated using different techniques. Optically simulated luminescence (OSL) and radio carbon (C-14) methods have specifically been used to date these sites. However, one early Holocene site is yet to be dated. This site, FxJj 108, was included in this study based on its elevation and the materials recovered from it. **Table 3.1** below shows a summary of the sites under study and their dates.

Table 3.1: Sites under study and their dates (Kya) (Adapted from Phillipson, 1977; Ndiema, 2011)

SITE	OSL DATE	C14 DATE
GeJk4	–	7.47+/-0.2
FxJj108	–	–
FxJj12N	–	9.00+/-0
FwJj25W	4.140+/-0.53	–
FwJj27	4.30+/-0.27	–

3.4 Sources of obsidian, East of Lake Turkana

Obsidian is abundant in the Great Rift Valley and is generally found in many volcanic areas of the world (Negash et al., 2007). An initial investigation of obsidian sourcing was conducted by Mary Leakey in the central rift (M. D. Leakey, 1945 in Ndiema, 2011). However, it was not until the 1960s that trace element analysis was basically used. In the mid-80s however, Merrick and Brown initiated the obsidian sourcing and characterization project and later expanded it to include the Turkana Basin.

Surveys conducted in the Turkana Basin have suggested that obsidian sources are few and generally localized geographically (Merrick & Brown, 1984). The sources are located in different parts of the region mostly further from the lake margins. The sources mostly contain small-sized pebble lapilli or nodules and very few boulder sizes (Ndiema, 2011). The sites include North Island- an island in the Lake Turkana, Surgei, Shin and Suguta and are shown in Fig 3.6.

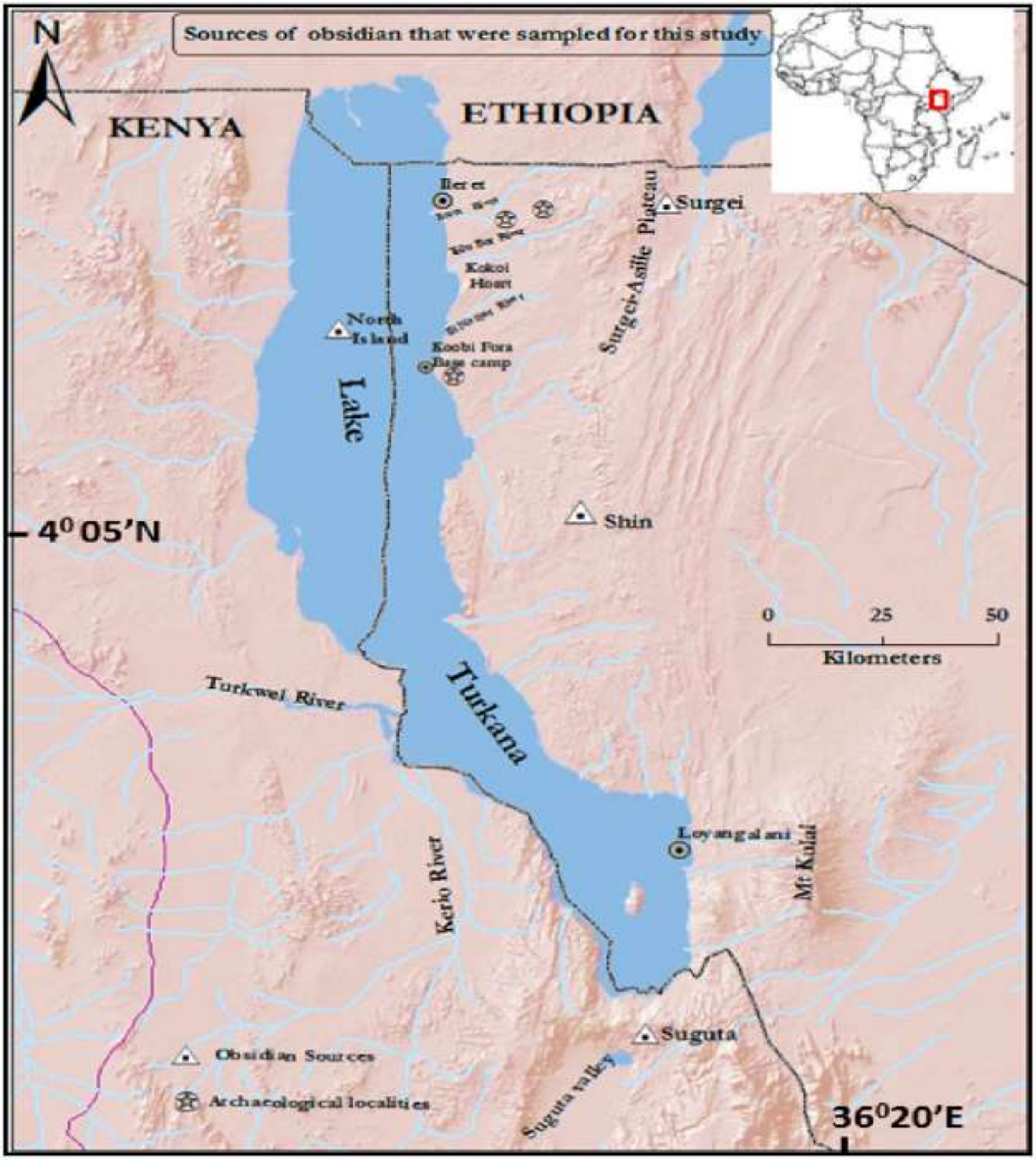

Figure 3.7: Map showing obsidian sources considered for this study (Source: Ndiema, 2011:61).

CHAPTER FOUR

METHODOLOGY

4.1 Introduction

This chapter outlines the two methods used in this study: Cortex ratio analyses as well as geochemical characterization of obsidian artefacts. The steps taken to gather and analyze the data for this study are then explained after mentioning the materials.

4.2 Materials

The lithic assemblage used for this study was excavated under the directorship of J. Barthelme in the 1980s and E. K. Ndiema in the 2000s. The specimens available for analysis had been collected from the surface during targeted surveys and excavated, catalogued and stored in wooden trays according to their sites and when they were recovered. The excavations were done by grids of 1m by 1m and later extended as deemed fit for the research questions at hand. The lithics were catalogued and given specimen numbers for those mapped in the excavation squares, as well as the surface, finds. Those recovered in the sieve were given identification numbers (IDs) during this analysis. These assemblages are housed at the archaeology laboratory of the National Museums of Kenya in Nairobi.

The data presented and interpreted in this study as part of the Holocene assemblages include 688 obsidian artefacts. These artefacts range in size from less than a centimetre to slightly more than two centimetres in length. I attributed the small sample size to the general pastoral way of life as they tend to have fewer material possessions. There exist other raw materials (chert, chalcedony and basalts) at the sites that were not considered in this study.

4.3 Methods

This study employed a couple of methods in data collection and presentation. The investigated sites were chosen through purposive sampling. The early Holocene site, FxJj108 was studied because its archaeological assemblage has not been analysed before. FxJj12N is a bit farther (approximately 1.5 kilometers away) from FxJj108. It was analyzed by Barthelme in the 1980s. FxJj108 and 12N are closer to the North Island obsidian source. Lowasera, on the other hand, is farther south of the Lake and closer to the Surgei obsidian source. The mid-Holocene sites studied were previously studied by Emmanuel Ndiema. Therefore, there is available obsidian artefact source data from these sites, thus the possibility of comparing them to those analysed for the early Holocene in this study.

4.3.1 Data collection, recording, processing and analysis

This study used materials in the laboratory at the National Museums of Kenya. The initial step in the data collection process was tracing artefacts in the archaeology laboratory for analysis. I liaised with the collections manager at the laboratory in order to locate the archaeological assemblage for the sites. The trays were taken out of the racks and placed on the benches for analysis.

Data from each specimen (obsidian stone tool) were recorded as explained below:

Site name: The site names were recorded in order to distinguish data of one site from the other one. Other than Lowasera, which is named after the hills in close proximity, the rest of the sites were recorded by their SASES numbers, e.g., FxJj12N.

Artefact ID: Each specimen has a unique identifying number; some of which were issued in the field by those who collected them while others were issued during this analysis in the laboratory. Those issued in the laboratory were mostly recovered from the sieve during excavations.

Size: Two size categories were used for this study, micro (<2cm) and macro (>2cm). This is because the Later Stone Age industries are generally characterized by microliths.

Artefact type: Debitage type was recorded for the whole assemblage. To avoid subjectivity, Braun's (2008) classification was followed to aid with definitions used in this study. Core frags, flakes as well as angular fragments were recorded in the artefact type column. Identifiable microliths, for example, crescents and blades, were recorded under the notes section. This is because different artefact types, for example, the blades, require tool preparation before they are made, and this tempers with the interpretation of the amounts of available cortex on them.

Colour of obsidian: This is not a very reliable way to tell apart different types of obsidian, but it is helpful in overall sampling. Green, opaque, brown, and grey colours were recorded. These were most useful for the sampling for XRF analysis

Coordinates, X, Y, Z values: Exact location of the artefacts was recorded using a Garmin handheld GPS. The elevation is mostly useful in determining the location in relation to the palaeo-lake stand and hence determining whether it is an early or mid-Holocene site.

Mass: The artefact weight was measured and recorded in grams. This was useful in determining the volume of the original obsidian nodule.

Maximum dimensions: Maximum length, width and thickness were all taken using a digital vernier caliper. The dimensions were recorded in millimetres.

Observed cortex (% cortex): Each detached piece was assigned to one of the five cortex proportions: 0%, 25%, 50%, 75%, or 100% (Lin et al., 2015).

Platform type, retouch, rounding and termination: All these were recorded in the notes section to assess flake sequence, tool use and original cortex from rounding

ED-XRF analysis of obsidian artefacts from early Holocene sites at UoN Institute of Nuclear Science

A visit to FxJj 108 to put into context the Holocene of East Turkana Basin

Cortical and non-cortical obsidian artefacts

Plate 4.1: showing a summary of different stages taken for data analysis and contextualization

4.3.2 Cortex ratio analysis

The whole population (688 artefacts) were analyzed following the small assemblage from the five sites under study. Cortex ratio is the ratio of the total cortical surface area present in an assemblage to the amount of cortex that should be represented when it is assumed that the nodules present are a representation of cores completely reduced and discarded in this location (Holdaway et al., 2004). The methods for calculating observed and expected amounts of cortex were calculated following Douglass et al. 2008 and Lin et al. 2015. The observed amount of cortex is achieved by summing up the cortical surface area found on each artefact. This requires providing an estimate of the cortical surface area for each artefact within the assemblage. All artefacts were analyzed as detached pieces where the surface area was estimated by multiplying the maximum length of an artefact with its maximum width. The resultant surface area was then multiplied by the proportion of cortex of the artefact to obtain an estimate of the cortical surface area. The cortical surface area of each artefact was then summed up to obtain the observed amount of cortex within an assemblage.

On the other hand, the expected amount of cortex was determined by estimating the number of nodules necessary to create an assemblage of a specific size, as well as the average size and initial surface area of its nodules. Here, it was assumed that the number of nodules needed to create an assemblage would be equal to the number of cores found in each assemblage (Douglass et al., 2008). By dividing the overall volume of the collection by the total number of assemblage cores, the mean initial nodule size was estimated. Once all variables were collected statistical analysis using R package was carried out to determine the ratios.

They were then interpreted following Douglass et al. (2008) interpretation where a ratio of one implies onsite production; that means that the tools are recovered where they were manufactured and the further you are from the location of manufacture, the lower the ratios. An example is a ratio of 0.9 is closer to the production site than a ratio of 0.5. The lower the ratios the further they are from their production site and since the movement of stone tools tracks human mobility then the ratios can be used to determine the mobility of Holocene populations on the eastern shores of Lake Turkana.

4.3.3 Geochemical analysis

A total of 18 obsidian stone tools were analysed as a result following multi-step sampling. Though not a definitive quantifier of obsidian type, color was used as the first step in getting the sample for this study. Opaque, grey, brown and green obsidian artifacts were separated by site. After which the rest were purposively selected; they had to have relatively flatter surfaces. For the larger assemblages, the required number, 2 in this case was randomly selected. With the sample ready, the artefacts were first brushed over to remove the loose sediment attached to them. Once clean, two surfaces of each artefact were exposed to primary X-ray beams. Trace element concentrations from the two surfaces were then averaged. Dello-Russo (2004) states that exposing multiple surfaces, two in this case minimizes the possibility of the data being affected by uneven concentrations of trace elements. Objects with flat surfaces are preferable for this method. If they are naturally occurring pieces, then it would be advisable to come up with thin slices to be exposed to the radiation. However, artefacts, being of cultural significance, should not be sliced through and, therefore, we could only expose multiple surfaces and average the findings.

An ED-XRF laboratory-based spectrometer housed at the University of Nairobi's Institute of Nuclear Science (see Appendix 5) was used for measurement. Finestone et al. (2020) assert that semi-quantitative ED-XRF can be used to establish geochemical differences among different sources. The Amptek Experimenter's ED-XRF Kit (a division of the AMETEK Electronic Instruments Group) was used to analyse 18 obsidian artefacts. This spectrometer has an X-ray tube with a silver target anode and a silicone drift detector. The instrument was set at a voltage of 30-kilo Volts (kV) and a current of 80 milli-amperes (μA).

Each artefact was placed on a sample holder and irradiated for 200 live seconds. Additionally, each artefact was irradiated two times on two different phases. The spectra were collected using an Amptek DppMCA Display and Acquisition software and stored. Spectral data were de-convoluted using AXIL (Analysis of X-ray spectra by iterative least-squares fitting) software. Processing of the spectra included:

1) format conversion of the spectrum, and

2) fitting the spectrum to obtain respective areas of peaks of elements of interest.

Concentrations of different elements were calculated by the direct comparison method (achieved by relating different areas of the respective peaks to the concentration values in parts per million (ppm) (Brouwer, 2010). Using known USGS standards analysed for this study, the relationships between concentrations and peaks were calculated. Calibration was done using commercially available USGS standards.

The elemental concentrations of the artefacts were calculated from a total of five USGS reference standards. These included RGM-1, BIR-1, SCO-1, BVHO-1 and W-2. To test the efficiency of the calibration curve, intensities of the characteristic elements were plotted against respective concentration values by use of a direct comparison method in the AXIL programme. The resultant calibration curve was then used to quantify the elements of interest.

The findings were saved in Excel and different regressions were run using both R and basic Excel to first establish ratios of different trace elements and then match sites to sources in the east Turkana Basin.

4.4 Presentation of findings

Photographs (plates) have been used to elaborate some attributes (presence of cortex as well as its absence) under study. The photos also show some of the core fragments available from the sites under study. The findings from quantitative data are presented in tables and charts to illustrate the findings. Descriptions have also been used to present the study findings. A list of figures is attached at the end of the document.

4.5 Ethical Issues

Archaeological research must be done in a professional way (Sharer & Ashmore, 2003). Additionally, the Museums and Heritage Act of 2006 gives guidance on handling and working with archaeological and cultural materials. Among these are:

1. Acquisition of a research permit prior to carrying out research.
2. Research findings should be disseminated at the museum and a copy filed with the respective section.

3. Responsibility with archaeological specimens, i.e., these should be handled with care and returned upon borrowing.

The process of this research entailed the acquisition of a permit from the National Museums of Kenya to allow me to carry out lithic analysis in the laboratory. This was followed by a meeting with the head of the Archaeology section. I also got permission from the Museum to take samples to the University of Nairobi's Institute of Nuclear Science to carry out geochemical analysis.

The obsidian artefacts studied were handled with care both while taking measurements, checking for available cortex and when being photographed. Once done with a particular collection, the specimens were returned to their respective trays and put back on the racks in their original places/locations.

ED-XRF was the other method, and this does not pose a threat or destroy the cultural materials under study (Obsidian in this case). The artefacts were only exposed to the x-rays for 200/s per session to minimize the amount of exposure. Protocol was followed to ensure proper handling and non-exposure of the x-rays to humans in close proximity. The casing covering the stone artefacts was always closed before the process was initiated for each artefact. Once the chemical characterization data had been collected, the artefacts were taken back to the Archaeology section at the National Museums of Kenya for storage in their respective locations.

The ultimate goal for research is to report findings without Bias (Champe et al., 1961, cited in Nyanchoga, 2012). These results will be made available to both private and public audiences through this project paper, conferences and workshops.

CHAPTER FIVE

RESEARCH FINDINGS

5.1 Introduction

The materials analysed for the early and mid-Holocene sites were both from surface collections and excavations by John Barthelme in the 1980's and Emmanuel Ndiema from 2008 to 2019. A sample of 688 obsidian stone tools was analysed for cortex ratio and 18 obsidian stone tools analysed for ED-XRF. The Geochemical findings presented here are for the artefacts from the early Holocene sites that are to be compared to those established in mid-Holocene sites from previous studies.

5.2 Raw material and raw material sourcing

The raw material used in this study was obsidian. This raw material has good properties that allow it to fracture. It has a cryptocrystalline structure and is elastic. Obsidian is a rare raw material that can be used to predict mobility. To the east of the Turkana Basin, there are currently four known obsidian sources. One of these locations is North Island, an island in Lake Turkana. The rest stretch from the North to the southern edge of the basin margin including Suguta, Surgei and Shin.

5.3 Geochemical characterization

Obsidian raw material sources were geochemically distinguished by rare trace elements such as Nb, Y, and Zr. North Island and Shin are the most distinct sources. Notably, the Zr/Y ratios for Shin are higher (9-11/ppm) than those for North Island (5 - 8/ppm). These findings are shown in Figure 5.1 below.

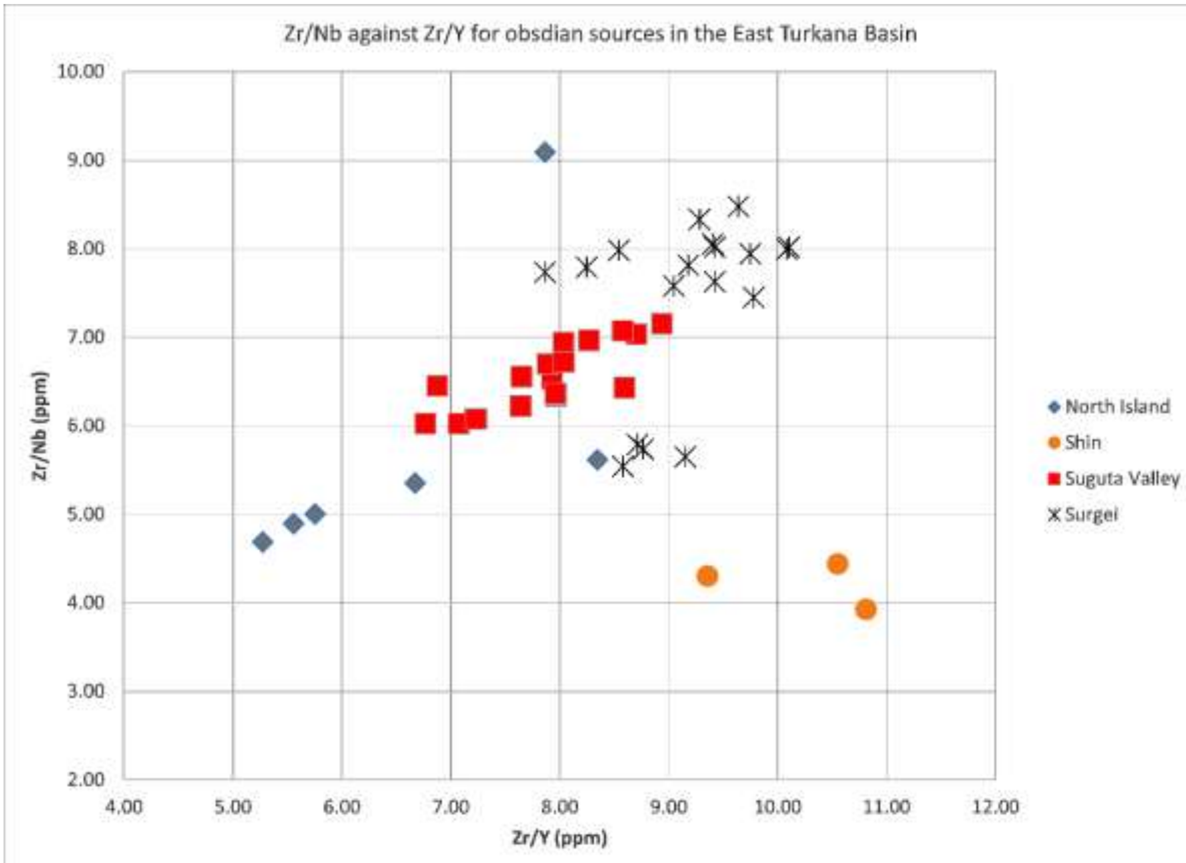

Figure 5.1: Sources of obsidian within the East Turkana basin as a result of plotting ratios of Zirconium (Zr) and Yttrium (Y) against Zr and Niobium (Nb).

There is, however, a high intra-site variation at the obsidian sources, and Shin seems not be a preferred raw material source for the sites studied. Surgei and Suguta seem to share some geochemical similarities as some of their values overlap. The artefacts from the early Holocene populations relied on these sources in the east Turkana basin.

When elemental ratios are plotted against each other, for instance, Zr/Y against Zr/Nb they predict three possible sources. However, specific elemental plots, for example, plotting Zirconium (Zr) against Niobium (Nb), indicate that there might have been four sources of obsidian for the early Holocene populations. The Early Holocene sites in the Turkana basin, therefore, can be said to be getting their raw materials from three to four sources as shown in Figures 5.2 and 5.3. This contrasts with the variety of sources explored by the East Turkana Basin's Mid-Holocene populations. However, ratios are preferred when performing geochemical characterization because they reduce errors and increase the chances of matching raw materials to their sources.

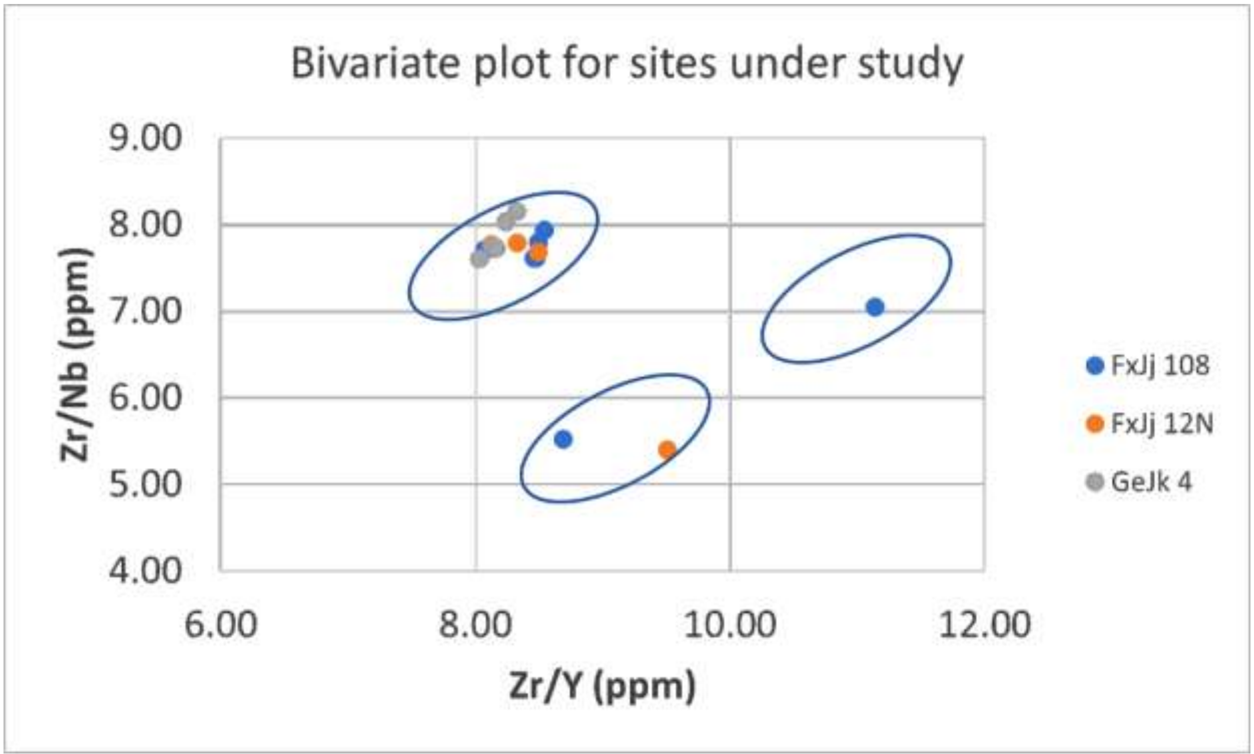

Figure 5.2: Bivariate plots for Zr/Y, Zr/Nb for obsidian artefacts from the early Holocene sites

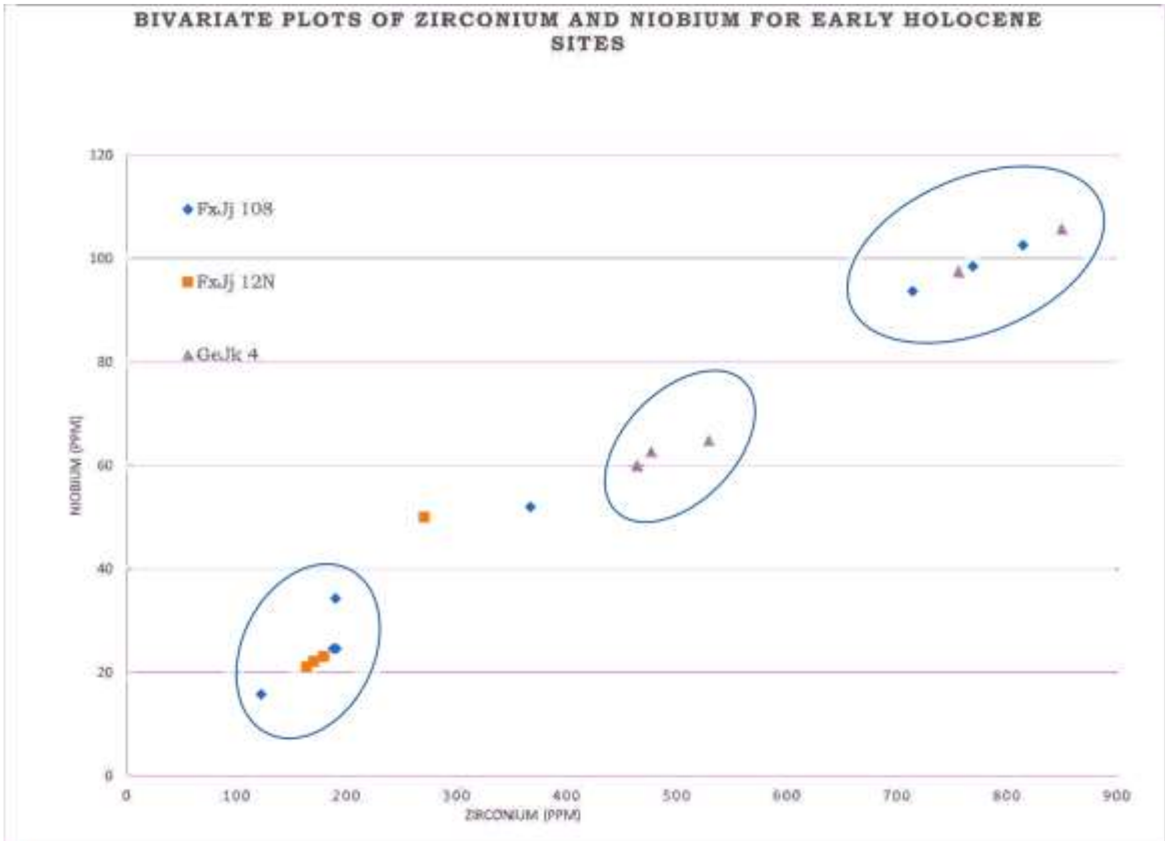

Figure 5.3: Elemental plots of Zr against Nb for early Holocene sites

Raw material sourcing during the early Holocene within the East Turkana Basin shows variations in material sources between sites, although all sites depict multiple sources. These populations sourced from similar sources as shown in Figure 5.5. The established sources in East Turkana Basin account for Ninety-four percent of the artefacts analysed. GeJk 4, FxJj12N and FxJj108 used obsidian from Surgei as indicated by plotting Zr/Y against Zr/Nb for both sites and sources of obsidian within the Turkana Basin (Figures 5.4).

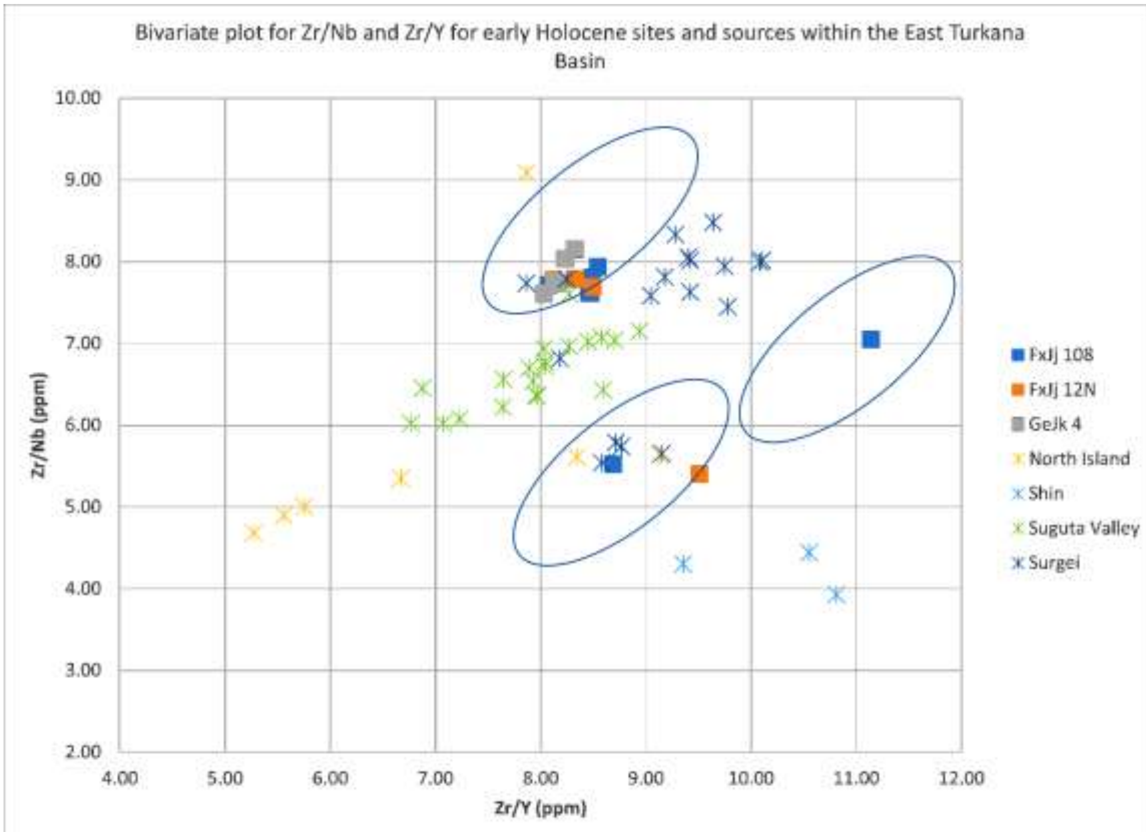

Figure 5.4: Zr/Y against Zr/Nb plot for sources and sites in the east Turkana basin

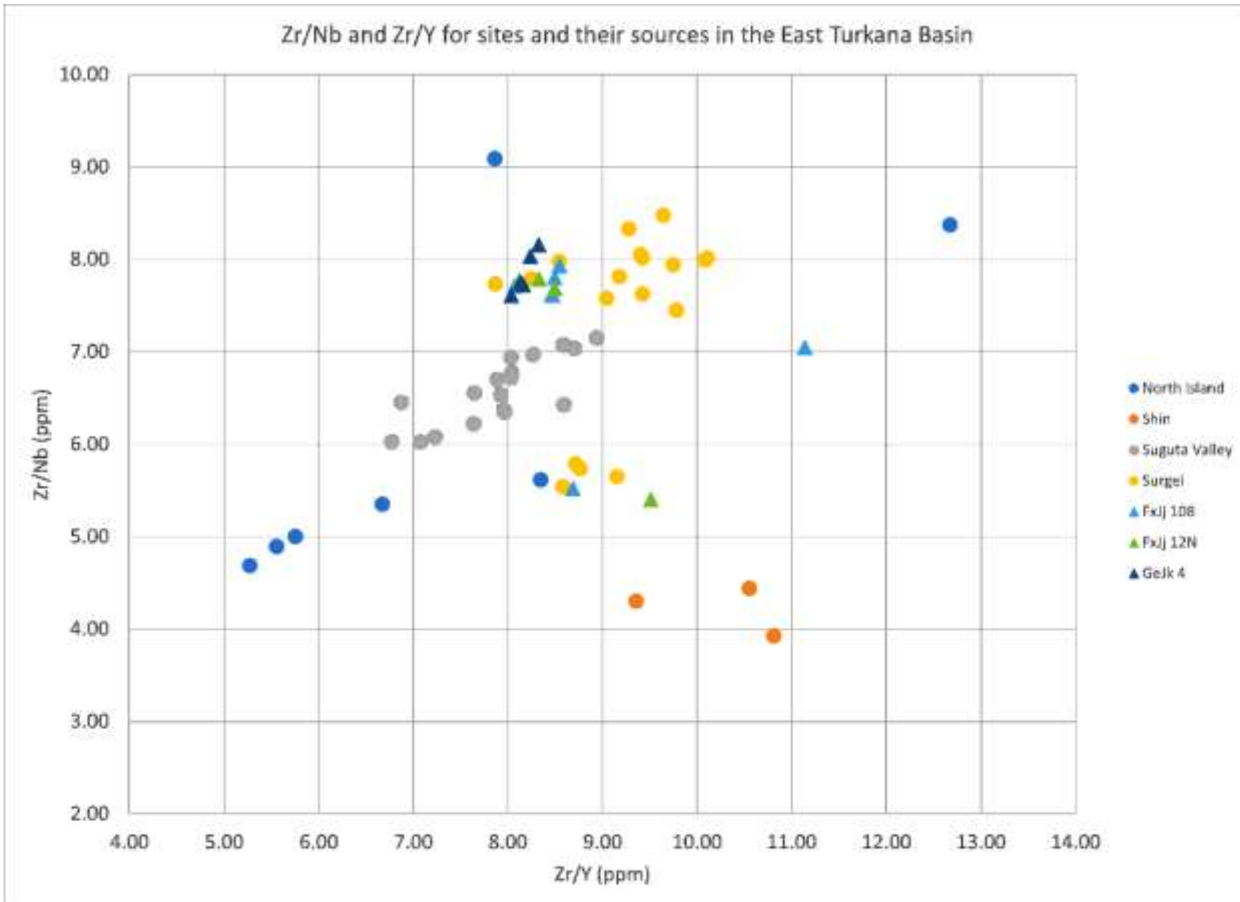

Figure 5.5: Sites against sources in the East Turkana Basin

Ninety-four per cent of the total artefacts analysed for the early Holocene sites, were identified to their sources (Table 5.1), in contrast to Mid Holocene sites where only 66% were identified to sources. This indicates that most of the populations in the early Holocene relied on sources from the East Turkana Basin. Early Holocene populations relied on fewer resource bases while the mid-Holocene ones diversified their resource bases (more unmatched sources**).**

Table 5.1:Distances in kilometres between sites and sources in east Turkana Basin

	GeJk4	**FxJj108**	**FxJj12N**	**FwJj27**	**FwJj25W**
Shin	162.74	35.6	36.91	22.53	24.29
Surgei 1	162.71	37.15	38.41	24.97	26.74
Surgei 2	162.84	31.29	32.75	14.84	16.53
North Island	145.16	32.82	32.82	38.47	36.81
Suguta	87.95	215.02	213.46	236.23	235.78

The following three sites (FxJj108, FxJj12N and GeJk4) shared one source, Surgei. GeJk4 (Lowasera) is most distant from Surgei (162km) among the sites relying on this source. FxJj12N and FxJj108 are averagely 38km and close proximity might have been the reason for populations occupying these sites to have had it as a preferred source. Irrespective of the source distance however, the stone tools are heavily reduced, all ranging between <1cm to <3cm in maximum dimensions. This is the case for both cores and detached pieces for all sites studied.

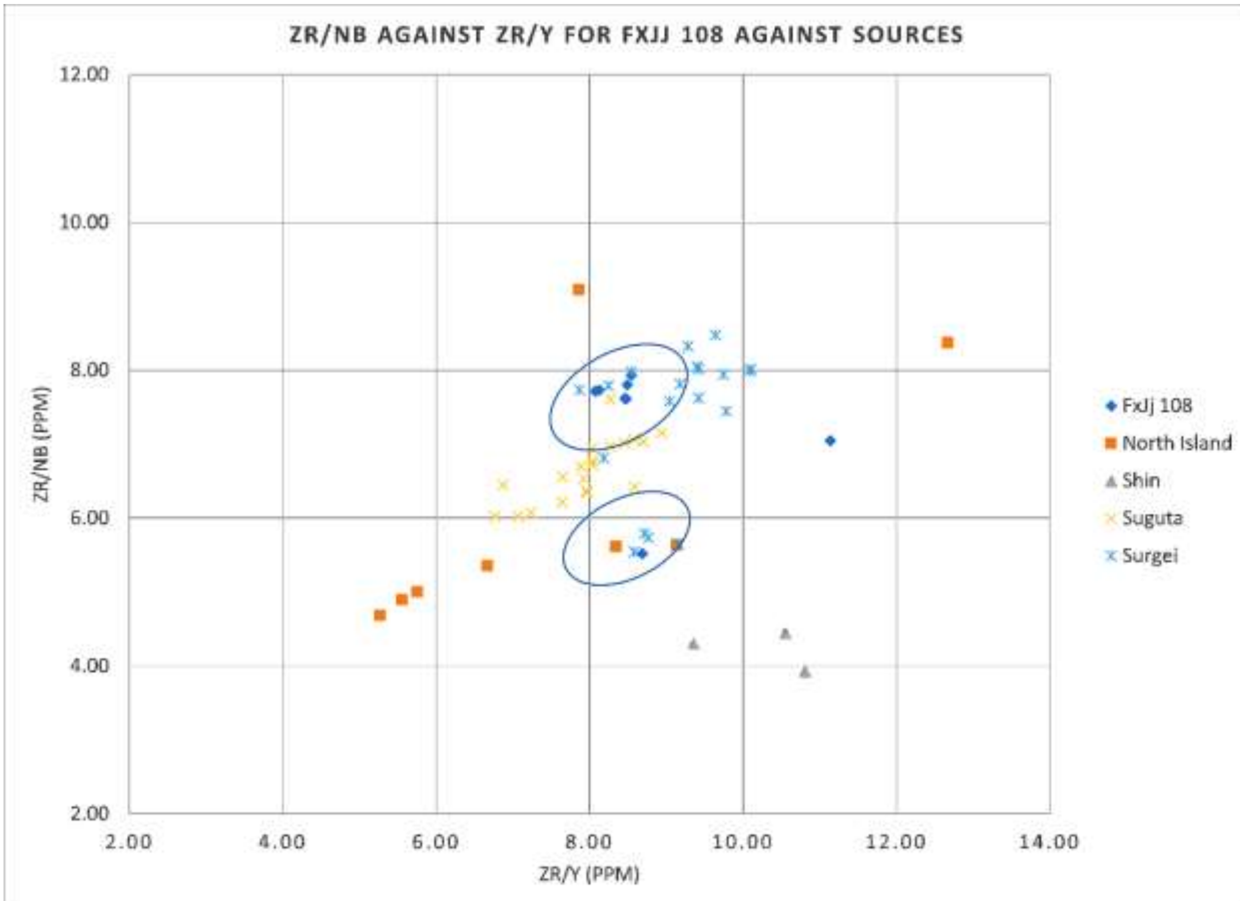

Figure 5.6: Results of Zr/Y against Zr/Nb for FxJj 108 and the sources

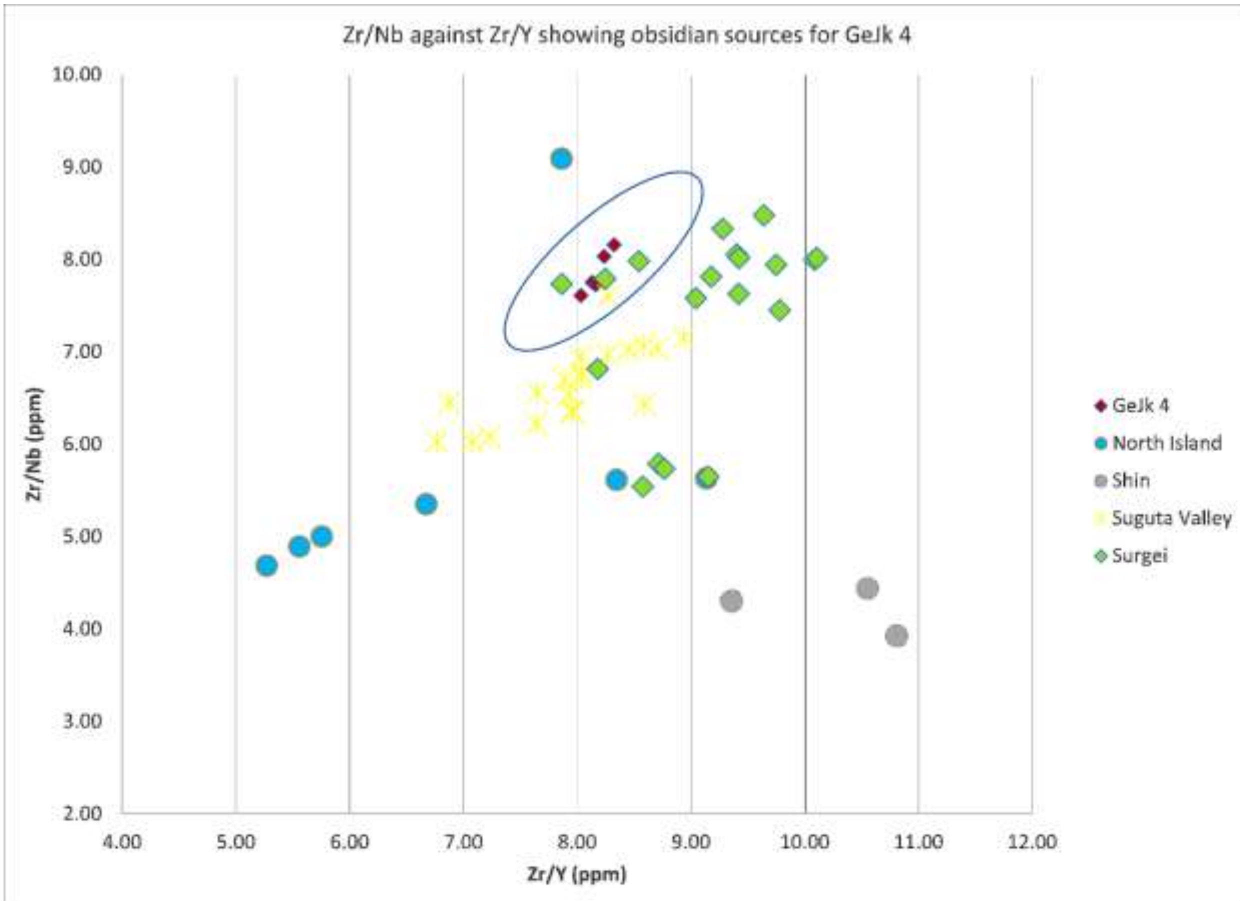

Figure 5.7: Sources for GeJk 4

FxJj108 exhibits multiple sources within the site. The people at this site sourced from Surgei, possibly North Island and from an unknown source (Figure 5.6). GeJk4 sourced from two sources, Surgei (162km) and Suguta (88km). FxJj12N, on the other hand, only sourced from one source, nearest to the site but still quite far (38km). The findings are shown in Figure 5.7 above.

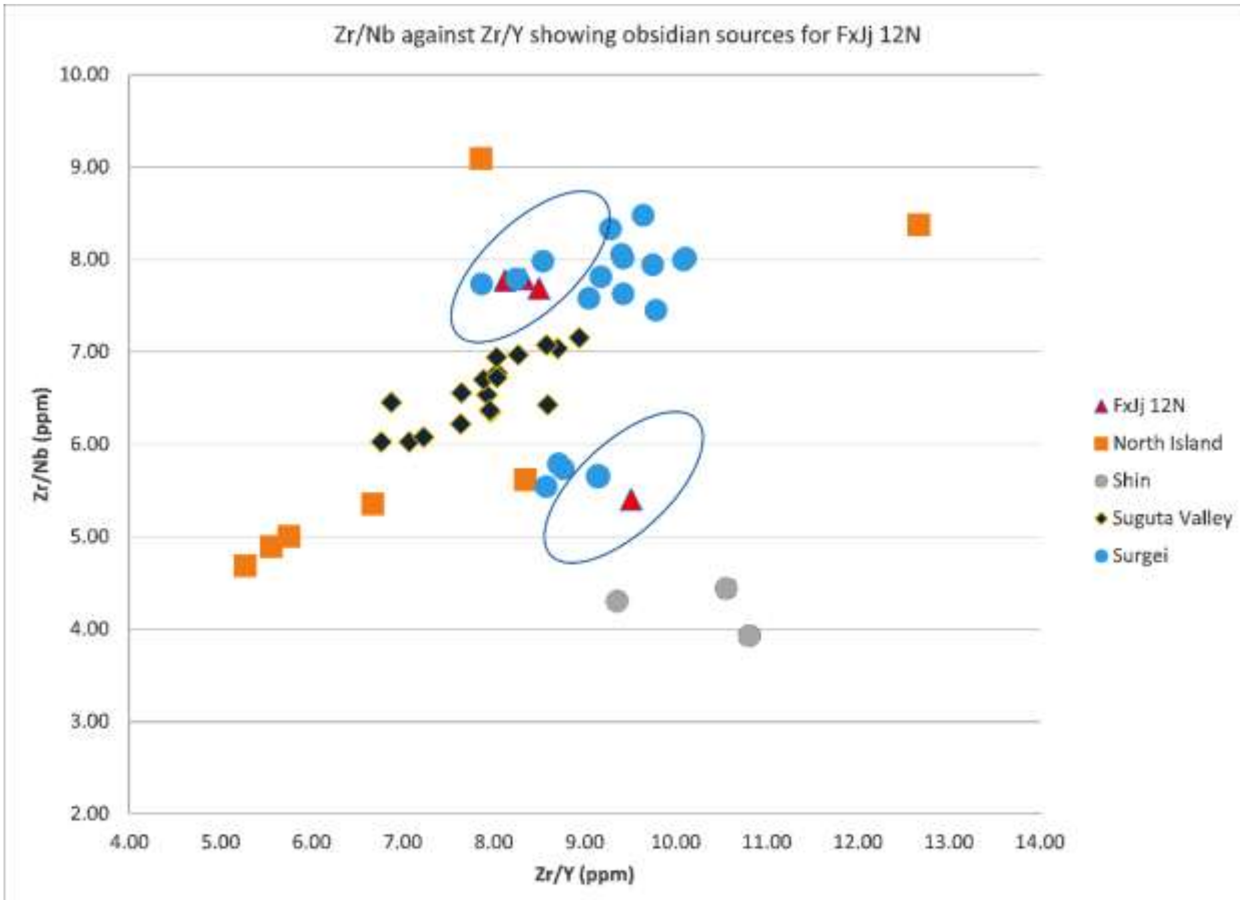

Figure 5.8: Results of the Zr/Y against Zr/Nb plots for FxJj 12N and the sources in the east Turkana Basin

5.4 Cortex ratios

The sites were plotted against mass (g) and maximum width (mm). There was slight significant difference between the early and mid-Holocene sites. At site level, FxJj12N had the fewest artifacts analysed and thus may be an outlier in this presentation. However, if with increased sample size, the trend remains the same, then this could be justified with the shorter distance from its main source, Surgei (see Figure 5.8 above). The artefacts had varying amounts of cortex on their dorsal surfaces as shown in Plate 5.1.

Plate 5.1: Cortical obsidian pieces from Holocene sites in Northern Kenya

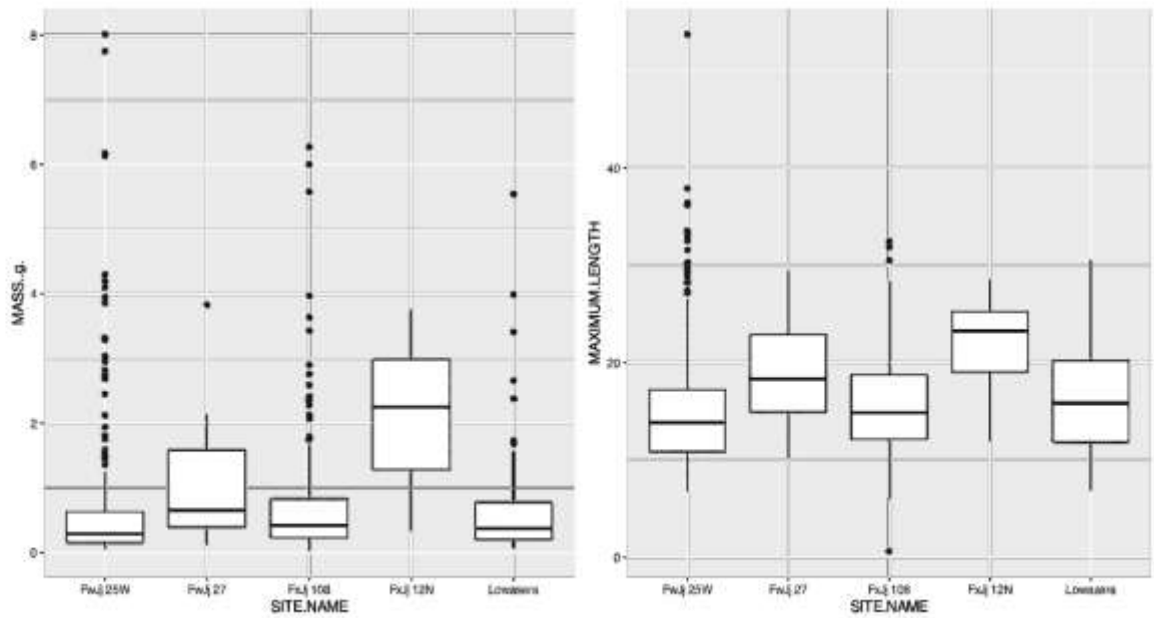

Figure 5.9: Plots of mass (g) and maximum length (mm) against sites under study

Mass and Maximum length plotted against sites for the Holocene sites in the East Turkana basin show little variation with FxJj12N showing some significant difference (Figure 5.9). FxJj12N is sourcing from one site, Surgei, which is only thirty-eight kilometers away. On the other hand, the cores recovered from all sites under study are overly reduced and non-cortical as shown in plate 5.2.

In terms of cortex ratio, there are only minor differences between these sites. Cortex ratios of one (1) indicate on-site production, while those less than one (<1) indicate transport. Because they are all less than 0.09, the materials from these sites do indeed demonstrate increased mobility. It is worth noting, however, that the mid-Holocene sites have slightly lower ratios compared to the early Holocene ones. FxJj25W, a mid-Holocene site has the lowest ratio of 0.046 six while FxJj108 and GeJk4 have the highest at 0.086 as shown in Table 5.2. The findings indicate that all the sites are located far from their material sources.

There is very little observed cortex as opposed to the expected cortex for Holocene populations to the east of the Turkana basin. This typically reflects the farther distances between sites and sources. Nonetheless, the slightly lower ratios, for example, FwJj25W, point to a population that is a little more mobile. FwJj27 has a value (0.82) close to those observed with the early Holocene counterparts. The site's faunal record is also dominated by fish remains also observed by the earlier inhabitants of the region. This shows inter-period differences suggesting complex societies in the Turkana basin during the Holocene.

Two early Holocene sites, FxJj108 and GeJk4, have an equal ratio of 0.086, indicating a pattern of the general land use and mobility patterns of the early Holocene population.

Plate 5.2: Core fragments from the early Holocene sites

The third early Holocene site, FxJj12N, with a cortex ratio of 0.084 generally conforms with the cultural behaviour of the early Holocene. The results for FxJj12N could be biased based on the sample size. However, if the trend remains, with an additional sample size then this could indicate high intra-site mobility. This implies that the hunter-forager-fishers are extensively moving around in the landscape close to their camp.

Table 5.2: Cortex ratios for the sites under study

Site	Observed cortex	Expected cortex	Cortex ratio
FxJj108	14.234	164.690	0.086
FwJj27	4.804	58.794	0.082
FwJj25W	8.512	184.387	0.046
GeJk4	7.399	85.706	0.086
FxJj12N	5.455	64.967	0.084

CHAPTER SIX

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter discusses the results presented in the previous chapter and their significance in addressing the goals and objectives of the study. The interpretive and cultural ecology theories used in this study have demonstrated variable interactions and how they affected the overall mobility and land use patterns. Conclusions of the study based on the findings are presented and discussed. Based on these conclusions, the chapter then presents the main recommendations derived from the study.

6.2 Mobility during the Holocene period

During the Holocene period, climatic variability has been recorded by various proxies. This variability basically affected the past landscapes and life that depended on them including that of humans. Biological and cultural evidence preserved in east Turkana have shown how Holocene communities were impacted by the climatic variability. One of the cultural lines of evidence that have been studied in the past to trace such impact is the obsidian artefacts.

Obsidian is scarce and found at distant places in the eastern Turkana landscapes. Transportation of obsidian as a raw material for longer distances and in larger quantities began ~200Kya (Blegen, 2017) and increased towards the end of the Middle Stone Age (MSA) (Ambrose, 2012). As a result, this was an important part of the late Pleistocene and Holocene human behaviour in the east African region (Ambrose, 2012). The cortex ratios of the obsidian used in this study to interpret, and infer mobility demonstrate that Holocene populations traveled long distances to acquire raw materials.

Populations at FxJj12N and FxJj108 possibly used North Island as one of their raw material sources. These two sites, being on land and the source in the lake, the evidence suggests that people used water rafting as a mode of transport to access raw materials in the Early Holocene. This, therefore, pushes back the dates of rafting earlier than 4000 BP as suggested by Ndiema et al.,

2011. Water rafting as a mode of transport in the early Holocene indicates cultural and technological sophistication by hunter-gatherer communities.

In comparison, the mid-Holocene populations relied on a broader resource base. They are relying on sources from the eastern Turkana Basin and many more sources outside the basin. This complemented their subsistence patterns as they also incorporated new modes of subsistence. The addition of pastoralism to their subsistence during the mid-Holocene greatly impacted their lifestyles. The people had to move greater distances to find water and pasture for their livestock and collect other resources like obsidian in the process. This would however justify the regional movements. There are more unmatched sources for the mid-Holocene (Nash et al., 2011). This suggests that they obtained their raw materials either from across the lake or from the neighbouring countries (Ethiopia). In addition to increased mobility on the landscape, they might have traversed across the lake, through rafts and collected some raw materials.

Obsidian stone tools in the Koobi Fora assemblage show tool acquisition, reduction and movement across the landscapes during different periods. The diversity in raw material sources can be attributed to both mobility and trade and/or exchange between different groups (Ambrose, 2012). The obsidian tools across the Holocene period show increased reduction and very little amount of cortex. The hunter-gatherer lifestyles changed gradually as the climates shifted. This was not a single-day event and therefore the population might have had to come up with different coping mechanisms over time. For instance, most of the plant species they relied on were dying out as the new arid-adapted species started growing. They were unfamiliar with the new plants and might have had to travel longer distances to forage for more familiar resources.

The introduction of a new subsistence strategy, the domestication of animals, would have greatly impacted hunter-gatherer lifestyles. The reliance on more predictable resources during the mid-Holocene complimented what the environment could not have readily provided. They may then have led to the formation of alliances to trade or gift as opposed to going farther distances to acquire resources. This is supported by the results from this study as well as the presence of evidence of domesticates that have been reported from sites in the region (Marshall & Barthelme 1984).

Mid-Holocene sites show that populations at this time mostly relied on the Suguta Valley as a source as opposed to the early Holocene sites that used Surgei as their major source. There was however, diversification of resource bases with increasing variability. The scarcity of resources combined with their unpredictability would result in high mobility. The early Holocene hunter-gatherers were also highly mobile as shown by both cortex ratio data and the obsidian sourcing data.

Generally, food producers in highly variable climates demand that humans move longer distances and in multi-direction to meet their dietary requirements. It is therefore obvious that foragers must have a good knowledge of the local environment and resourceful locations. The aridification would further have demanded that foragers manage their food acquisition and production. On the other hand, during the aridity seasons, pastoralists would have had unpredictable food, water and pasture resources. Hence, they would have become more mobile as opposed to when climates were favourable and stable. Drawing from the modern-day Dassanach community, they rarely slaughter their livestock. Also, in the event of droughts, or sickness there is no milk and the inability to subsist on livestock for fear of illness or death. These factors when projected to the past would decrease further the food resource base for the mid-Holocene populations.

The geochemical findings indicate a diverse range of resources for FxJj108, an early Holocene site. The other two sites, however, had one or two sources. Similar diversification is noted in the mid-Holocene sites. One of the factors contributing to this diversification is high mobility. This is also demonstrated by the cortex ratio data. The diversity observed in obsidian sources suggests that the populations procured from far areas, had broader procurement ranges, and may have exchanged with other communities.

The inter-site differences in raw material sourcing could be indicative of long-distance mobility across the landscape, knowledge of the existence of the sources and the difference in quality or social ties between different communities that supplied them with the raw material from different sources. Most artefacts from early Holocene were mapped to sources east of the Turkana Basin showing that their mobility might have been limited to this region.

In contrast, the mid-Holocene has more than 30% from unknown sources that could be from the larger Turkana Basin (including the west side) or from the north in the neighboring countries

(Sudan and Ethiopia). In this aspect, therefore, mid-Holocene populations were more mobile than their early Holocene counterparts. The differences in unmatched artefacts to sources reflect the loci of movement of different communities. The early Holocene populations are generally moving within one region with a slight possibility of going further distances. However, FwJj 27 (a mid-Holocene site with a large assemblage of fish bones) that might have heavily relied on aquatic resources also has ratios only slightly lower than those of early Holocene counterparts. This is suggestive of inter-period variability signifying an even more complex society. In as much as the mid-Holocene populations were impacted by harsh conditions populations are adapting differently.

The farther the artefacts are from their raw material sources, the smaller they will be. They will depict intense reduction and have lower cortex ratios. In our case, we had 6 overly reduced core fragments showing that they were recovered from far distances. The lack of cores and core fragments suggests that the tools were made elsewhere. Thus, these populations would have moved around with their ready-made tools which they then used and reused over time. This use and reuse would have required that these tools are retouched often to ensure maximum utilization of the scarce resources.

In modern observation, local migrations across the Koobi Fora landscapes are linked to rain patterns and by extension, water availability in this region. When it rains, resulting in water pans, movement reduces because water is available and within easy reach. Rainfall nourishes the pasture across the landscape, availing food resources for the livestock, hence the community becomes more sedentary. During the drought season, on the other hand, people tend to migrate to the lake, with livestock relying on lake water and feeding on sedges, and people relying on fishing as an alternative subsistence strategy. FxJj 108, for example, contains raw materials sourced from a variety of sources. Various groups of people looking for water and pasture during periods of desiccation may have interacted and/or traded with one another.

This analogy implies that the patterning of movements is dictated by prevailing climatic conditions. When there is increased rainfall, for instance, there is reduced mobility as the resources are more readily available. This explains the increased mobility during the mid-Holocene as the climates became increasingly drier and arid.

6.3 Land Use Patterns

The early Holocene eastern Africa received abundant rains that resulted in the development of stable grasslands and high lake levels, as well as abundant fish and wild (Olago et al., 2009). The populations exploited their environments to obtain readily available resources. They took advantage of the lake's resources, foraged for wild berries, fruits and tubers, and also hunted wild game. They did, however, travel longer distances to obtain obsidian, which they used to obtain and process food. They were aware of the best raw materials as well as their general surroundings. They may have foraged for additional resources along the way, increasing their supplies.

The mid-Holocene, however, experienced low precipitation that led to dry and arid conditions in eastern Africa. With decreased lake levels and precipitation, mid-Holocene populations sought alternative strategies, that is, domestication of goats and sheep. They continued fishing along the receding lake. In addition, they had to forage from longer distances with well-calculated moves. Because of the unpredictability of these resources, mid-Holocene populations had to manage their food acquisition and production. In comparison with their early Holocene counterparts' landscape approach, these would have resulted in different land use practices as large regions were explored within a very short time. They would also have exhausted one location before moving on to another one. The limited resource availability during this time might also have necessitated storage hence storage equipment, manufacture and acquisition. This, in turn, would have led to the exploitation of social networks to acquire that which they lacked.

A new mode of subsistence introduced during the mid-Holocene would have diversified the land use practices even more. Domestication of livestock implied domestication of humans (Hodder 1990). This meant that the people had to constantly care for their herds, including providing them with water and pasture. As a result, the people may have altered their landscape in order to obtain these necessities for their livestock. While out looking after the livestock in other areas, they may have met other groups and traded, obtaining obsidian from previously unknown sources.

Pastoralists were more mobile and extensive in their travels with their livestock, coexisting with local hunter-gatherers. As a result, during the mid-Holocene, the land was more extensively exploited as different groups exploited the available resources. They exploit land and water resources both for themselves and their livestock leading to depletion and movement to further regions to fend for themselves. Once in those further regions pasture would slowly regenerate especially where they had put their livestock enclosures and this will in turn lead to a comeback to these locations.

Some sources appear to have been preferred by the Holocene populations over others. Shin for instance, is close to some of the sites under consideration, but no single site sourced raw materials from there. From the modern-day perspective, Shin is quite inaccessible and has poor-quality obsidian (Ambrose 2022 personal comm). If this was the case, during the Holocene, then it would explain the lack of artefacts sourced from there. This shows deliberate usage or, rather for particular resources as opposed to the others, irrespective of their availability in the landscape.

6.4 Conclusion

The mobility patterns witnessed in the early and mid-Holocene are reflected in the amounts of cortex on the stone tools. Differences are also observed in sites belonging to the same period. The inter-site variation indicates different strategies employed by different people at the same time across space showing complex societies. The Holocene populations to the east of Lake Turkana Basin generally used tools for prolonged periods of time. This is indicative of limited resource availability and potentially the long amount of time taken to get the raw materials.

The energy required to go get raw material and/or prepare new tools cool have been saved to survive the intensity of the changing environments. There is generally increased reduction in amounts of cortex as well as cortex ratios for both the early and mid-Holocene populations. This indicates how far the sites are from the sources and confirms that the artifacts were created long before they arrived at these locations. However, when it comes to differentiating mobility within individual sites, the method does not show a significant relationship between sources and sites. The sites are quite far from where they are sourcing their raw materials. ED-XRF data gives us the distances between sources and sites that are confirmed through cortex ratios. However, the difference is minimal and thus requires another proxy and/or survival strategy to explain this occurrence.

Further, as for the Holocene populations, the procurement of raw materials from North Island via water transportation suggests highly mobile populations who are using different modes of transportation. As for the early Holocene, GeJk4 using Surgei as a source demonstrates that, in addition to mobility, there was an increase in social interactions such as trade and/or exchange. They explored water and land to enable sustenance as the climates gradually became drier. The exploitation of water not only hints at the intense reliance on aquatic resources but also, the possibility of manipulating water from the lake to lead to the sustenance of other land resources.

The land use strategies varied between the early and mid-Holocene with the decreasing precipitation. There was a variation from the usage of readily available resources during the early Holocene to the reliance on distant sources to ensure sustainability. The sources closer to the raw materials were relatively less mobile compared to those far away. During the early Holocene, the populations used their immediate lands and might have foraged on their way to the obsidian sources. On the other hand, the mid-Holocene saw an even increased and more diverse land usage with pastoralists circumnavigating through the vast lands in search of water and pasture and hunter-gatherers still finding resources to forage on. The receding lake also saw a decrease in aquatic resources for the lake and mostly leading to a reliance on land resources. Furthermore, the pastoralists also, practiced fishing and hunting leading to the maximum exploitation of resources at any particular location and necessitating further movements to find resources.

6.5 Recommendations

This area has potential for future research. To gain a better understanding of the region's mobility and land use practices, we need to sample at many different source locations within the same sites to understand the high intra-site variations observed. More surveys, surface collections and even excavations are needed, particularly for the early Holocene sites, to increase the sample sizes and obtain statistically significant data. For example, a single data point for FxJj 108 that has been treated as an outlier in this study could actually indicate that they sourced from North Island. Refining this is critical because it would imply earlier water transport by Holocene populations.

The cortex ratio as a method does not reveal a clear distinction in mobility when comparing populations that are sourcing their raw materials from distant sources. Both Holocene populations are relatively far from their sources and therefore, combining cortex ratio with other stone tool proxies such as core reduction and flake sequences, would be useful in making mobility inferences.

To better comprehend Holocene populations, an ethnoarchaeological study can also be used to comprehend the social elements that affect movement in the pastoral Daasanach group of today. This can be achieved by posing inquiries that identify connections (across social networks and geographic distances), as well as by borrowing from others and giving things as gifts to get that which they do not have.

A future possibility is to delve deeply into the issue of water rafting in the Turkana Basin and connect it to the basin's high mobility. The past influences both the present and the future. Climate change, for example, can be investigated using a broader range of sites for a Ph.D. thesis. This would aid in understanding different resource exploitation at various sites and ages, as well as establishing survivorship. Subsistence strategy shifts, such as how modern pastoralists are turning to fishing, are emerging, as are more sedentary lifestyles.

More importantly, there is a need to date FxJj108 to establish the certainty of the site's chronology. This might explain the difference in occupation at this Holocene site. Could there have been multiple occupations at the site leaving behind different signatures, including where they are getting their raw materials from? Or is the site simply displaying complexities in social relationships of the people that inhabited it? It would also be important to expand the scope of research to include sources in the west Turkana basin so as to better understand the relationship between culture transfer and mobility, such as similarities in burial cairns. Changes in subsistence methods, such as how contemporary pastoralists are moving to fishing, and the emergence of more sedentary lifestyles with these pastoralists are crucial to investigating past human behaviour.

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APPENDICES

Appendix 1: XRF sample geochemically characterized at the University of Nairobi's Institute of Nuclear Science lab

SITE NAME	ARTEFACT ID	K	Ca	Ti	Mn	Fe	Zn	Rb	Y	Zr	Nb	Zr/Nb	Zr/Y
FxJj 108	17700	0.7	1858.6	720.6	234.8	0.9	47	30.6	22.1	187.3	24.6	7.61	8.48
FxJj 108	17766	0.6	1528.5	649.4	448	0.9	69.2	38.7	32.9	366.5	52	7.05	11.14
FxJj 108	180	2.7	4203	2119.4	976.2	3.5	204.2	126.5	90.5	768.6	98.5	7.80	8.49
FxJj 108	163	0.7	873.9	367.5	223	0.8	47.6	30	23.4	190.2	24.6	7.73	8.13
FxJj 108	221	2.9	3317	1862.2	915.8	3.3	192.5	127.7	95.3	814.2	102.6	7.94	8.54
FxJj 108	17793	0.5	1061.4	684.6	445.5	0.8	46.2	23.8	21.8	189.4	34.3	5.52	8.69
FxJj 108	32	2.8	4203	2038.8	967	3.2	185.7	118.6	84.4	714	93.7	7.62	8.46
FxJj 108	17713	0.6	1277.4	456.7	217.2	0.6	38.8	21.7	15.1	121.9	15.8	7.72	8.07
FxJj 12N	17688	0.6	1365.7	509.1	236.8	0.8	44.8	27.5	20.1	163.3	21	7.78	8.12
FxJj 12N	121	0.7	882.9	451.1	233.3	0.8	46.2	29.9	21.5	179.1	23	7.79	8.33
FxJj 12N	122	0.6	962.8	406.8	240.1	0.8	45.1	29	20	169.9	22.1	7.69	8.50
FxJj 12N	128	0.7	964.5	900.5	736.9	1.3	76.4	30.5	28.4	270.1	50	5.40	9.51

GeJk 4	234	3.1	4850.5	2169.3	1220.7	3.7	193.9	136.5	103.1	849.2	105.7	8.03	8.24
GeJk 4	248	1.9	2692.2	986.8	696.9	2.3	135.2	80.2	59.3	476.4	62.6	7.61	8.03
GeJk 4	275	2.9	1.3	1881.4	981.7	3.3	188.5	123.3	92.9	755.3	97.4	7.75	8.13
GeJk 4	309	1.7	3601	1098.1	660.3	2.1	132.7	78.4	56.8	463.6	60	7.73	8.16
GeJk 4	269	1.9	2680.8	1284.3	692.3	2.3	140	84.3	63.5	528.6	64.8	8.16	8.32

Appendix 2: Sample of lab data sheet for cortex ratio at the east Turkana Basin

SITE NAME	ARTEFACT ID	ARTEFACT TYPE	SIZE	COLOUR	NORTHING	EASTING	MAXIMUM LENGTH	MAXIMUM WIDTH	MAXIMUM THICKNESS	MASS (g)	%CORTEX	
FxJj 108	1212103	Angular frag	Micro	Green	453859	204611	19.44	11.56	5.12	1.01	25	N
FxJj 108	1212104	Angular frag	Micro	Brown	453860	204609	12.46	10.16	1.49	0.16	0	N
FxJj 108	1212096	Flake	Micro	Green	453811	204642	20.27	10.74	2.81	0.58	0	N
FxJj 108	1212091	Flake	Micro	Grey	453826	204626	25.34	9.03	3.71	0.9	25	N
FxJj 108	1212099	Flake	Micro	Green	453803	204648	14.28	12.79	3.57	0.47	25	N
FxJj 108	1212105	Flake	Micro	Green	453858	204605	19.03	12.35	2.3	0.61	25	N
FxJj 108	1212101	Angular frag	Micro	Green	453815	204653	24.5	19.27	5.53	1.79	25	N
FxJj 108	1212098	Flake	Micro	Green	453804	204644	25.21	8.37	3.03	0.56	25	N
FxJj 108	1212090	Flake	Micro	Grey	453837	204625	13.09	8.16	2.46	0.28	50	N
FxJj 108	1212092	Flake	Micro	Opaque	453828	204634	12.1	9.61	2.65	0.21	25	N
FxJj 108	1212095	Angular frag	Micro	Grey	453814	204641	10.12	8.81	3.86	0.34	25	N
FxJj 108	1212093	Angular frag	Micro	Green	453820	204645	14.35	7.49	2.92	0.38	25	N
FxJj 108	1212108	Flake	Micro	Brown	453904	204604	18.43	8.06	3.35	0.53	25	N
FxJj 108	1212088	Flake	Macro	Green	453840	204631	22.52	19.05	5.22	2.41	25	N
FxJj 108	1212097	Core frag	Micro	Green	453806	204645	16.17	14.31	10.38	2.37	25	
FxJj 108	1212107	Flake	Micro	Brown	453884	204606	10.64	7.18	1.7	0.14	0	N

For complete dataset visit

https://docs.google.com/spreadsheets/d/1F-51VRLuxTTYpi8PewHmKhVfgrXz5alZJNURPjy7wvY/edit?usp=sharing

Appendix 3: Site coordinates

SITE NAME/SASES	**NORTHING**	**EASTING**	**ELAVATION**
Lowasera (GeJk 4)	37N 246209	324753	451m
FxJj 108	37N 204613	453870	459m
FxJj 12N	37N 204780	452322	458m
FwJj 27	37N 201069	474846	438m
FwJj 25W	37N 199406	474228	446m

Appendix 4: Cortex ratios of obsidian artefacts by use of R

site	detached_mass	detached_volume	detached_cortical_surface_area	cores_mass	cores_volume	cores_cortical_surface_area	nodule_volume_quartile	core_count	assemblage_volume	nodule_vol_core_count	nodule_frequency_quartile
FxJj 108	176.19	69.09412	9.768932	30.7	12.03922	4.464664	2.311765	6	81.13333	13.52222	35.09584
FwJj 27	13.43	5.266667	0.339406	30.7	12.03922	4.464664	2.311765	6	17.30588	2.884314	7.486005
FwJj 25W	214.395	84.07647	4.047801	30.7	12.03922	4.464664	2.311765	6	96.11569	16.01928	41.57676
GeJk 4	46.97	18.41961	2.934555	30.7	12.03922	4.464664	2.311765	6	30.45882	5.076471	13.17557
FxJj 12N	20.56	8.062745	0.990157	30.7	12.03922	4.464664	2.311765	6	20.10196	3.350327	8.695505

For a complete view visit: https://docs.google.com/spreadsheets/d/1RTs8sJ8m7Kk757IyQV-BX9rgvT38BJkaHn4_3J66cw8/edit?usp=sharing

Appendix 5: ED-XRF setup at the University of Nairobi's Institute of Nuclear Science.

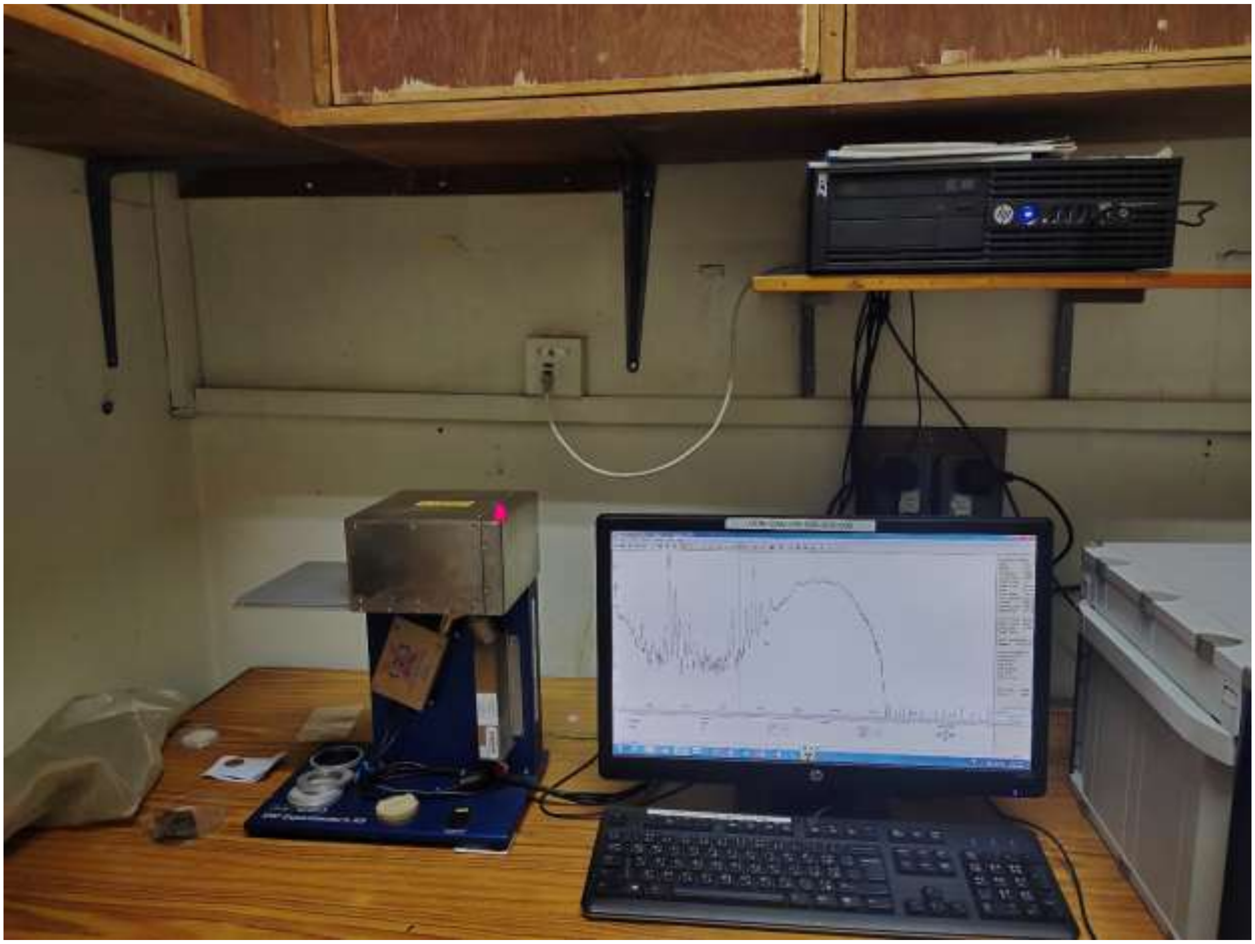

Photo credit: Author